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HUMAN FACTORS

FOR DESIGNERS OF EQUIPMENT

PART 5: STRESSES AND HAZARDS

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Revision Note

Historical Record

Arrangement of Defence Standard 00-25

Human Factors for Designers of Equipment
Part 1 - Introduction
Part 2 - Body Size
Part 3 - Body Strength and Stamina
Part 4 - Workplace Design
Part 5 - Stresses and Hazards
Part 6 - Vision and Lighting
Part 7 - Visual Displays
Part 8 - Auditory Information
Part 9 - Voice Communication
Part 10 - Controls
Part 11 - Design for Maintainability
Part 12 - Systems
Part 13 - Human Computer Interface Design Guidelines

Two or more Parts may apply to any one equipment and it is therefore essential that all Parts be read and used where appropriate.

HUMAN FACTORS FOR DESIGNERS OF EQUIPMENT

PART 5: STRESSES AND HAZARDS

PREFACE

i This Part of the Defence Standard takes into account some of the main environmental factors which affect work efficiency and personnel well-being. These should be considered by designers in defence equipment applications.

ii This Part of the Defence Standard is published under the authority of the Human Factors Subcommittee of the Defence Engineering Equipment Standardization Committee (DEESC).

iii This Standard should be viewed as a permissive guideline, rather than as a mandatory piece of technological law. Where safety and health is concerned, particular attention is drawn to this Standard as a source of advice on safe working limits, stresses and hazards etc. Use of this Standard in no way absolves either the supplier or the user from statutory obligations relating to health and safety at any stage of manufacture or use.

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vii Any enquiries regarding this Standard in relation to an invitation to tender or a contract in which it is incorporated, are to be addressed to the responsible technical or supervising authority named in the invitation to tender or contract.

viii This Part of the Defence Standard is being issued as an INTERIM Standard. It shall be applied to obtain information and experience of its application. This will then permit the submission of observations and comments from users using DGDQA Form No 0825 enclosed.

A review of this INTERIM Standard should be carried out within 12 months of publication. Based on the comments received the author and/or the committee responsible for the preparation of the Defence Standard shall judge whether the INTERIM Standard can be converted to a normal Standard or decide on what other action should be taken.

CONTENTS

CONTENTS (Contd)

HUMAN FACTORS FOR DESIGNERS OF EQUIPMENT

PART 5: STRESSES AND HAZARDS

Section One. General

0 Introduction

There is an optimum environment in which man works most effectively. Changes from this optimum, if sufficiently large, result in adverse effects. These may appear as discomfort, degradation in job performance, physiological changes or ill-health.

Performance limits will normally lie between comfort and physiological criteria. However, in some circumstances discomfort will itself result in performance decrement and thus to preserve performance the stricter comfort criterion is to be employed.

In other circumstances the physiological limit must be employed as some environmental substances can have imperceptible effects which will render an individual incapable of rational perception of changes in his own behaviour.

This part of the Standard discusses the environmental factors (collectively known as stressors) which can adversely influence task performance and individual well-being. It indicates limit values where available and suggests ameliorative techniques where stressors exceed appropriate limits.

The information available is not always definitive, and some limits are merely advisory. For other factors, mandatory limits and procedures apply.

1 Scope

This Part of the Standard considers some of the main environmental factors which affect work efficiency and personnel well-being. These should be considered by designers in defence equipment applications.

2 Related Documents

2.1 The documents and publications referred to in this Part of the Defence Standard are listed in annex A.

2.2 Reference in this Part of the Standard to any related documents means in any invitation to tender or contract the edition and all amendments current at the date of such tender or contract unless a specific edition is indicated.

2.3 Related documents can be obtained from:

DOCUMENT	SOURCE
British Standards (BS) International Standards (ISO)	BSI Sales Department Linford Wood MILTON KEYNES MK14 6LE Tel: 0908 221166
Defence Standards	Directorate of Standardization Kentigern House 65 Brown Street GLASGOW G2 8EX Tel: 041-224 2531/2
Joint Services Publication (JSP)	MOD Forms & Publications Branch Mwrwg Road Llangennech Llanelli SA14 8YP Tel: 0554 820771 Ext 4058
Book of Reference (BR)	Ministry of Defence CS(PS)3 Building 25A Royal Arsenal West LONDON SE18 6TJ Tel: 081 854 2044 Ext 2938

3 Definitions

3.1 For the purpose of this Part of the Defence Standard the following definitions apply.

3.2 Hertz (Hz). SI unit of frequency, indicating the number of cycles per second (c/s).

3.3 L_{eq}. The steady sound level which would produce the same, energy over a stated period as specified time-varying sound. Provided the "L_{eq}" and long-term r.m.s are equivalent.

3.4 Lux. Unit of illuminance or illumination in the SI system, 1 lumen per square metre.

3.5 Sievert unit. A unit of x-ray dose, being the dose of radiation delivered in 1 hour at a distance of 10 mm from a point source of 1 mg of radium element enclosed in platinum 0.5 mm in thickness.

Section Two. Submarine Atmosphere

4 Introduction

The need for personnel to spend extended periods within the enclosed, sealed environment of a submarine requires special consideration. Without action, atmosphere contaminants and waste products produced either from the personnel themselves or from the submarine’s machinery and construction materials will rise to exceed acceptable levels. Oxygen on the other hand will be utilized causing diminishing levels; both trends continuing until external ventilation can take place again.

4.1 The Hazard

4.1.1 Submarine atmospheres contain a complex mixture of agents in gaseous vapours and aerosol form which may pose a number of different hazards:

(a) toxicity: ranging from the acute effects of short exposure to chronic effects occurring many years after exposure has ceased;

(b) reduction in the performance of personnel such that the performance or safety of the submarine becomes impaired;

(c) fire and explosion: from the build up of inflammable agents.

4.1.2 The different hazards may in turn be produced by a number of separate mechanisms:

(a) the action of a specific contaminant;

(b) interaction of mixtures of contaminants;

(c) specific action of a breakdown product produced by the interaction of specific contaminants with the submarine environment;

(d) interaction of mixtures of breakdown products.

5 Control

5.1 The range of both potential hazard and methods of causation identifies the need for all materials suggested for submarine use to undergo evaluation before such use is sanctioned. The requirement for a comprehensive evaluation system and the need to maintain levels of certain agents, produce the need for a system of Submarine Atmosphere Control. Such control is exerted by both the passive limitation of quantities of materials allowed on board and by active removal and production systems.

5.2 Passive control. The vast majority of submarine contaminants are controlled by a passive system which requires all proposals of material for use in submarines to be forwarded to Chief Naval Architect, Bath. All such proposals are evaluated with regard to Toxicity, Fire Characteristics and interference with atmosphere monitoring systems, following which a decision is made with regard to the materials suitability and it is listed within the Submarine Materials Toxicity Guide: BR1326A.

5.2 (Contd)

BR1326A thus represents a comprehensive list of all materials that have been considered for submarine use, materials not included in the book have not been evaluated and are not be used. Detailed instructions on the procedure for clearance of a material and the information required from the sponsor are included in the volume itself and promulgated by DCI. It should be noted that evaluation may be time consuming and complex thus clearance may take a significant time. The volume is reissued by CNA every 6 months.

5.3 Active control. In addition to the passive control measures contained within BR1326A, submarines are equipped with varying systems for active removal of certain contaminants and for the production of oxygen. Details of the machinery and individual submarine fitments are contained within BR1326 Air Purification in Submarines.

6 Maximum Permissible Concentrations (MPCs)

6.1 Both active and passive control systems require the promulgation of safe levels for some atmospheric agents, to provide design constraints for what must be achieved. Within industry safe levels are specified by the American Conference of Governmental Industrial Hygienists as Threshold Limit Values (TLVs) and by the Health and Safety Executive and Occupational Exposure Limits (OELs). However, both these systems are specified for single agents for an eight hour day, 40 hour week, industrial exposure and are thus totally unsuitable for use within submarines. A unique system of levels is therefore promulgated within BR1326 exclusively for use within submarines as Maximum Permissible Concentrations (MPCs) for a maximum 90 days continuous exposure. These levels take into account effects of breakdown and mixing as well as constant exposure. This allows their specification as ceiling or maximum values unlike most other industrial values which are quoted as time weighted averages.

Section Three. Acceleration and Deceleration

7 Acceleration

7.1 Acceleration occurs whenever there is a change in velocity (linear acceleration), or a change in direction of motion at uniform velocity (centripetal acceleration). The effect of acceleration on man depends upon a number of factors including:

(a) Magnitude. Forces due to acceleration are measured in units of G, this being the ratio of the applied acceleration (in metre per sec^2) to the standard acceleration of gravity g, or 9.81 m/s^2.

(b) Duration. In their actions on man, accelerations may be broadly classified into impact acceleration - those acting for a second or less, and often for only tens of milliseconds, and sustained accelerations - those acting for a second or more. Impact forces are met within accidents - vehicle collisions, crashes, ejections etc - and human tolerance is determined by the mechanical strength of the body and irreversible failure of its component bones, ligaments or blood vessels. Sustained accelerations occur during routine flight - particularly in aircraft manoeuvring - and human tolerance depends upon the body’s physiological response, the limit generally being a reversible loss of consciousness. Impact and sustained forces will, therefore, be discussed separately.

(c) Direction. The vector direction of acceleration forces is defined according to a three-coordinate system based upon the long (spinal) axis of the body. Note that these axes may differ from those relating to the vehicle, or to the vertical of earth’s gravity, depending upon body orientation.

(d) Body restraint. The greater the restraint, the more the body will be accelerated as a whole and the lower will be forces induced by independent motion of body parts. Limb and head flailing in a high-speed aircraft ejection is an example where injury can be reduced by increased restraint.

(e) Site and area of application. Applying the accelerating force to a strong part of the body (the bony part of the hips, for example) and distributing it over as large an area as possible will also reduce the risk of producing local injury.

(f) Rate of onset. The body responds to an application of force dynamically so that the transmitted force may be attenuated, amplified or unchanged depending upon pulse duration or acceleration onset rate.

7.2 In normal circumstances, linear forces tend to be of low magnitude, though carrier operations can expose aircrew to acceleration of ±3Gx for several seconds. Much greater and sustained forces are caused by the radial accelerations of aircraft manoeuvring with levels up to +9Gz lasting for 15 seconds or more.

Impact forces are met within accidents and may exceed 25G in any axis. The launching of free-fall lifeboats or sea survival capsules and the effects of mines on ships and armoured vehicles are other examples of predominantly +Gz impact forces.

7.2 (Contd)

Slamming in ships and jolting in land vehicles are more commonplace examples of appreciable G forces in both z-and y-axes.

