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HUMAN FACTORS

FOR DESIGNERS OF EQUIPMENT

PART 8: AUDITORY INFORMATION

AMENDMENTS ISSUED SINCE PUBLICATION

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Revision Note

Historical Record

This Defence Standard has its origins in the 2-volume handbook "Human Factors for Designers of Naval Equipment" published in 1971.

Arrangement of Defence Standard 00-25

The arrangement of the Parts comprising Def Stan 00-25 is shown below:

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

Two or more Parts may apply to any one equipment and therefore, it is essential that all relevant Parts be consulted.

HUMAN FACTORS FOR DESIGNERS OF EQUIPMENT

PART 8: AUDITORY INFORMATION

PREFACE

i This part of this Defence Standard presents guidelines on the important factors concerning the design of auditory signals and displays, and the selection of suitable characteristics for association with specific meanings.

ii This Part of this Standard is published under the authority of the Human Factors Subcommittee of the Defence Engineering and 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.

iv This Standard has been devised for the use of the Crown and of its contractors in the execution of contracts for the Crown and, subject to the Unfair Contract Terms Act 1977, the Crown will not be liable in any way whatever (including, but without limitation, negligence on the part of the Crown, its servants or agents) where the Standard is used for other purposes.

v This Standard has been agreed by authorities concerned with its use and shall be incorporated whenever relevant in all future designs, contracts, orders etc and whenever practicable by amendment to those already in existence. If any difficulty arises which prevents application of the Defence Standard, the Directorate of Standardization shall be informed so that a remedy may be sought.

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

vii Users of this Standard shall note that some material may be claimed to be subject to copyright in this or other countries. Copyright where known is acknowledged.

viii The principles underlying the use of complex auditory signals may be claimed to be subject to patent rights in this or other countries and are reproduced with acknowledgement to British Technology Group, 101 Newington Causeway, London SE1 6BU.

ix This Defence Standard is being issued as an INTERIM Standard and is provisional in order to obtain information and experience of its application. This will then permit the submission of observations and comments from users, using D Stan Form No 22 enclosed.

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HUMAN FACTORS FOR DESIGNERS OF EQUIPMENT
PART 8: AUDITORY INFORMATION

Section One. General

0 Introduction

0.1 In presenting information to a human operator the equipment designer may have an apparently wide choice of channels from among hearing, vision and other senses. Touch, kinaesthetics, balance, taste and smell are of limited use, and are called "low capacity" channels. Vision is the preferred channel for the transfer of detailed information, (see Part 7 of this Standard). Not only are auditory signals independent of lighting conditions, and visual load, but hearing is omni-directional. Hence hearing is the preferred channel for the diversion of an operator's attention from a current activity, and to alert multiple operators with a single signal. It is comparable in importance to vision, and is the primary means of perceiving speech. In this context the meaning of non-verbal auditory signals must be learned, in contrast to the assumed understanding of speech gained at an early age. An initial non-verbal component of a signal may be used to attract attention to subsequent words, phrases or complete sentences. Verbal components should follow the guidelines laid down in Part 9 of this Standard.

0.2 An auditory display is produced when an auditory signal is designed to vary in response either to changes in a known factor or to the actions of a human operator.

0.3 In order to be effective an auditory signal must be heard, recognized and understood.

0.4 The aim of this Part of this Standard is to provide both the sponsors for the procurement of defence equipment, and also the designers of that equipment, with guidance on the design, selection and assessment of auditory signals.

1 Scope

1.1 This Part of this Standard concerns the transfer of information to human operators using their hearing and a learned set of auditory signals.

1.2 This document identifies the factors influencing the effectiveness of auditory signals, provides guidelines for the design and selection of auditory signals, and states how the effectiveness of proposed auditory signals may be assessed. These guidelines include occasional mandatory requirements where experience indicates them to be necessary. These requirements include the word 'shall' underlined, eg 'shall' or 'shall not', and are listed in the Index under Mandatory Requirements.

2 WARNING

This Standard calls for the use of substances and/or procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and 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.

3 Related Documents

3.1 The documents referred to in this Part of this Defence Standard are listed in annex A.

3.2 Reference in this 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.

4 Definitions

4.1 For the purpose of this Part of the Defence Standard the definitions in BS 4727 apply together with those listed in annex B.