7.3 Tolerance to +G acceleration. With a moderately rapid rate of onset of acceleration (1.0G per sec or more), loss of peripheral vision occurs at +3-4 Gz, blackout at +4-5 Gz and loss of consciousness at +5-6 Gz. A slow rate of G onset (0.1 Gs-1) allows the baroreceptor response to develop along with the increasing stress and these tolerance levels are increased by about 1G. Since modern fighter aircraft are capable of sustaining +8Gz, or more, a considerable degree of aircrew protection is required to prevent visual symptoms and to preclude loss of consciousness. Two methods currently employed are the anti-G suit and positive pressure breathing.

7.4 Other acceleration vectors

7.4.1 +Gx (transverse supine G). Cardiovascular tolerance to all axes of transverse and lateral inertial forces is high, as the vertical height of the body is greatly reduced and the vertical pressure gradient between heart and brain, in particular, is abolished. Tolerance is greatest when the hips and knee are flexed to 90° and body weight supported on an individually moulded couch, when +15 Gx may be tolerated for many seconds. Breathing becomes difficult at levels greater than +8 Gx and impossible at +12 Gx, though this problem can be overcome by breathing at positive pressure.

7.4.2 ±Gy (left/right lateral G). The effective symmetry of the body about the sagittal plane means that there is no discernible difference between the two directions of Gy acceleration. Gy acceleration is becoming of interest to aviation, however, with the advent of lateral flight control, though as the levels are quite low, ±1 Gy maximum, no significant physiological effects are expected.

7.5 Disorientation in flight

7.5.1 Disorientation induced by linear acceleration. The human body senses linear acceleration by means of the otolith organs of the inner ear and through pressure receptors in the areas of skin which are in contact with the seat or the floor. When two accelerations are superimposed these sensors indicate to the brain the direction and magnitude of the single resultant acceleration. Because the acceleration due to gravity is the only sustained acceleration experienced in everyday life, the resultant of two sustained accelerations will tend to be perceived as gravity alone and therefore as indicating the vertical. Thus a sustained acceleration in the line of flight tends to generate an illusion of pitch-up and deceleration an illusion of pitch-down. This illusion is known as the somatogravic illusion.

The somatogravic illusion has a visual counterpart the oculogravic illusion, which consists of an apparent movement of the external visual scene, upwards during forward acceleration and downwards during deceleration. This illusion is only evident when the visual scene lacks detail as, for example, during night flying, when fixed ground lights may appear to be in motion.

7.5.1 (Contd)

The somatogravic illusion is regularly experienced when an aircraft is put into a turn. If the manoeuvre is initiated gently and the corresponding roll of the aircraft occurs at a sub-threshold rate (<2 deg/s) the aircraft will feel to be straight and level and, apart from instrument information, only external vision will indicate the true aircraft orientation. Loss of external vision during a turn may lead to a form of disorientation known as 'the leans'.

7.5.2 The Leans. This illusion consists of a sensation of the aircraft being in a banked attitude when it is in unaccelerated straight and level flight. The illusion only occurs when there is no clear visual horizon as when flying in cloud or at night, but may be so powerful as to cause the pilot to lean in his seat towards what he perceives as the vertical. It is rapidly dispelled when clear external vision is regained. Correct aircraft control when a pilot is suffering from the leans, as with other forms of spatial disorientation, is likely to be assisted by the provision of a clear unambiguous attitude display.

7.5.3 Disorientating effects of angular accelerations. The ability to perceive angular acceleration is almost exclusively mediated by the semi-circular canals of the inner ear. These structures behave as heavily overdamped accelerometers. In consequence, during everyday activities the neural signal relayed to the brain represents the angular velocity of the head. This neural signal is used to generate angular eye movements of an appropriate velocity to maintain a stable visual lineage of earth fixed targets (the vestibulo-ocular reflex). In terms of frequency response the system behaves as an accurate angular velocity transducer down to about 0.05 Hz. Below this frequency there is a progressive reduction in gain and an increasing phase error (lead). Thus in circumstances of longer duration angular acceleration the velocity coded signal from the semi-circular canals underestimates the true head velocity, and in conditions of constant velocity angular rotation this signal decays to zero. This results in visual blurring of earth-fixed targets and a reduction in the perceptions of rotation when visual cues are absent. These conditions are exemplified by spinning manoeuvres in aircraft.

7.5.4 For all illusions it is vital that instruments should provide clear and unambiguous information about the true aircraft attitude in order to assist the pilot in re-orientating himself.

7.6 Human tolerance to impact accelerations. The effects of impact forces may be classified into primary effects caused by whole body acceleration in the absence of local forces or body displacements; secondary effects caused by missiles, for example, impacts from other components or contents of the vehicle which have not decelerated to the same extent as the occupant; and tertiary effects caused by body displacement. These include a whole range of injuries from head impact to broken limbs, ribs etc and depend to a great extent on vehicle and seat design and the degree of body restraint. The product of acceleration and the time for which it acts gives velocity change (or v) and, for brief impacts, this becomes the critical factor which determines tolerance (compare with long duration acceleration when it is the acceleration level which is critical). The time-dependent change in response of the body to acceleration - from velocity change to acceleration level - is similar to that seen in a simple mass-spring system, and is

7.6 (Contd)

related to the ratio of the length of the acceleration pulse to the undamped natural period of the system. Figure 1 shows that for long duration forces (pulse length/period >10) the response is equal to the input, while for brief impacts (pulse length/period <0.4) the velocity change is critical. For intermediate values (pulse length/period 1) dynamic overshoot leads to amplification of the response. This is a particular problem with the forces induced by operation of aircraft ejection seats and has led to the use of the dynamic response index, or DRI, a mathematical model of the subject's compressible spine, to predict the risk of spinal injury (see ASCC Air Std 61/1B - Ejection Acceleration Limits).

7.7 Body restraint. The whole body impacts considered above assume that the force is applied uniformly so that local injuries are precluded. Each with optimum restraint, however, some parts of the body will be stressed more than others, in particular, lateral forces applied to the head may exceed ±7 Gy.

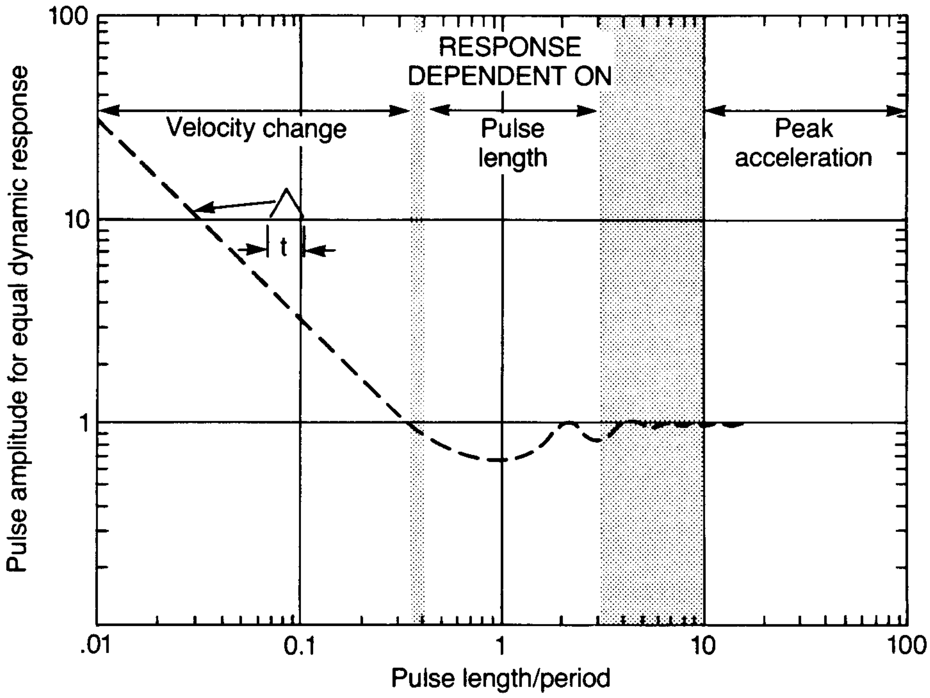

Fig 1 Dynamic response to a triangular acceleration pulse depending upon the ratio of pulse length (t) to the natural period of the system

In practice, man is usually subjected to impact accelerations in conditions in which full restraint is impracticable, though in a vehicle crash a rearward-facing seat with a lap belt to prevent rebound ejection from the seat offers the nearest compromise. At the other end of the scale comes the exposure to impact of unrestrained sitting or standing subjects where body displacement and tertiary injuries will be inevitable unless the impact forces are very small. Ship shock is a particular example in which deck heave caused by mine blast is most likely to cause head injury and broken limbs, while injury to the feet or ankles is relatively rare.

7.8 Tolerance criteria. The pass/fail criteria which are used in a particular condition of impact depend greatly upon the circumstances. With a potentially lethal impact, major injuries may be accepted and the pass criterion would simply be survival. In an aircraft crash, however, the risks of fire or drowning make it essential that survivors of the impact should not be concussed or suffer incapacitating bony injuries, so the criterion becomes more rigorous. For the services, maintenance of effectiveness in combat will be a critical criterion.

7.9 Tolerance levels. Tolerance curves exhibit wide differences depending upon the degree of restraint and the criterion selected. Differences due to the direction of applied acceleration will also exist.

(a) Horizontal impacts

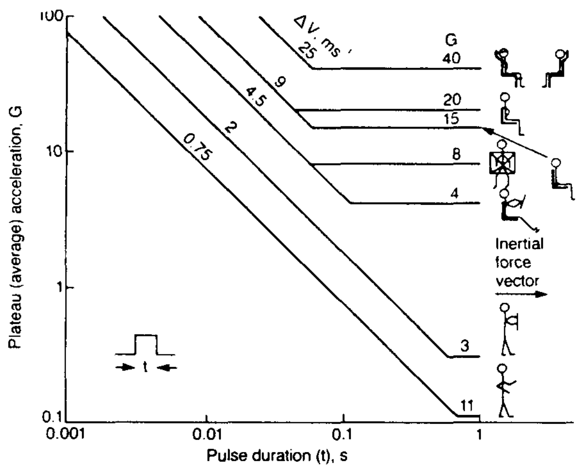

Fig 2 Human tolerance to ±Gx and ±Gy impacts under various conditions of body restraint

It may be seen from fig 2 that the greatest tolerance is obtained when the impact load is most evenly distributed. This is achieved in -Gx impacts (forward-facing crash deceleration) by the restraint of head, arms and legs in addition to a lap belt, shoulder and upper torso harness; but is simply achieved in a +Gx impact (rearwards-facing seat) with a lap belt to prevent the subject from rebounding out of the seat. The omission of restraint for head, legs and arms leads to a significant reduction in tolerance, mainly because the head is free to move forwards and its peak resultant acceleration may be considerably greater than that of the body. Using only a lap belt, tolerance is further reduced owing to the very high local belt loads and risk of injury to abdominal organs as the body 'jack-knifes' over the belt. Optimal positioning of the belt is important.

Tolerance figures given in fig 2 assume that the resulting body motion will not bring it into contact with any injurious structures, motion of the head again being critical. With no restraint at all, primary tolerance to -Gx acceleration depends upon the subject’s ability to maintain posture by muscular effort. Given some support, such as a steering-wheel and foot pedals, the trunk can be kept from moving forward at about -4 Gx.

The data upon which the lower two curves are based come from studies of passenger transport systems and the tolerance criterion used was public acceptability of a system intended for everyday use.

7.9 (Contd)

Exposure of human subjects to lateral acceleration (±Gy) is less frequent than exposure in the Gx axis, but occurs on primary impact in vehicles with sideways seating and in secondary impacts following rotation of the crashing vehicle. It also occurs when vehicles are struck from the side. With full restraint, tolerance should be similar to that in the fore and aft axis, but if the head is not restrained, potentially injurious neck loads occur at quite low levels of acceleration. Voluntary tolerance curves for lap belt and contoured couch restraints are also given in fig 2.

(b) Vertical impacts. Fig 3 illustrates, in the same way, human tolerance to vertical impact. The upper line is similar to that of fig 2, since the acceleration vector is identical (+Gx). The other lines, however, all refer to ±Gz forces. The second refers to aircraft ejection accelerations on which quite precise data are available. In particular, the effect of dynamic response is shown by the curved portion which dips below the plateau G level over the critical pulse duration of about 0.2s.

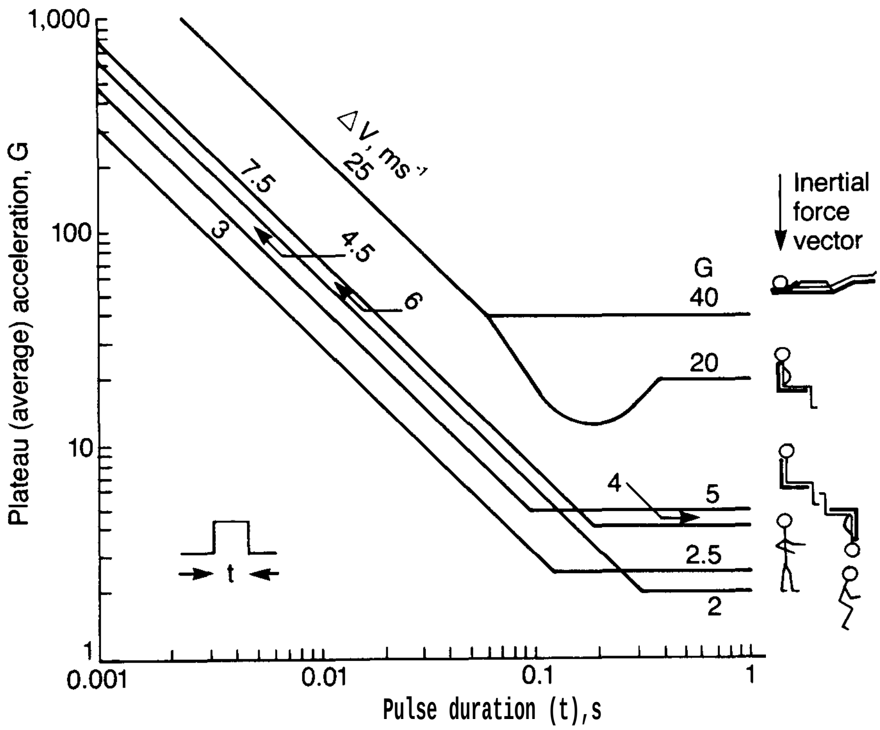

Fig 3 Human tolerance to +Gx and ±Gz impacts under various conditions of the body restraint

Fewer data is available on unrestrained subjects in whom tolerance depends on leg muscle strength, the crossover of the two lines is due to the greater energy absorbing capacity of flexed legs (as in jumping).

No attempt has been made to include actual data points nor ranges, in figs 2 and 3. These tolerance curves must, therefore, be treated with caution and are intended only as an indication of the most probable level of tolerance which could be expected for each of the various situations.

7.10 Crashworthiness. Crashworthiness implies that the overall design of a vehicle is such as to minimize the risk of injury in a crash. It involves the maintenance of workspace integrity with adequate seat strength and restraint; the avoidance of additional hazards such as post-crash fire, fumes, missiles or sinking etc, and the provision of energy absorbing devices to attenuate the peak forces transmitted to the crew member, or to parts of his body most at risk.

Specific example of energy absorbing devices are the use of crushable beams and panels in automobiles to provide a controlled stopping distance in a crash and energy absorbing seats for helicopters in which the seat is permitted to stroke vertically at a just tolerable level of +Gz acceleration in order to attenuate any greater peak forces. Objects which may be struck by a flailing head or limbs should be adequately padded to prevent local injury, the thickness of padding needed and its crush resistance being readily calculable from the anticipated impact parameters.

7.11 Restraint systems. The function of a restraint system is to transfer impact forces from a vehicle to its occupant in such a manner as to minimize the risk of injury. As restraint harnesses will normally be used for long periods in the absence of impact forces they should be easy to use, comfortable and offer the minimum of restriction, while still functioning efficiently when needed. Active systems require the co-operation of the user in fastening buckles and so on, while passive systems such as airbags operate independently of the occupant.

Further details of aircraft restraint systems are given in AP 8C while specifications for automobile restraints are given in BS 3254: specification for seat belt assemblies for motor vehicles and in BS AU 183. Industrial restraints are used to arrest potential falls and are covered by BS 1397: specification for industrial safety belts, harnesses and safety lanyards.

Section Four. Wind

8 General

8.1 Wind velocities of 10 knots and upwards can deleteriously influence walking and other activities which must be performed in open air. Gusts of 45 knots will blow people over, although higher wind speeds can be tolerated by leaning into them (Murakami and Deguchi). Speed of walking is reduced by a factor of four in wind speeds of 40 knots.

8.2 Where walking surface is wetted or greasy, slipping may occur, although it is estimated that toppling equilibrium is likely to be lost before slipping occurs for any coefficient of friction exceeding u = 0.6 (Lloyd).

8.3 Baggy outer clothing will increase the surface area exposed to wind and reduce tolerance to wind forces. Where tasks must regularly be performed in conditions of wind hazard, windshields or windbreaks should be provided wherever possible. If this is not possible, personnel must be adequately secured to avoid being blown over, eg from ship’s flight decks. Task equipment should provide handholds and harness securing points. If lightweight, stabilizing mounts should be fitted.

8.4 Task automation should be considered if it is estimated that, after all measures are taken, wind is likely to constitute a major hazard.

Section Five. Motion

9 Whole Body Motion Phenomena

9.1 The motions of military vehicles and platforms can have adverse effects on the comfort, well-being and task performance of personnel. In some circumstances, health and safety may also be hazarded.

The consequential induced body motions and their effects appear as four primary phenomena:

(a) Motion sickness: low frequency motion and occurring with both short and long term exposure.

(b) Motion-induced task interruptions: low frequency, large amplitude motion, specific short-term events. Abrupt changes in acceleration are frequently present, eg in slamming, jolting or turbulence.

(c) Motion-induced fatigue: low frequency, large amplitude motion and resulting from long-term exposure.

(d) Vibration: medium to high frequency, with exposure time depending on tolerance to the motion severity. Vibration is considered in section six of this Part.

9.2 Characteristics of inducing motions. International Standard 2631 (Parts 1 and 3) and British Standard 6841 provide detailed guidance on and description of those motions which specifically affect the human.

9.2.1 Motion sickness. Characteristically, sickness occurs as a result of exposure to motion in the frequency range 0.05 to 0.7 Hz, while vibration effects are primarily seen between 0.5 and 80 Hz.

Motion sickness appears to be predominantly due to linear acceleration in the vertical (z) axis, although rolling (rotation about the x-axis) and pitching (rotation about the y-axis) may also contribute. Lateral low frequency motions may also cause sickness but this is not well-quantified. The peak frequency for incidence is about 0.17 Hz, while incidence also increases steadily with r.m.s acceleration over the range considered.

It should be noted that these data are derived from studies employing single sinusoidal applied motions. The effects of complex motions are less well known and a variety of models have been developed in an attempt to represent multiple-frequency effects (see Burns and Smith). However, until more data is available, the treatment of the effects of both broadband and multiple-frequency motion, including significant non-vertical components, remains equivocal.

Over longer periods (3-4 days), adaptation to motion usually occurs and the incidence of sickness declines. Since such habituation is to particular motions, however, changes in motion characteristics can result in a re-occurrence of the illness syndrome.

9.2.1 (Contd)

Motion sickness incidence should not be used as an unqualified predictor of the likely effect on task performance. For experienced personnel, conditions can be such that task performance is affected although symptoms of motion illness are not experienced (McLeod et al).

9.2.2 Motion-induced interruptions. The concept of motion-induced interruption (MII) was developed (Baitis et al) to quantify the effects of local, mainly lateral, motions which cause a person to lose balance or slip, and thus interrupt any task they may be performing. A frequency domain technique, known as the Lateral Force Estimator (LFE), provides a means for estimating the incidence of such interruptions and hence for setting appropriate limiting values for task performance, or for evaluating the degree of degradation in performance when the levels of applied motions exceed specified limits.

Extension of the technique is required to include non-lateral motion effects, tasks involving major force requirements, eg manual reloading of weapons and tasks performed by the seated operator. The current method assumes a standing operator applying relatively small forces.

9.2.3 Motion-induced fatigue. Motion-induced fatigue, which should be distinguished from the fatigue and malaise induced by motion sickness, is primarily due to the need of having to continually compensate for whole body displacement and in order to preserve suitable postures for task and other activities. In ships at sea, the primary contributory factor is considered to be the following motions experienced.

Although ISO 2631 describes a "fatigue-decreased proficiency boundary", this is not well-founded and the designer is advised to consult an appropriate source of expertise regarding the likely effects of motion-induced fatigue on the performance of any specific task.

9.3 Effects of motion and motion illness on task performance. The estimation of the adverse effects of motions on task performance is critically dependent on consideration of exposure duration. Motion sickness shows some recovery with increasing exposure duration, as described, but fatigue, motion-induced interruptions and continuous vibration are likely all to have cumulatively adverse effects on well-being and task performance. Their combined influences are likely to be at least additive.

The malaise resulting from motion illness can result in complete withdrawal from a task. Conversely, ‘some individuals’ task performance may be unaffected, even though they report quite severe symptoms of sickness. The effect of motion sickness itself can thus range from 0%, no change, to 100%, complete degradation (Strong). These effects are at least partially independent of type of task. Changes in performance of sensory tasks, eg vision or hearing, motor tasks, eg tracking, writing or lifting and loading activities, or cognitive processing, eg memory or decision making, may be comparable where the primary influencing factor is disinterest due to motion sickness malaise.