4.2 Nomenclature for alarms and warnings. For ships, auditory signals are defined in Naval Engineering Standard 599 and for aircraft, 3 categories of auditory signal are defined in Defence Standard 00-970 and STANAG 3370. Different nomenclatures are apparent in these documents for the meaning of 'Warning'. It is emphasized however that there is consistency between naval and air Standards in the priority allocated to auditory signals of similar category but of different name. (For definitions of categories of auditory signals see Annex B10 to B14).

Section Two. Valid Use of Auditory Signals

5 General

In early stages of concept definition for new systems or equipment, the need to transfer information to human operators through auditory signals or other means should be reviewed.

6 Suitable Use of Auditory Signals

6.1 Auditory signals are appropriate when:

(a) the information to be processed is short, simple, transitory, and requiring immediate or time-based responses;

(b) the critical nature of the response to the information makes supplementary or redundant transmission desirable, through audio as well as visual modes, when for example;

(i) it is desirable to warn, alert or cue the operator to subsequent further response;

(ii) custom or usage has created anticipation of an audio display;

(iii) voice communication is desirable, and needs to be cued by a non-verbal signal;

(iv) operational or environmental factors limit vision but not hearing.

7 Examples of Suitable Auditory Signals

7.1 Equipment designed to detect dangerous objects or substances produce auditory signals coded for proximity to them. In such equipment, fault warnings, derived from Built-In Test Equipment (BITE), shall produce a broad band noise which obliterates all normal detection signals, thus preventing normal use of unserviceable equipment. Such a choice conforms to **6.1** (a) and **6.1** (b)(ii).

7.2 In order to warn the occupants in a building of fire, the choice of a strident bell conforms with **6.1** (a), **6.1** (b)(ii) and **6.l** (b)(iv) above, yet signal improvement, eg by the addition of speech supplements, may be necessary to overcome the habit of ignoring bell-like sounds heard as frequent false alerts from burglar alarms.

7.3 Further information may be found in ISO 7731, Patterson and Milroy (1979), Patterson (1982). Doll and Folds (1986), and US DOD MIL STD 1472 C (1981).

8 Inappropriate Use of Auditory Signals

8.1 Auditory signals are inappropriate when:

(a) environmental noise prevents effective listening, eg noise from engines in ships, aircraft or land vehicles, or from air conditioning plant in buildings;

8.1 (Contd)

(b) personnel, other than the intended listeners, can hear auditory signals and are distracted from important tasks by those signals;

(c) specific auditory signals can be confused with existing signals, or with known interactions with the operational environment. Further information may be found in ISO 7731 and US DOD MIL STD 1472 C. The comprehensive list of prohibitions found in the MIL STD 1472 C should be taken as cautionary advice for specific operational circumstances.

9 Unsuitable Types of Auditory Signals

9.1 The following types of signal shall not be used where confusion exists because such signals occur in the operational environment:

(a) modulated or interrupted tones which resemble navigation signals or coded radio transmissions;

(b) continuous signals which resemble hisses, static, electrical interference, or electrical mains hum.

Section Three. Signal Audibility

10 General

10.1 Ideally all intended listeners should hear an auditory signal on every occasion under all operational conditions. Such a requirement is difficult to specify, particularly when it is recognized that any or all of the reference data may not be available or may change during the service life of an equipment or even during its development. The need for an audible signal (see **B.6)** may be stated as an operational requirement, against which designers should match auditory signals (see **B.7)** as closely as possible.

10.2 For the purposes of this Standard, equipment designed to generate, transmit or control auditory signals shall include a low-cost means of easily and rapidly modifying the physical characteristics of those auditory signals.

11 The Auditory Communication Window

Signal audibility depends on signal frequency and level in relation to hearing threshold at the same frequency. In the presence of noise the threshold is elevated to a masked threshold, when a higher signal level is needed for audibility at a given frequency. Conversely very loud noise can distort human hearing and reduce signal audibility and recognition. Hence there is an upper limit to the level of auditory signals (Patterson 1978, 1982) which is similar to that recommended for the avoidance of hearing hazards (see Part 5 of this Standard). These points are conveniently represented in an auditory communication window (see Figure 1). Further information is available in Part 9 of this Standard. The absolute threshold, the lowest line in Figure 1, is unsuitable, since it is derived from the sounds just heard by about 50% of persons within the age limits of 18 to 25 years inclusive (see BS 3383:1988). An effective limit some 12 to 15dB higher than the 'absolute' threshold may be assumed for User populations that are monitored regularly for good hearing, eg aircrew. According to Coombe (1980) some 17% of army recruits at induction had hearing losses of 30 dB or more at one or more of the standard audiometric test frequencies between 250Hz and 8kHz. Assuming that these losses were evenly distributed over frequency, a hypothetical lower limit can be made as an example of the reduction which can occur in the available auditory communication window, illustrated in Figure 1 by the dashed line labelled Effective service limit. Auditory signals should be based on frequencies in the range 300Hz to 3kHz. There should be sufficient energy in the frequency range below 1500Hz to meet the needs of personnel with hearing loss or wearing hearing protectors.