In contrast, the performance of short-term tasks with major motor (whole body) movement requirements is likely to be adversely affected primarily by

9.3 (Contd)

motion induced interruptions alone. Calculations indicate that acceptable levels of MIIs of one per minute or below are equivalent to applied accelerations of approximately 0.11g (rms) or less. MIIs of five or more per minute (0.16-0.17g) are considered extremely hazardous.

Longer-term tasks of whatever sort, eg helicopter maintenance on ships; sensor operation; repeated weapon loading activities, are likely to be affected by a combination of MII and fatigue, together with motion sickness if personnel are unadapted. No precise predictions are possible because of the complexity of the effects and the influence of individual task - specific parameters. In general, however, it is likely that tasks having restricted needs for taking in information and only a small motor component, will be the ones least affected by motion.

9.4 Implications for vehicle, equipment and task design. For conventional vehicle and platform designs, little scope may exist for dramatic improvement by the elimination of provocative motion characteristics. Unconventional designs which substantially reduce motion at particular frequencies will be of assistance, however, eg marked attenuation of major frequency peaks below 0.7 Hz will substantially ameliorate the incidence of motion sickness.

Stabilization of the whole platform, or isolation of specific workstations on stabilized or damped mountings may be of benefit. Bittner and Guignard suggest this and other techniques to help reduce adverse motion influences.

Steps can be taken to locate critical workstations and tasks near to the centre of gravity of the vehicle, to reduce the rotational movements about the primary axes.

Head movements can be minimized by appropriate placement of visual tasks and displays (and associated controls) at each workplace, since this will reduce the severity of motion sickness symptoms. Head rests for seated operators may also be of benefit.

Operator workstations should be aligned with the principal axes of motion of the vehicle, ideally along the longitudinal (x) axis, thereby facing either directly forward or to the rear.

Where possible, an external visual frame of reference should be available to aid visual stabilization and to provide an external reference for predicting repetitive motion changes. This may be possible using display techniques where a view of the outside world is not possible, eg the Malcolm horizon (Malcolm) or contact analog displays (Roscoe).

Where tasks require delicate movements, control techniques which show greater resistance to motion should be chosen. McLeod and Griffin describe alternative methods and their sensitivity to motion. Arm and wrist supports will be important to help ameliorate the effects of jolting and other sudden movements. Substitution of relatively gross physical movements, eg whole circuit board replacement, for fine manipulative actions, eg circuit board touble-shooting in-situ, will be advantageous.

9.4 (Contd)

For moving heavy loads in adverse motion conditions hand holds on fixed equipment and on the loads themselves will be of assistance. Where both hands are required for this task, a body harness or support should be considered.

Where it is anticipated that adverse effects of motion are likely to remain despite ameliorative measures, automation of the task should be considered.

Section Six. Vibration and Shock

10 Vibration

10.1 Vibration is any sustained mechanical oscillatory disturbance, whereas shock or jolt is a transient mechanical disturbance. In this section, consideration is given to the non–auditory effects of environmental vibration and shock having frequency components within the range 0.06 to 1000 Hz.

Transportation devices, whether over land, on the sea or in the air invariably expose the occupants to vibration which, depending upon the intensity and direction of the stimulus, the frequency spectra of the vibration and the duration of exposure can impair operational efficiency. Likewise, vibration transmitted to the occupants of buildings or off-shore fixed structures, either from machinery within the building or from the dynamic response of the structure to external forces (eg wind and/or waves), can cause discomfort and degrade working efficiency. Disturbance by mechanical shocks occurs during industrial activities, such as pile driving and blasting, as well as in military operations on detonation to explosive charges. Gunfire from automatic weapons engenders a mechanical stimulus that may be classified either as repeated shocks or as vibration with a high crest factor (ie ratio of peak acceleration to root mean square acceleration).

Vibration and shocks may be transmitted to the body through, for example, the feet of a standing person, the buttocks, back and feet of a seated person or the hand(s) when using a vibratory tool such as a chain saw. The adverse effect of a particular vibration environment is thus dependent not only upon the physical characteristics of the vibration stimulus but also upon the dynamic characteristics of the interface between the individual and vibrating structure (eg compliance and damping of a seat cushion) and upon the posture, orientation and muscle tone of the subject. In the performance of certain tasks it is the vibration of displays or hand controls rather than of the operator that is of critical importance.

10.2 Effects of vibration and shocks

10.2.1 The principal effects of vibration and shocks on man can be categorized as:

(a) degraded health and injury (which may be immediate or follow long-term exposure);

(b) impaired task performance;

(c) impaired comfort;

(d) motion sickness.

10.2.2 It must be recognized, however, that many variables influence human response to vibration and shocks, these include:

(a) intrinsic factors:

(i) body size and build (age, sex, stature, etc);

10.2.2 (Contd)

(ii) body posture;

(iii) seating and restraint;

(iv) activities and nature of task performed;

(v) experience, expectation, arousal and motivation.

(b) extrinsic factors:

(i) physical characteristics of acceleration stimulus (magnitude, frequency spectrum, direction);

(ii) input location of stimulus;

(iii) duration of exposure;

(iv) other environmental factors (noise, heat, illumination etc).

Precise guidance on the effects of vibration and shock is thus rarely possible, but the relevant British Standards (see annex A) provide information which should assist the designer in quantifying the mechanical stimulus to the subject and the exposure dose, annexes to the Standards give broad guidance on the effect of a defined vibration or shock stimulus and provide sufficient information to guide the designer on how to minimize the deleterious effects of vibration.

When using the data and "limits" presented in the annexes to the British Standards it is important to bear in mind the restrictions and constraints placed on their application. The "limits" are for guidance only. As noted above, there are many factors which influence the effect of vibration and these are frequently highly dependent upon the task being performed. Thus an analysis of the task must be made before any useful generalizations on the influence of vibration and shock on task performance can be obtained. Information on the effect of vibration on some specific tasks is to be found in the scientific literature referenced in the annexes to the British Standards and by Griffin et al.

Section Seven. Weightlessness

11 General

11.1 Stationary objects on the surface of the earth are subject to a constant linear acceleration of 9.81 m/s^2 or 1 g. This gravitational acceleration may be nulled, such that the object experiences an acceleration close to 0 g:

(a) transitorily (< 1s) on being dropped, ie in free fall in the atmosphere;

(b) for periods of 10-40s during flight in a Keplerian (parabolic) trajectory in an aircraft;

(c) for prolonged periods during orbital (space) flight.

In a zero g, or more precisely a microgravity environment in which the linear acceleration is typically less than 10^{-3}g, objects become essentially weightless and there is no reactive force between the object and the surface upon which it is placed. Likewise there is no friction to stabilize the position of the object on a surface unless an external force, with a component normal to the surface, is applied. An object, not in contact with a surface will maintain its position until acted on by a force, whereupon it will be accelerated and, depending upon the mass of the object and the magnitude and duration of the force applied, will achieve a velocity that will be maintained until acted upon by an opposing force to decelerate it and bring it to rest.

11.2 Human factors in weightlessness. Microgravity imposes certain constraints on human activity and imposes special Human Engineering requirements, these may be summarized:

11.2.1 Spatial orientation. The absence of a gravity reference and hence no stimulation of the otolith organs of the vestibular apparatus, necessitates orientation within the vehicle being achieved solely by visual and tactile cues.

11.2.2 Task performance. Patterns of motor activity employed on earth for locomotion, for the maintenance of posture and for the performance of certain movements, may no longer be appropriate in microgravity. On initial exposure to weightlessness difficulties may be experienced and working efficiency decreased (typically by 30% during first day in orbit), but new patterns of sensory–motor co-ordination are acquired relatively rapidly (2–7 days) and thereafter many tasks may be performed with an efficiency comparable to that achieved during ground-based training. Performance may also be degraded during the first few days in weightlessness because of motion sickness-like symptoms (space sickness) and discomfort due to venous congestion of the head and neck.

11.2.3 Controls and displays. Most human engineering criteria for the design of controls and displays for use in 1 g (as detailed in other sections of this Standard) are applicable for zero g use. Controls and displays should, however, be able to withstand crew-imposed loads, such as may be imparted by a free-floating crew-member on moving himself or a heavy mass from one position to another in the vehicle.

11.2.4 Restraint and temporary fixation. Provision has to be made for the restraint of crew members when performing tasks and for the tethering or temporary fixation of tools and implements that are used. The forces that can be a development by voluntary muscular contraction in weightlessness are similar to those achieved on earth (see section three), but these manipulative forces can be achieved only if structures and devices capable of withstanding the reactive forces are provided. Loss of muscle strength, particularly of extensors, may decrease with prolonged exposure to weightlessness, but this effect is largely prevented by appropriate daily exercise in flight.

11.2.5 Habitability. Space vehicles present problems similar to those of other environments in which humans have to live in an enclosed space with integral life-support systems (eg submarines) and the same or even more stringent constraints and standards for the maintenance of the thermal and gaseous environment apply (see section two). In addition, special facilities have to be provided for essential activities, such as food preparation, ablution, urination, defaecation and sleeping.

11.2.6 Safety. The space vehicle and its payload present numerous potential risk situations which directly or indirectly affect the safety of the crew or ground personnel. Safety standards are related to ten basic hazard groups, namely:

(a) collision;

(b) contamination;

(c) corrosion;

(d) electrical shock;

(e) explosion;

(f) fire;

(g) injury and illness;

(h) radiation;

(i) temperature extremes;

(j) loss of re-entry capability.

Extensive safety guidelines have been prepared by both the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) to whom enquiry should be directed for current obligatory requirements and recommendations.

11.2.7 Physiological adaptation to weightlessness. Physiological changes occur in a number of bodily systems during space-flight. Significant adaptive changes are detectable in:

(a) fluids and electrolytes;

(b) the Neurovestibular System;

11.2.7 (Contd)

(c) the Cardiovascular System;

(d) the Haemopoetic System;

(e) the Skeletal System;

(f) the Sensory-Motor System.

These processes are appropriate to the microgravity environment and, in general, are not detrimental to efficient performance in flight. They are, however, disadvantageous on return to earth and normal gravity. After a space-flight of several weeks' duration the cardiovascular deconditioning and the alteration in sensory-motor control and postural activity can be a significant impediment to operational efficiency until readaptation to the normo gravic environment is achieved.

Section Eight. Effects of Noise

12 General

12.1 Noise affects human health and performance in a number of ways. Apart from such environmental considerations as annoyance to the community at large, which lie outside the scope of this Standard, the most important and best researched effects are those on speech communication and on hearing acuity. The effect of noise in masking speech communication and other wanted sounds is considered in detail in part nine of this Defence Standard.