12 Signal Audibility in Quiet Conditions

12.1 For the purposes of this Standard quiet conditions occur when ambient or background noise levels are less than 50 dB(A). Limiting sound levels from auditory signals to be heard in quiet conditions are suggested at **12.2** and **12.3.** For free-field conditions, the sound levels are relevant to the head position of a listener, but measured in the absence of the listener. For conditions requiring the use of headphones, the sound levels are relevant to signals measured beneath the headphones at the ear of a listener who is present.

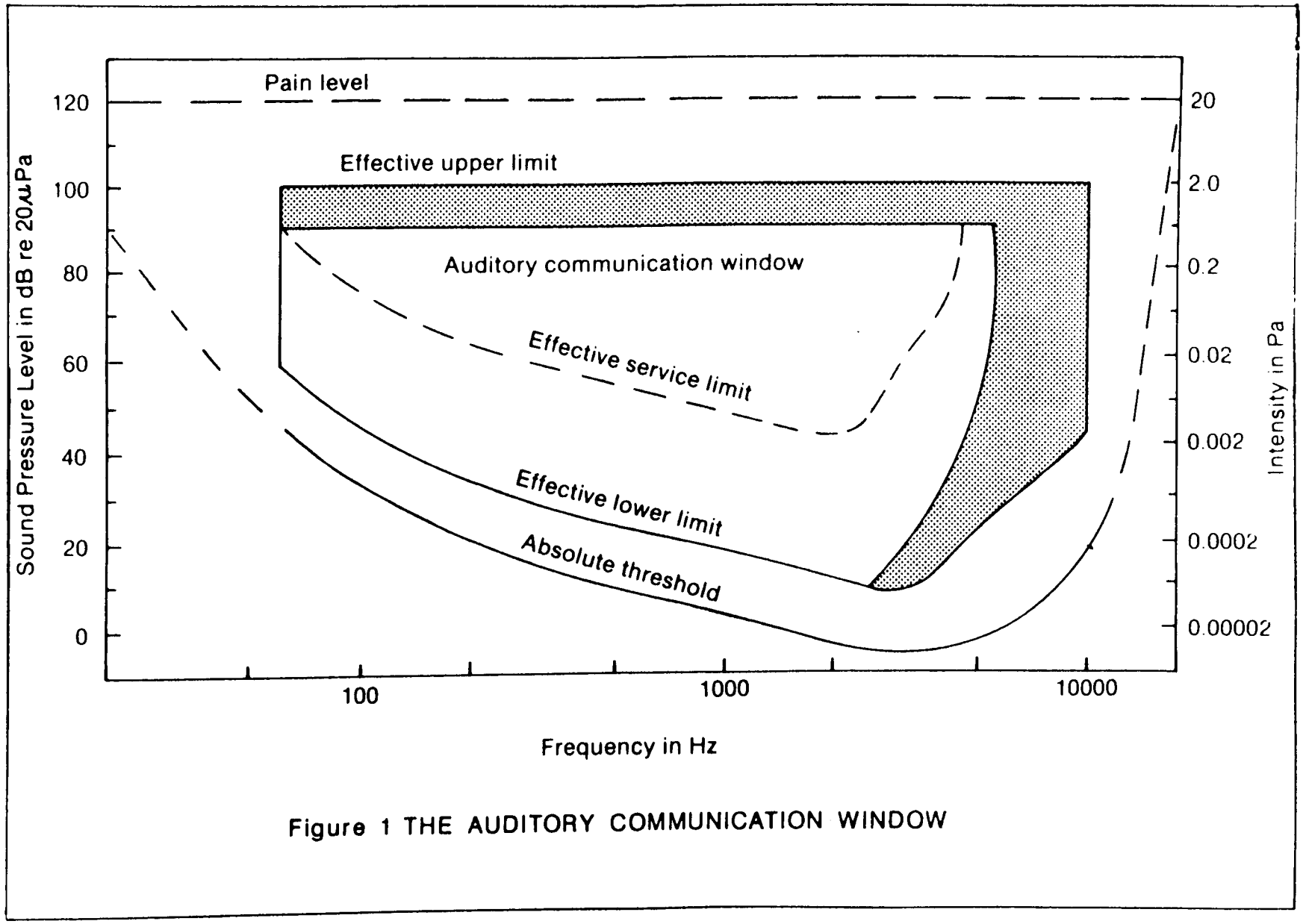

Figure 1 THE AUDITORY COMMUNICATION WINDOW

12.2 Maximum limit. The maximum level for an auditory signal presented in quiet conditions should be 90dB(A), preferably 85dB(A). Even so,at this level an undesirable startle reaction may be produced (see **17).** Unexpected auditory signals, particularly those in category one (See B10 to B14), should be audible to all intended listeners. Signal levels above 90dB(A) may be justifiable in some signal reception areas, and for some listeners, in order to achieve signal audibility for others. Potential hazards to hearing should be minimized by limiting exposure duration (see Part 5 of this Standard).

12.3 Minimum limit. The minimum sound level for an auditory signal presented in quiet conditions shall be 65dB(A), (see ISO 7731: 1986). This limit shall be reduced only when there is direct evidence of population hearing levels suited to a lower limit.

12.4 Night operations. For equipment to be used silently at night the sponsor may designate a single value of 60dB(A) at the ear under an earphone. In this case personnel should be monitored regularly for good hearing.

13 Signal Audibility in Noise

13.1 The presence of noise will affect both upper and lower limits for auditory signals. However, in the absence of data for assessment and prediction of suitable sound levels very little positive guidance can be given. The suggested levels are free field or at the ear as for signals in quiet conditions (see **12).**

13.2 Maximum limit. The maximum sound level for a signal presented in noise is based on three criteria: the need to avoid hearing hazards, startle reactions and distortion of the signals presented. Signals need be no more than 15dB above masked threshold in order to be effective.