12.1.1 The effect of noise on hearing is to produce a permanent and incurable loss of hearing acuity, typically greatest around 4 Hz, which increases with increasing noise exposure and which combines with losses from ageing or other causes. The magnitude of the loss varies between different individuals, and in susceptible individuals can lead both to social disability and an inability to perform tasks (especially tasks of a military nature) requiring good hearing. Noise-induced hearing loss in Service personnel can therefore lead to medical down-grading or, in extreme cases, discharge. There is no completely "safe" noise exposure, and the maximum permitted exposure is therefore a compromise between the risk of hearing loss and the technical difficulties in reducing noise exposure; it therefore follows that noise exposure should always be reduced as far as is reasonably practicable.

12.1.2 Other effects of noise include:

12.1.2.1 Psychological effects on performance. The effects, most evident at levels above 90 dB(A), depend very much on the nature of the task; in general, performance on simple repetitive tasks is unlikely to be as badly affected as performance on more intellectually demanding tasks. The topic has been reviewed by Broadbent.

12.1.2.2 Effects on general physical health, other than on hearing. These have proved very difficult to quantify (Burns 1979). However, it appears that limits set in respect of noise-induced hearing loss will also protect against other effects on health.

12.1.2.3 Sleep disturbance and general annoyance to off-watch personnel in living spaces.

12.2 For hearing conservation purposes, continuous noise (from machinery, vehicles, aircraft etc) is measured either in terms of A-weighted sound level expressed in dB(A), or in terms of equivalent continuous sound level (8 hour), usually written as L_{eq} (8 hour) and also expressed in dB(A).

The use of L_{eq} is described in British Standard 5330 (BSI). It can be regarded as an average level referred to a nominal 9 hour period; see table 1. Some equipment can make direct measurements of L_{eq}.

The "A" in dB(A) refers to the A frequency weighting applied to the measuring system; it is described, together with other requirements for sound level measurements, in British Standard 5969. The quantity L EP, d is similar to L_{eq}, except that it takes no account of any hearing protection which may be used.

12.3 The limit to noise exposure set by the Defence Standard is an 8 hour L_{eq} at the ear of 85 dB(A); this L_{eq} shall not be exceeded during any 24 hour period.

It is, however, strongly recommended that, as far as possible, the sound level at the ear should not exceed 85 dB(A). Exposure to noise must in any case be reduced to the lowest level reasonably practicable.

The use of L_{eq} is only possible where the exposure duration can be defined. Note that, where noise exposure results from use of more than one item of equipment, both the level and the L_{eq} should be derived from all noise sources, not from one item of equipment only.

Where noise exposure is of short duration, an L_{eq} of 85 dB(A) implies sound levels considerably above this value; this may cause a performance decrement even where the effect on hearing is within the requirements of this Standard.

Levels below 85 dB(A) may be necessary where the ability to hear speech or other sounds is required; see part nine of this Defence Standard.

12.4 Measurement of impulse noise from weapons and other explosive sources presents special problems and equipment intended for measurement of continuous noise is not suitable. Detailed guidelines for the measurement of impulse noise in Appendix 1 to the final report of NATO DRG Panel 8 Research Study Group 6 (NATO). This Defence Standard, in common with Civil Standards, does not consider limits to personnel exposure from impulse noise; however, limits are given in Defence Standard 00-27.

12.5 Use of hearing protection. In principle, the use of hearing protection (ear plugs, ear muffs or noise-excluding helmets) can give a very substantial reduction in noise exposure, depending on both the nature of the protector and the frequency content of the noise. In practice, the use of personal hearing protection gives rise to a number of problems (for a detailed discussion, see Alberti):

12.5.1 The protection, measured in practical usage, is generally less than that measured in ideal laboratory conditions specified in such standard methods as British Standard 5108.

12.5.2 Protectors can be fragile and will deteriorate over prolonged use. Ear muffs in particular tend to clash with other headgear, such as safety helmets. Some protectors are very uncomfortable to wear. British Standard 6344, Part 1 specifies minimum requirements for ear muffs; another part of this Standard is planned to consider ear plugs.

12.5.3 While persons of normal hearing are able to hear speech in noisy surroundings as well with protectors as without, persons with impaired hearing (noise-induced hearing loss, for instance) will have severe difficulty in hearing speech and other wanted sounds (including warning or cautionary signals) while using hearing protectors.

It is therefore necessary to reduce noise exposure by other means (such as reduction of noise at source, or location of personnel away from noisy areas) as far as is practicable; only if the noise exposure remains excessive should the use of hearing protection be considered. The

12.5.3 (Contd)

manufacturer shall advise the equipment procuring authority of any requirement for hearing protection.

12.6 Checklist

12.6.1 Has the noise exposure in areas likely to be occupied been measured or estimated?

NOTE: Where equipment is to be installed in a workshop or other space, noise will depend on the acoustic characteristics of the space. In this case, prediction of the noise may be aided by measurements of sound power from the equipment.

12.6.2 Will personnel exposed to the noise need to communicate by voice, or need to hear other auditory signals? If so, consult part nine of this Defence Standard.

12.6.3 Will off-duty personnel be exposed to noise?

12.6.4 Will personnel exposed to noise have to perform complex mental tasks?

12.6.5 Will personnel be exposed to noise from other sources? If so, combined exposure should be considered, not merely exposure from the equipment under consideration. Remember that speech and other noise transmitted by communications systems adds to the total noise dose.

12.6.6 What steps have been taken to reduce noise from the equipment, or to remove personnel from noisy areas?

12.6.7 Is the noise impulsive, or does it contain impulsive components (eg from gunfire or explosions)?

12.6.8 If, after all practicable means of noise reduction have been employed, unprotected noise exposure approaches or exceeds an L_{eq} (or, if duration is undefined, a level) of 85 dB(A):

(a) Has the procuring authority been informed of the need for personnel hearing protection?

(b) Have the practical problems associated with the use of hearing protection been considered? What solutions are offered?

(c) Can the noise reaching the ear be reduced to 85 dB(A) by use of protection?

(d) Are the communication problems likely to be encountered by some users acceptable?

(e) If special forms of protector, eg incorporating communication facilities, are required, has procurement action been initiated?

Table 1

Relation Between Sound Level and Duration for an L_{eq} of 85 dB(A)

SOUND LEVEL	DURATION
80 dB(A)	24 hours
82 dB(A)	16 hours
85 dB(A)	8 hours
86 dB(A)	6 hours
88 dB(A)	4 hours
91 dB(A)	2 hours
94 dB(A)	1 hour
97 dB(A)	30 minutes
100 dB(A)	15 minutes

Section Nine. Darkness and Dazzle

13 General

13.1 The human eye is an extremely versatile sensor. Most people possess the ability to perceive a broad range of colours and have a high degree of acuity (see section six, Vision and Lighting, clauses **6** and **7).**

13.2 In addition the human eye can function very effectively over a considerable range of ambient illumination, from bright sunlight (10^7 lux) down to starlit night and lower (approx 10^{-5} lux). At the extremes of this scale the brightest tolerable light is 10^{12} times that of the lowest brightness necessary to produce the sensation of light. There are two consequences of this range which are of particular significance in military operations. One is that at night the colour system of the eye does not operate and secondly a period of adaptation is required for efficient visual functioning in the dark after leaving a lighter zone. The period of adaptation required in the light, after leaving a relatively dark area, is considerably less.

The implications of this are readily obvious if naked eye surveillance must be undertaken at night after leaving a brightly-lit room, or if viewing through an image intensifier is succeeded by naked-eye viewing.

13.3 For a detailed exposition of this topic, and practicable solutions, the reader is directed to Part six of this Defence Standard, clause **5** (Light Sensitivity) and clause 30 (Illuminance Requirements for Particular Military Circumstances).

Section Ten. Effects of Radiation

14 Ionizing Radiation

14.1 Radiations that cause ionization, either directly or indirectly, include the electromagnetic X and gamma rays, alpha and beta particles, protons, neutrons and certain other particles are of no practical significance. There is a natural background of ionizing radiation originating from cosmic radiation, the natural radioactivity of the earth and from radioactive substances naturally present in our bodies. Alpha and beta particles have a short range, particularly in tissue and are emitted principally from radioactive isotopes. The greatest hazard in this case is from taking the isotope into the body by inhalation, ingestion or the contamination of wounds. Neutrons generally originate from nuclear reactions, particularly fission. They have a long range in air and penetrate tissue fairly well where they indirectly cause ionization and thus damage cells. They are particularly potent in causing certain long term damage such as inducing cancer or cataracts of the lens of the eye. For example, they are considered to be at least 10 times more able to induce cancer, absorbed dose for absorbed dose, than X or gamma rays. Gamma rays originate from the nuclei of radioactive isotopes. They have a long range and penetrate tissues with increasing ease with increasing energies (measured in thousands or millions of electron volts, KeV or MeV) where they cause damaging ionizations of molecules. X-rays are virtually identical to gamma rays although often of a lower energy, their source is the only difference as they do not arise in the nucleus of an atom but from the electrons orbiting the nucleus. The unit of absorbed dose is the Gray Gy) which equals 100 of the old rad units, for biological effects the absorbed dose equivalent is used for which the unit is the Sievert (Sv) which equals 100 of the old rem units.

14.2 Biological effects of ionizing radiations. The ionization of human tissue will be damaging to some degree depending on the amount (ie absorbed dose), its type (ie absorbed dose equivalent when absorbed dose is multiplied by a quality factor, eg 10 for neutrons) and the dose rate. The longer the period of time over which a fixed dose is received the less will be its effect. The volume of the body irradiated is also important. If only part of the body is irradiated the effect is less.

The effects of ionizing radiation are divided into two. Some occur at random, eg induction of cancer or genetic defects, where increasing doses increase the chance of developing an effect. These include the particularly radiosensitive bone marrow whereabout 5 Sv (acute dose) would cause such depression of blood cells that about 50% of those exposed would die within 2 months. Other effects include skin damage similar to burning particularly from beta emitting isotopes on the skin and damage to the lining cells of the gastro-intestinal tract causing gastro-intestinal symptoms.

After an acute whole body dose of penetrating ionizing radiation in the 3 to 5 Sv range there will be a period of between 0.5 and 3 hours without any symptoms. This will be followed by a period of 12 to 48 hours of nausea, some vomiting, possibly some diarrhoea. This will pass and the patient will seem quite well but blood tests will reveal a falling white cell count. After 2 to 3 weeks there will be a recurrence of nausea, vomiting, diarrhoea, with loss of hair, bruising and a risk of death from

14.2 (Contd)

infections or possibly bleeding. Higher doses shorten this timescale until after some 10's of Sieverts, brain effects (coma etc) cause a death within hours or at the most a few days.

It is believed that any dose of radiation, however small if given to sufficient numbers can cause cancer or leukaemia. The best estimate available at present is that 10,000 person Sieverts (eg 0.1 Sv to each of 100,000 persons or 0.01 Sv to each of a million persons) will cause about an additional 125 cancers in the period of between 10 and 40 years after the exposure. A further 40 cases of hereditary ill health will also be produced in the first 2 generations. Because of a lack of any evidence for a threshold below which no long term random risks arise, a basic tenet of radiological protection is that all doses shall be kept "As Low As Reasonably Achievable" (ALARA).