13.3 Minimum Limit. In the absence of suitable data for assessment or prediction it is only possible to recommend that signals are at least 15dB above masked threshold in at least one preferably three 1/3rd octave bands (see also ISO 7731: 1986).

14 Signal Level

14.1 Auditory signals should preferably be presented within a predetermined and fixed range of sound level. When an equipment must be used both in relatively high ambient noise levels and also in very quiet conditions, eg without detection by a potential enemy, it is permissible to provide a volume control, which shall not permit a zero signal. A volume control shall therefore provide either a choice between present levels, usually high and low, or continuous adjustment between preset minimum and maximum signals. Throughout the range of a volume control, auditory signals shall comply with the requirements for audibility and safety (see Part 5 of this Standard).

14.2 A regular auditory signal shall be available to permit the human operator to set and monitor a volume control. The confidence signal, when provided, shall be used for this purpose.

14.3 When provided, a volume control shall adjust to a similar extent the sound levels of all the auditory signals in the set, subject to permitted minima and maxima.

15 Signal Intrusiveness and Cancellation

15.1 It is known that without taking the intended action, overloaded human operators will occasionally use a cancelling control in order to remove an intrusive warning signal. In order to avoid such situations, designers are advised to reduce the intrusiveness of the signal, or to reduce operator workload. It is important automatically to link cancellation to the corrective action, and, if an erroneous response is made, to generate an automatic increase in signal urgency. Provided required responses and actions can be correctly identified within the equipment, an increase in safety could be achieved.

15.2 Cancellation of an auditory signal should reinstate automatically signals of lower priority which had been suppressed. It is preferable that reinstatement should be delayed pending identification of correct response to the signal of higher priority.

Section Four. Signal Recognition

16 General

In order to be effective an auditory signal must be recognized. In this context recognition of an auditory signal occurs when attention is gained and listeners successfully discriminate the signal from all other sounds. The association of a meaning with a recognized sound is covered in Section Five.