14.3 Protection against ionizing radiation. The three basic principles of protection are time, distance and shielding. The shorter the time exposed to a certain dose rate the less the dose will be. The further away from a source of radiation, the lower will be the dose rate due to the inverse square law and absorption of the radiation in air or other materials. Shielding requirements depend on the type of radiation:

(a) Alpha. A piece of paper will stop alpha particles, as will intact human skin. Prevention of intake into the body is the prime concern.

(b) Beta. Perspex, glass, aluminium etc will completely absorb beta radiations if about 10 mm thick. The thickness required depends on the energy of the beta particles.

(c) X and Gamma Rays. Dense material such as lead will reduce the intensity of these radiations but may need to be very thick to reduce them to acceptable levels.

(d) Neutrons. Materials containing a high proportion of hydrogen atoms are best at slowing down neutrons. Water, polythene and concrete are examples but these may need to be several metres thick. Once slowed, substances such as boron can be used to absorb these slow neutrons but interactions with other substances can produce high energy gamma rays which will require lead or similar shielding.

Personnel dosemeters (thermoluminescent materials have largely replaced the film badge) are used to measure the dose of radiation received by individuals. But if there is a significant dose rate or radioactive contamination hazard, appropriate instrument measurements are necessary before personnel are permitted to work in the area.

14.4 Radiofrequency and other non-ionizing electromagnetic radiations. There is a wide spectrum of electromagnetic radiations, unable to cause ionization, ranging in frequency from ultra-violet light (3×10^{16} Hz in frequency, 10-8 metres in wavelength) down to power frequencies (50 or 60 Hz). The amount of absorption and depth of absorption of this energy depends on frequency/wavelength. In all cases the hazard is due to heating of tissues, varying from sunburn of the skin from ultra-violet to whole body heating in the 30–300 M Hz region. The lens of the eye and the testes

14.4 (Contd)

are particularly sensitive to heating hazards. Above a specific absorption rate of 4 WKg^{-1} there is clear evidence of harmful effects and thus limits are based on a fraction of this, in the case of the USA, one tenth (0.4 WKg^{-1}). UK limits will be the subject of an EEC directive in due course. Lasers can also produce similar harmful heating effects particularly affecting the eye. Lasers are classed from a hazard free class I to the most hazardous class IV.

Section Eleven. Chemical and Biological Contaminants

15 General

15.1 Two aspects of chemical and biological contaminants should be considered: (a) equipment, and (b) the human operator.

15.2 Equipment. Equipment used in the field is likely to become contaminated by a variety of agents and will require decontamination. Particular attention should be paid to case design and the construction of switches, knobs, displays etc. Comprehensive design information is given in "A Guide to the Chemical Hardening of Equipment", Chemical Defence Establishment Technical Memo 79, 1986.

15.3 Human Operators. The presence or threat of chemical and biological contaminants require the human operator to use defensive measures which can impair his efficiency and hence performance. The measures are (a) physical and (b) pharmacological and the impairments may be physical, physiological and psychological, or all three.

15.3.1 Physical defence is provided by Individual Protective Equipment (IPE) comprising a smock with hood, trousers, plastic overboots, inner cotton and outer synthetic rubber gloves and a respirator (currently S6 or S10).

15.3.1.1 Physically, IPE is bulky; it restricts movement and increases the effective size of the body, hands, feet and head by as much as 50%. Also, the respirator restricts peripheral vision and the wearer needs to turn his head more than normal. Equipment should allow adequate access room for hands, fingers and feet and extra room for the head to allow for both access and movement.

15.3.1.2 Physiologically, IPE reduces the capacity for sustained physical exercise progressively with time as the ambient temperature and humidity increase. Equipment should involve the minimum of heavy and/or sustained physical effort, particularly if intended for use in hot, humid climates.

15.3.1.3 Psychologically, IPE attenuates and distorts perception and thus affects the ways in which information should be conveyed to the operator. Hearing is attenuated and distorted by the hood and auditory information, particularly that in the speech frequency range, may require amplification or filtering. Peripheral vision is distorted and the visual field is narrowed by the respirator eyepieces (foveal vision may be distorted slightly depending on direction of gaze). Visual information should be designed for foveal vision in the photopic range and symbols should subtend a minimum visual angle of 20 minutes of arc. Peripheral vision should not be used except to direct attention. Visual displays should also make allowance for the respirator bulk and eyepiece design. Touch, and thereby finger dexterity, are severely impaired by the glove assembly; switches and other controls should be large and widely spaced (see above under physical impairments) with a positive amount and resistance of mechanical movement.

Research into the physiological and psychological effects of wearing IPE is still in progress. Details may be obtained from the Chemical Defence Establishment and the Army Personnel Research Establishment.

These effects of IPE may well interact with other environmental factors such as visual and auditory noise.

15.3.2 Pharmacological defence is provided by pretreatment and therapeutic drugs. It is impossible to give specific guidelines regarding these since the effects vary with a multitude of factors and research and development is still in progress. However, some general points can be made.

15.3.2.1 There is no evidence that the current pretreatment for nerve agent poisoning (NAPS) produces any significant behavioural impairment at the dose available and NAPS may be ignored for the purposes of equipment design.

15.3.2.2 The current therapy for nerve agent poisoning comprises a mixture of drugs which, together or separately, will impair performance in ways which could be significant for equipment designers. The drugs are combined in a self-injection device and up to three doses may be administered. The effects are generally mild following one injection and increase in severity with further injections. They include impairment of visual perception, decision-making processes, memory and response co-ordination. Equipment designers should allow for the effects of up to two injections. Generally, this means that normal ergonomic guidelines should be followed with extra allowance for imperfect performance. Visual displays, markings, instruction etc should be large and clear to allow for blurred vision. The relationships between displays and controls should be simple and unambiguous to allow for slowed decision processes. Sequences for instructions and operations should be clear and short to allow for impaired memory. Controls should be large and widely separated to allow for impaired response co-ordination (see above). Research into the clinical and psychological effects of drugs is still in progress. Details may be obtained from the Chemical Defence Establishment.

Section Twelve. Safety Standards

16 Guidelines

16.1 Guidelines on safety of equipment for use by the Services may read across from the civilian situation. The Health and Safety at Work etc Act 1974 applies to all employees including those in control of members of the armed forces, designers, manufacturers, importers and suppliers of articles and substances for use at work by employees and to persons in control of premises, including vehicles and tents, occupied by employees at work. Members of the armed forces are not exempt, although in practice the Health and Safety Executive only inspects premises and activities which are not classified as “operational”. It must be remembered that equipment designed for use under operational conditions will also need to be used in a training, non-operational situation.

16.2 The general standard of safety of equipment premises and systems of work for use by the armed forces is thus at least the same as for any other employee. Due regard must also be paid to the expected conditions of work, which could be harsher than in civilian life and to the tactical consequences of a failure of either the equipment, the method of work or the operator. These considerations will lead to a decision on the standard of safety to be aimed for by the designer and others.

16.3 There is a wide amount of literature on hazards at work, and Standards are specified for many situations. Details are contained in statutes (Acts, Regulations and Orders), Codes of Practice and Guidance Notes issued by the Health and Safety Commission and Executive and in Standards and other documents issued by national Standards houses, trade and professional associations and other civilian and military authorities.

16.4 The general procedure will be that the authority responsible for specifying a defence equipment requirement will, in consultation with users and planners if necessary, define the proposed conditions of use. Designers and suppliers will be responsible for providing information about the safety of equipment under these conditions and under other foreseeable conditions including partial equipment failure and misuse by operators. They will be responsible for obtaining research data if this information is not already available. It is probable that a dialogue between designers, suppliers etc on the one hand and the procurement authority, together with their operational and human factors advisers, on the other hand will be established during the design and development of more complex items of equipment. This procedure could include an analysis of possible hazards leading to refinement of the design and to recommendations for a system of work and training methods.

Section Thirteen. Thermal Environments

17 General

17.1 A number of national and international standards are relevant source materials for designers who seek advice and guidance concerning thermal environments. Further details are given under the headings below.

17.2 Units and Measurements. ISO 7726 contains internationally agreed definitions and methods of measurement of heat and cold. This Standard should be consulted for guidance on these matters. Ambient temperatures are correctly specified in degrees Centigrade (Celsius), and although air temperature may be measured with a conventional thermometer this is not a sufficient description of the thermal environment. Details are provided in ISO 7726. One generic way to describe the thermal environment is by means of Effective Temperature. It is important to note that there are several Effective Temperature scales, the most recent being designated ET. This scale of subjective temperatures has superseded all others (see NOTE).

NOTE: Effective Temperature is equal to air temperature when the Relative Humidity is 50%, the air movement is 0.1 metres per second and when the walls of the room are at the same temperature as the air.

17.3 Table 2 below gives typical human responses to a range of effective temperatures.

Table 2

Typical Human Responses to Effective Temperature

°F	°C	RESPONSES
110	43	Just tolerable for brief periods.
90	32	Upper limit of reasonable tolerance.
80	26	Extremely fatiguing to work in. Performance deteriorates badly and people complain a lot.
78	25	Optimal for bathing, showering. Sleep is disturbed.
75	24	People feel warm, lethargic and sleepy. Optimal for unclothed people.

Table 2 - Continued

°F	°C	RESPONSES
72	22	Most comfortable year-round indoor temperature for sedentary people.
70	21	Optimum for performance of mental work.
64	18	Physically inactive people begin to shiver. Active people are comfortable.
60	16	Manual dexterity impaired (stiffness and numbness of fingers).
50	10	Lower limit of reasonable tolerance.
32	0	Risk of frost-bite to exposed flesh.

17.4 Heat stress. Heat stress may be defined as the loading which circumstances impose upon the thermoregulatory mechanisms of the human body (Pheasant 1987). The degree of heat stress is a function of a number of factors; physical workload, thermal insulation of clothing, air temperature, thermal radiation from nearby surfaces, air humidity, and air speed. the currently favoured index is the Wet Bulb Globe Temperature (WBGT) index as defined in ISO 7243. An alternative, more sophisticated, method of calculating heat stress, based upon predicted sweat rate, is given in ISO 7933.

17.5 Thermal comfort. Thermal comfort is defined in ISO 7730 as "that condition of mind which expresses satisfaction with the thermal environment". ISO 7730 is based upon the work of Fanger in the USA and contains detailed equations which relate metabolic rate, clothing and a number of environmental factors to the subjective feelings of comfort of a typical group of people.

ISO 7730 specifies two indices; Predicted Mean Vote (PMV) on a particular comfort rating scale, and the Predicted Percentage, of people, who would be Dissatisfied (PPD).