17 Attention Gaining

An auditory signal must gain the attention of human operators concentrating on tasks other than listening for an unexpected signal. Increasing signal level can, and often does, cause startle reactions (see **18).** The better course of action is to select distinct signal characteristics, as different frequency content or temporal patterns are likely to be more effective in this respect than an increase in signal level. Specific operator tasks will have an important influence on attention gaining. Therefore these design suggestions should be trialled using listeners who are carrying out their normal duties.

18 Startle Reaction

Abrupt onset and offset of an intense warning sound can and often does produce a startle reaction characterized by transitory general muscle tension. Such abrupt sounds can cause a temporary disruption of cognitive thought (Patterson 1982). Hence signals shall be arresting yet not startling. This apparent conflict stems from the belief that all warnings must be generated as quickly as possible, when in fact instantaneous response is often beyond human capability, and in some cases should be discouraged. Correct onset of warnings can permit decisions undiverted by startle reaction. In general, designers shall avoid using, in the first 0.2s of a signal: abruptly rising waveforms; square topped waveforms, eg use trains of rounded pulses (see **22);** or maximum level. Startle reactions may be expected when sound level rises by more than 30dB in 0.5s.

19 Signal Discrimination

When signal audibility and sufficient attention gaining have been secured for a signal, it is still necessary to ensure discrimination from other signals. Historically, variation of one acoustic dimension has been regarded as sufficient for this purpose. For signals in categories one and two, the signal shall be dominantly different from other sounds in the reception area, in at least two of the following acoustic parameters; sound level in a selected bandwidth; frequency combination; and temporal pattern. All other categories of a signal shall be so in at least one of the above acoustic parameters.

20 Discrimination of Signal Level

Subjective assessment of signal level is unreliable (Schubert 1979) and shall not be used as the sole means of discrimination between signals. Within a signal, changes in level are recognizable, as in interrupted signals or amplitude modulation.

21 Discrimination of Frequency

Although signal recognition should never rely on a sense of absolute pitch, discrimination between frequencies is easier than between signal levels. Even small changes in frequency within a signal are recognizable when presented for immediate comparison under quiet conditions, eg a few Hz either side of 1kHz. There should be sufficient energy below 1500Hz in the signal to permit recognition by listeners wearing hearing protection, or suffering from hearing loss. Selection of a harmonically related group of frequencies can produce signals which are more robust to the distorting effects of noise, even when the frequencies in noise vary. Such signals are robust to the effects of noise because of the human ability to recognize the fundamental frequency in such signals even when it is masked or even absent. Consequently designers should adopt multiple harmonic relationships within signals yet avoid them between the frequencies of signals intended to carry different meanings. In this respect it is important to evaluate all signals in the same trial.

22 Discrimination of Temporal Pattern

Regular interruption of a signal has been widely used as an aid to recognition. Consistency in repetition is more important than the value of on-off time selected from within the general guideline of 0.5 to 2s. More recently different rhythmic patterns of signal pulses have been formed into discriminable sequences, which themselves may be repeated to form pulse trains. (see Patterson 1982) The following sub-clauses are based on the principles referred to above. They have been derived for auditory signals on the flight deck of civil aircraft and efficacy in other situations should be confirmed experimentally.

"Users of this Standard shall note that the processes may be claimed to be subject to patent rights in this or other countries (see preface **viii**)."

22.1 In order to achieve the best compromise between signal recognition, avoiding startle reactions, and reducing interference with normal speech, pulses should be constructed from several harmonically-related frequencies suited to the available auditory communication window (see Fig 1 and Part 9 of this Standard) and the sound which is to be perceived. The optimum signal should be modulated (AM or FM) at between 0.5 and 4Hz. Each pulse should last for 100 to 150ms, rise or fall within 20 to 30ms, have a top level for about 100ms yet be rounded through 25ms quarter sine-wave gates.

22.2 A sequence of six pulses is illustrated in Figure 2. Within a sequence, the spacing need not be regular, although once fixed it should be retained in repetitions, unless a different sound is needed. It is possible to increase the apparent urgency of a sequence by reducing the spacing between say the first four elements (see Figure 2). In contrast longer spacings are appropriate for initial auditory signals or attensons. Short bursts of sound (pulse sequences) separated by 5 or 10 seconds can present information effectively with little or no interference with speech.

22.3 For Pulse Trains the overall level of repeated signal sequences can be varied (see Figure 3) such that the initial sequence is well above masked threshold, yet below startle level; middle sequences may be at a maximum compatible with the absence of hearing hazard; several final sequences may be at the lowest level audible thus reinforcing the message and permitting superimposed human voice communication. Such automatic reduction in level will make the signal appear less "selfish".