17.5 (Contd)

ISO 8996 gives guidance on metabolic rate determination, whilst ISO 9886 and ISO 9920 give information concerning thermal strain, and estimation of thermal characteristics of clothing ensembles. At the time of writing (1991) each of these latter two Standards is a Draft for Discussion.

17.6 Cold Stress. The most serious risks associated with cold stress are frost-bite and hypothermia.

Frost-bite occurs when flesh is exposed to sub-zero temperature. Hypothermia is a fall in body temperature. Suitable clothing, and appropriate space heating, should be capable of preventing either of these conditions. The cooling power of an environment is commonly expressed in the Windchill Scale.

$$K_o = (10\sqrt{V} + 10.45 - V)\ (33 - T_a)$$

K_o is windchill factor

V is air speed in metres per second

T_a is air temperature (°C)

The table below gives a rough guide to the interpretation of windchill.

Table 3

Interpretation of Windchill Index (K_o)

K_o	Interpretation
< 90	Hot
90 to 150	Warm
150 to 300	Pleasant
300 to 500	Cool
500 to 700	Very cool
700 to 900	Cold
900 to 1100	Very cold
1100 to 1300	Bitterly cold
> 1300	Exposed flesh freezes
> 1650	Exposed flesh freezes in one minute
> 2150	Exposed flesh freezes in 30 seconds

17.7 Hot Surfaces. Living human tissue will be burned when its temperature reaches 43°C.

The rate at which burning is initiated, and progresses, is dependent upon factors such as object temperature, composition etc. A BSI published document, PD 6504, should be consulted for further information.

17.7 (Contd)

At present, there is only one British Standard which deals with maximum temperatures for non-working surfaces. This is BS 4086, which relates to domestic cookers. An ISO Standard dealing with surface temperatures of touchable parts is currently under discussion. A draft European Standard covering hot surfaces is expected to be published in 1992.

Section Fourteen. Combined Environmental Stressors

18 Definition of Terms

18.1 Stress is a term used to refer to a situation or environment in which a person is overtaxed in some way. Strain is the negative or pathological outcome of stress.

Stressors - the environmental factors which produce a stress response in an individual.

18.2 Introduction and definitions of interactive effects. Previous sections of this Part of the Defence Standard have examined the effects of single environmental stressors or hazards. In a working situation, however, it is usual to find two or more of these stressors acting simultaneously. This section refers to the overall effect of such combinations on an operator within a system. These stressors will interact in different ways to produce one of three types of outcome. The interactions are defined according to Murray and McCally and are described below:

18.2.1 Additive effect. The combination produces a total effect which is equal to the linear sum of the single stressors.

18.2.2 Synergistic effect. The combination produces a total effect which is greater than the linear sum of the single stressors.

18.2.3 Antagonistic effect. The combination produces a total effect which is less than the single stressor or linear sum of the single stressors.

18.3 Factors affecting resultant stress. When assessing the effects of exposure to combined stressors the following must be considered.

18.3.1 The severity of the stressors. The intensity of two or more individual stressors and their combined effects should be considered. It is suggested that the resultant stress will depend on a person's perception of which stressor is the most uncomfortable or has the over-riding effect. At certain levels stressors may also be stimulating and arousing, resulting in better performance. The precise levels will vary according to the individual (see **18.3.2)**, complexity and duration of the task and type of stressors present.

18.3.2 Individual differences. The levels of stress produced and the susceptibility of the operator can determine the overall effect of the stressors. The effect on the individual will depend upon:

(a) previous experience;

(b) expectation;

(c) control over the stressors;

(d) type and complexity of task;

(e) experience at performing the task under stressors;

(f) motivation to succeed.

18.4 Stages in processing affected by stressors. The stressors are considered to act on the operator at the following points.

18.4.1 Input of information. The gathering of relevant information via various human senses can be inhibited by stressors. The effects are usually physical such as vibration affecting vision, or noise inhibiting reception of a signal.

18.4.2 Processing of information. Narrowing of attention and a reduced capacity for internal rehearsal that may arise from exposure to stressors are examples of information processing effects.

18.4.3 Response output. In most situations the operator has to respond and this, like input, may be affected by stressors. For example, vibration makes manual control tasks difficult.

18.4.4 The effects of stress on input and output are often immediate, but changes in information processing may not be seen at once. To prevent a decrement in task performance an operator will often alter his strategy. This may mean a higher workload as more attention or central processing is employed. Although performance of the immediate task is maintained, the more peripheral components of the task might suffer. Adding a second task under conditions of increased workload might also lead to a severe performance decrement, or collapse of both.

18.5 Duration of exposure. As the effects of stressors on information processing are usually time-dependent (see **18.4.4)** they may not be apparent during short periods of exposure. However, fatigue may arise from long periods of exposure. This fatigue can be physiological and/or psychological, affecting either the physical processes or central processing.

18.6 Guide to outcome of exposure to combined stressors. The many different interactions and effects listed in table 4 illustrate the difficulty in predicting the outcome of any combination of stressors. However, the following points may be used as a guide.

18.6.1 The outcome of stressor combinations may possibly be predicted by considering the inverted U–arousal model as discussed in Hockey and Hamilton (1983). This suggests that if the task is complex and/or workload high the operator will be more aroused than if the task is simple and/or workload low. In the former instance where arousal is already high, he will be more susceptible to the effects of environmental stressors which may induce over-arousal. Although the operator may maintain performance under one stressor, the combination of more may well lead to degradation. Increasing one or more of the stressors in a combination will not necessarily lead to a linear increment/decrement in performance.

18.6.2 The sensory inputs to the operator will not only relate to the task in hand but will also come from the environment, eg noise, acceleration, vibration. Since he cannot attend to all these inputs the effect of the stressors may cause 'selective attention'. This may mean that important information inputs are excluded. The greater the input load, the greater the degradation.

18.7 Interactive effects and guide to table 4. Table 4 shows the interactive effects found between combined stressors. The interactions stated make use of the definitions given in **18.2.** The original papers have been examined and only the interactions which are clear and unambiguous have been quoted.

Interactions shown in brackets are those descriptions used in the original papers if they vary from that found during verification. Lack of uniformity in defining the interaction terms probably caused this discrepancy in most cases. In others, insufficient information on single stressor or control conditions meant that the interaction stated in the paper could not be verified for this Standard. In this instance 'not verified' has been placed in the 'interaction' column.

Table 4

Stressor Interactions

STRESSORS	OUTCOME OF DETAILS OF INTERACTION	INTERACTION	REFERENCE
Vibration Noise	Vertical vibration (2.6-16 Hz 3.5 m/s^2) and noise (100 dBA) produce less of a decrement than the single stressors in a complex counting task.	Antagonistic effect	Harris and Shoenberger
Tic effect Vibration Noise	Noise (100 dB) and vertical vibration (6 Hz 1.0 m/s^2) give less of a decrement in a tracking task (horizontal and vertical error) than vibration alone.	Antagonistic effect	Sommer and Harris
Vibration Noise	Noise (110 dB) increases the decrement caused by vertical vibration (5 Hz 2.5 m/s^2) in a tracking task but this is not equal to the sums of the single stressors.	Antagonistic effect (Additive)	Harris and Shoenberger
Vibration Noise	Noise levels of 110 dB and vertical vibration (6 Hz 1.0 m/s^2) produce an additive effect in the vertical component of a tracking task and an antagonistic effect on the horizontal component.	Additive Antagonistic effect (Additive)	Harris and Sommer

Table 4 - Continued

STRESSORS	OUTCOME OF DETAILS OF INTERACTION	INTERACTION	REFERENCE
Vibration Noise	Vertical vibration (0.6-1.2 m/s^2 rms) with noise of equal perceived intensity (78-85 dBA) produces an effect on mental arithmetic scores which is less than that of the single stressors.	Antagonistic effect	Sandover and Champion
Vibration Noise	Semi-random vibration (1.6-4.0 m/s^2 rms) and noise (112 dB) produce no significant performance or physiological effects in simulated helicopter flight.	Not verified	Dean et al
Vibration Noise	Vertical vibration (2.5 Hz 2.3 m/s^2) and noise (78 dBA) produce no vigilance task effects.	Not verified	Ashley and Rao
Vibration Noise	The only significant effect produced by two levels of noise and vibration (6.5 m/s^2 + 94 dB, 13 m/s^2 + 102 dB) was on visual acuity.	Not verified	Loeb
Vibration Noise	Vertical random and horizontal vibration (1.54 m/s^2 1.08 m/s^2) and noise 94 dBA leq 5h produces a synergistic decrement in target detection and decoding times.	Synergism	Rylands
Vibration Noise Heat	Combined heat (49 deg C), vertical vibration (5 Hz 2.9 m/s^2) and noise (105 dB) produce less of an effect on tracking and RT tests than the single stressors or vibration and heat combined.	(Antagonistic effect)	Grether et al
Noise Heat	Noise (90 dB) and heat (31 deg C Effective Temperature) produce no significant performance loss, either singly or combined.	Not verified	Viteles and Smith

Table 4 - Continued

STRESSORS	OUTCOME OF DETAILS OF INTERACTION	INTERACTION	REFERENCE
Noise Heat	Noise (110 dB) and temperatures up to 43 deg C produce no significant degradation in performance or physiological thermal equilibrium.	Not verified	Dean et al
Vibration Acceler-ation	Acceleration of 3.85G and vibration at 11 Hz improves the visual decrement associated with the same vibration and acceleration of lG.	Not verified	Clarke et al
Vibration Linear Acceler-ation	Tolerance to resonating frequencies between 2.5 and 20 Hz is reduced by high linear acceleration. Higher mechanical impedance, greater transmission of energy to internal organs and pain were reported.	Synergism effect	Vykukal
Positive Acceler-ation Heat	Prior heat stress with minimal dehydration (l-3% body wt) lowers tolerance to acceleration (G value) by 15-18%. Peripheral light loss and poor co-ordination prevented light detection.	Not verified	Taliaferro, Wempen and White
Acceler-ation Heat	Heat (skin temp 37 deg C) reduces tolerance to acceleration by lowering G value for peripheral light loss.	Not verified	Martin and Henry
Upwards Acceler-ation Dehydrat-ion	Prior heat stress with dehydration (4.3% body wt) lowers tolerance to acceleration by decreasing the time to greyout.	Not verified	Greenleaf et al
Upward Acceler-ation Heat	An environmental temperature rise from 24 to 71 deg C reduces tolerance to acceleration by 1G. Peripheral light loss and poor co-ordination prevented response to target lights.	Not verified	Burgess

Table 4 - Concluded

STRESSORS	OUTCOME OF DETAILS OF INTERACTION	INTERACTION	REFERENCE
Acceler- ation Cold	Cold (skin temp 25 deg C) increases tolerance to acceleration over 15 seconds by raising the G value for peripheral light loss.	Antagonistic effect	Martin and Henry
Positive Acceler- ation Hypoxia	Hypoxia (9.5% inspired 02) reduces tolerance to acceleration by 18% lowers the G value for peripheral light loss.	(Additive)	Burgess
Hypoxia Upward Acceler- ation	Hypoxia (23000 ft equiv) lowers the G value tolerated during acceleration by 25%.	Not verified	Gauer
Hypoxia Cold	Hypoxia (18000 ft equiv) during cold exposure, raises heart rate but the effect was felt to be no more serious than exposure to each stressor singly.	Not verified	Brown
Hypoxia Cold	Hypoxia (10% inspired 02) and cold (5 deg C) produces an apparent synergistic increase in heart rate and ventilation rate. Shivering increased greatly during the first 15 minutes of exposure.	Not verified	Bullard
Hypoxia Heat	Heat (49 deg C) and hypoxia (equiv 14000 ft) increases the cardio-acceleration produced by the single stressors but does not exceed their linear sum.	Antagonistic effect (Synergistic effect)	Hale
Hypoxia Heat Noise	Heat (41 deg C), white noise (110 dB) and hypoxia (12000 ft equiv) studied in pairs or all combined, show additive interactions.	Not verified	Dean, McGlothlen and Monroe
Hypoxia Carbon Monoxide	Small amounts of CO reduce tolerance to hypoxia. Helps to promote unconsciousness.	Not verified	Armstrong

Section Fifteen. Effects of Sleep Loss

19 Introduction

The purpose of this Section is to summarize the effects of sleep loss relevant to designers; it is therefore not a fully comprehensive statement on the subject. Performance is impaired in many ways, with inability to concentrate being central amongst them. This effect, together with periods of difficulty in comprehension, misinterpretation, and feelings of disorientation, often appears after one night of total sleep loss, and is present in most individuals after 2 nights without sleep.

20 Lapses of attention

Inability to concentrate, or lapses of attention, are due to 'microsleeps' which last a few seconds; these short periods, when signals are missed, increase in frequency and duration with increasing sleep loss. These lapses are responsible for much of the performance impairment which is found following sleep-deprivation, especially in tasks that require continuous attention.

21 Vigilance

Because of the occurrence of these lapses, it follows that vigilance is impaired. Situations with little sensory stimulation increase sleep-loss effects; performance can be improved by the interjection of extra signals and, for example, by using 2 sensory modalities together (vision and hearing) for the detection of targets when surveillance equipment is used.

22 Memory

Also impaired is short-term memory, and so aide-memoires are important. Because of deterioration in memory, tasks requiring long sequences of actions need to have inbuilt devices which preclude order-of-events errors. Complex decision-making is also likely to be impaired if there is a long sequence of clauses to be remembered.

23 Long, uniteresting and monotonous tasks

Tasks that are long, uninteresting or monotonous are adversely affected by loss of sleep. Any variety, or change of stimulation, that can be introduced into the situation will help to reduce the impairment.

24 Work-paced tasks

Tasks that are work-paced, as opposed to self-paced, are adversely affected by sleep deprivation; this is because an attentional lapse may coincide with the need for a response.

25 High workloads

Following sleep deprivation, performance during periods of high workload is more impaired than during periods of low workload. This is because when workload is high there are few or no interludes, and so attentional lapses will almost certainly coincide with a work requirement. Even a short break in activity is very beneficial.

26 Tasks without feedback

Performance on tasks where there is little feedback will be adversely affected following loss of sleep, knowledge of results adds incentive.

27 Routine tasks

Routine but critical subsidiary tasks tend to be skipped; this is part of a general unwillingness to respond following loss of sleep. Added interest/incentive will assist personnel to carry out subsidiary tasks.

28 Speed of response

All tasks are likely to take longer following sleep deprivation, and reaction time to a stimulus is increased.

29 Erratic performance

Performance becomes more erratic, and there is increased variability in proficiency following loss of sleep.

30 Time of day

Performance is at its lowest ebb between 0200 and 0600 hours, coinciding with the low point in circadian rhythms. This drop in performance is exacerbated by sleep loss.

31 Eyestrain

Under conditions of prolonged sleep deprivation there are likely to be reports of feelings of eye strain, headache, blurred vision and double vision; these symptoms are particularly likely to occur during any prolonged close work, especially under conditions of poor lighting (see Part 6, Vision and Lighting). Performance can be improved by the-provision of clear, well-lit displays (see Part 7, Visual Displays).

32 Physical tasks

The performance of physical tasks will only be affected in the presence of severe physical fatigue.

SUMMARY

33 Tasks most affected by sleep loss

Complex, uninteresting, lengthy, requiring sustained attention, subsidiary, work-paced, entailing a long memory chain, demanding protracted viewing periods at short range.

34 Tasks least affected by sleep loss

Short, simple, interesting, self-paced, physical.

35 Main effects of sleep loss on mental processes

Lack of concentration
Lapses of attention
Reduced vigilance
Slowing of action
Impaired short-term memory
Difficulty in comprehension
Misinterpretation
Disorientation

Related Documents

The documents and Duplications referred to in this Part of the Standard are as follows:

IS0 2041	Vibration and shock - vocabulary
ISO 2631	Guide to the evaluation of human exposure to whole-body vibration.
ISO 6897	Guide to the evaluation of the response of occupants of fixed structures especially buildings and off-shore structures to low-frequency horizontal motion (0.063-1Hz).
ISO 7243:	Hot environments; estimation of the heat stress on working man, based on the WBGT-index.
ISO 7726:	Thermal environments; instruments and methods for measuring physical quantities.
ISO 7730:	Moderate thermal environments; determination of the PMV and PPD indices and specification of the conditions for thermal comfort.
ISO 7933:	Hot environments; analytical determination and interpretation of thermal stress using calculation of required sweat rate.
ISO 8996:	Determination of Metabolic Heat Production.
ISO 9886:	Evaluation of thermal strain by physiological measurements.
ISO 9920	Estimation of thermal characteristics of a clothing ensemble.
BS AU183	Passive seat belt systems.
BS 1397	Industrial safety belts, harness and safety lanyards.
BS 3254	Seat belt assemblies for motor vehicles.
BS 4086:	Recommendations for maximum surface temperature of heated domestic equipment.
BS 6472	Guide to Evaluation of human exposure to vibration in buildings (1Hz-80Hz).
BS PD6504:	Medical information on human reaction to skin contact with hot surfaces.
BS 6841	Measurement and evaluation of human exposure to whole body mechanical vibration and repeated shock.
BS 6842	Guide to measurement and evaluation of human exposure to vibration transmitted to the hand.
Defence Standard 00-25	Human Factors for Designers of Equipment.
Defence Standard 00-27	Acceptable limits for exposure to impulse noise from military weapons, explosive and pyrotechnics.
Defence Standard 05-74	Guide to the practical safety aspects of the use of radio frequency energy.
BR 1326	Air Purification in submarines.
BR 1326A	Materials toxicity guide.
JSP 390	Military laser safety.
JSP 392	Instructions for radiological protection (section 12).

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B.1 The Submarine Atmosphere

B.1.l Sea Systems Controllerate.
Chief Naval Architect
Submarine Safety Section NA 113
Foxhill
Bath

B.1.2 The Institute of Naval Medicine
(Senior Medical Officer, Submarines (SMO(SM))
Alverstoke
P012 2DL

B.2 Whole Body Motion Phenomenon

B.2.1 Army Personnel Research Establishment (APRE) Farnborough Hants GU14 6TD.

B.2.2 Institute of Aviation Medicine (IAM) RAE Farnborough.

B.2.3 Institute of Naval Medicine (INM) Alverstoke, Hants

B.2.4 Institute of Sound and Vibration Research, University of Southampton.

B.3 Vibration and Shock

B.3.1 Institute of Sound and Vibration Research (Dr M J Griffin). The University of Southampton, S09 5HN.

B.4 Weightlessness

B.4.1 European Space Research and Technology Centre (ESTEC). Noordwijk 2200 AG, The Netherlands.

B.4.2 NASA G C Marshall Space Flight Centre, Huntsville, AL35812 USA.

B.4.3 NASA L B Johnson Space Centre, Houston, Texas 7705 USA.

B.5 Effects of Radiation

B.5.1 Army Radiation, Health and Safety Committee.

B.5.2 Naval Radio Hazards and Safety Committee.

B.5.3 RAF Radiation Health and Safety Committee.

B.5.4 Defence Radiological Protection Service c/o Institute of Naval Medicine, Gosport, Hants.

B.6 Chemical and Biological Contaminants

B.6.1 Chemical Defence Establishment, Porton Down, Salisbury, Wiltshire.

B.6.2 Army Personnel Research Establishment Farnborough, Hampshire, GU14 6TD.

B.6.3 The Ergonomics Society c/o department of Human Sciences, University of Technology, Loughborough, Leicestershire.

B.6.4 Defence NBC Centre, Winterbourne Gunner, Salisbury, Wiltshire.

B.7 Safety Standards

B.7.1 Director of Safety Services, MOD(PE), Station Square House, St Mary Cray, Orpington, Kent.

B.8 Combined Environmental Factors

B.8.1 APRE Farnborough, Hants

B.8.2 IAM Farnborough, Hants

B.8.3 INM Alverstoke, Hants.

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When Defence Standards are incorporated into contracts users are responsible for their correct application and for complying with contract requirements.

Revision of Defence Standards

Defence Standards are revised when necessary by the issue either of amendments or of revised editions. It is important that users of Defence Standards should ascertain that they are in possession of the latest amendments or editions. Information on all Defence Standards is contained in Def Stan 00-00 (Part 3) section 4, Index of Standards for Defence Procurement - Defence Standards Index published annually and supplemented periodically by Standards in Defence News. Any person who, when making use of a Defence Standard encounters an inaccuracy or ambiguity is requested to notify the Directorate of Standardization without delay in order that the matter may be investigated and appropriate action taken.

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Date
April 1992

INTERIM DEFENCE STANDARD IMPROVEMENT PROPOSAL

Defence Standard No: 00-25 (Part 5) Issue 1

Title: Human Factors for Designers of Equipment
Part 5 Stresses and Hazards

The above Defence Standard has been published as an INTERIM Standard and is provisional because it has not been agreed by all authorities concerned with its use. It shall be applied to obtain information and experience on its application which will then permit the submission of observations and comments from users.

The purpose of this form therefore is to solicit any beneficial and constructive comment that will assist the author and/or committee to review the INTERIM Standard prior to it being converted to a normal Standard.

Comments are to be entered below and any additional pertinent data which may also be of use in improving the Standard should be attached to this form and returned to the Directorate of Standardization at the above address. No acknowledgement will normally be sent.

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1. Has any part of the Standard created problems or required interpretation during use:

☐ YES ☐ NO if 'yes' state,

a. clause number/s and wording:

b. recommendation for correcting the deficiencies:

2. Comments on any requirement considered too rigid:

Continued over

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