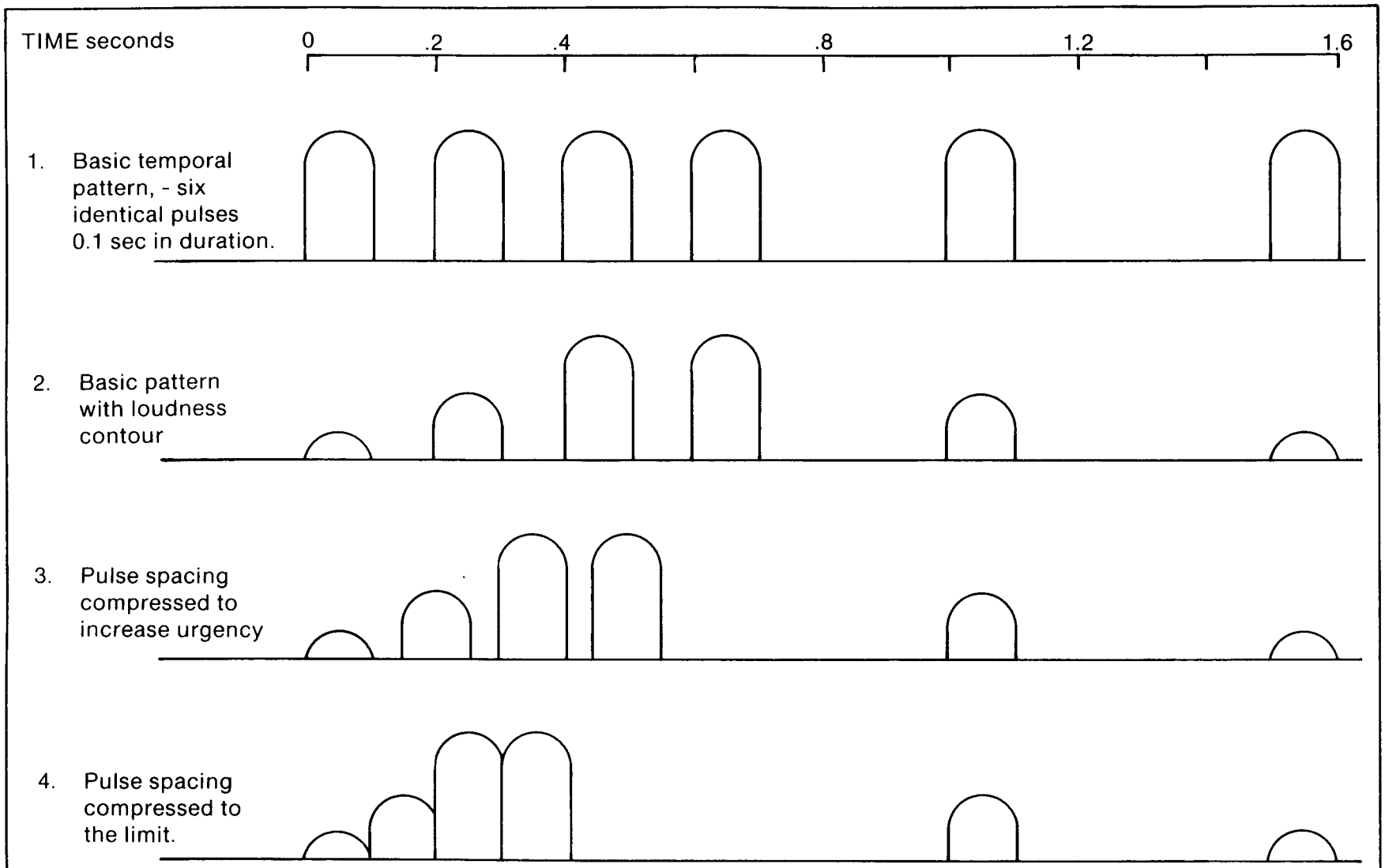

Figure 2 COMPONENT PATTERNS FOR AN ADVANCED AUDITORY WARNING SOUND

Note: The basic pattern is four regular-spaced pulses of sound followed by two irregularly spaced pulses. The different rows show varying levels of urgency.

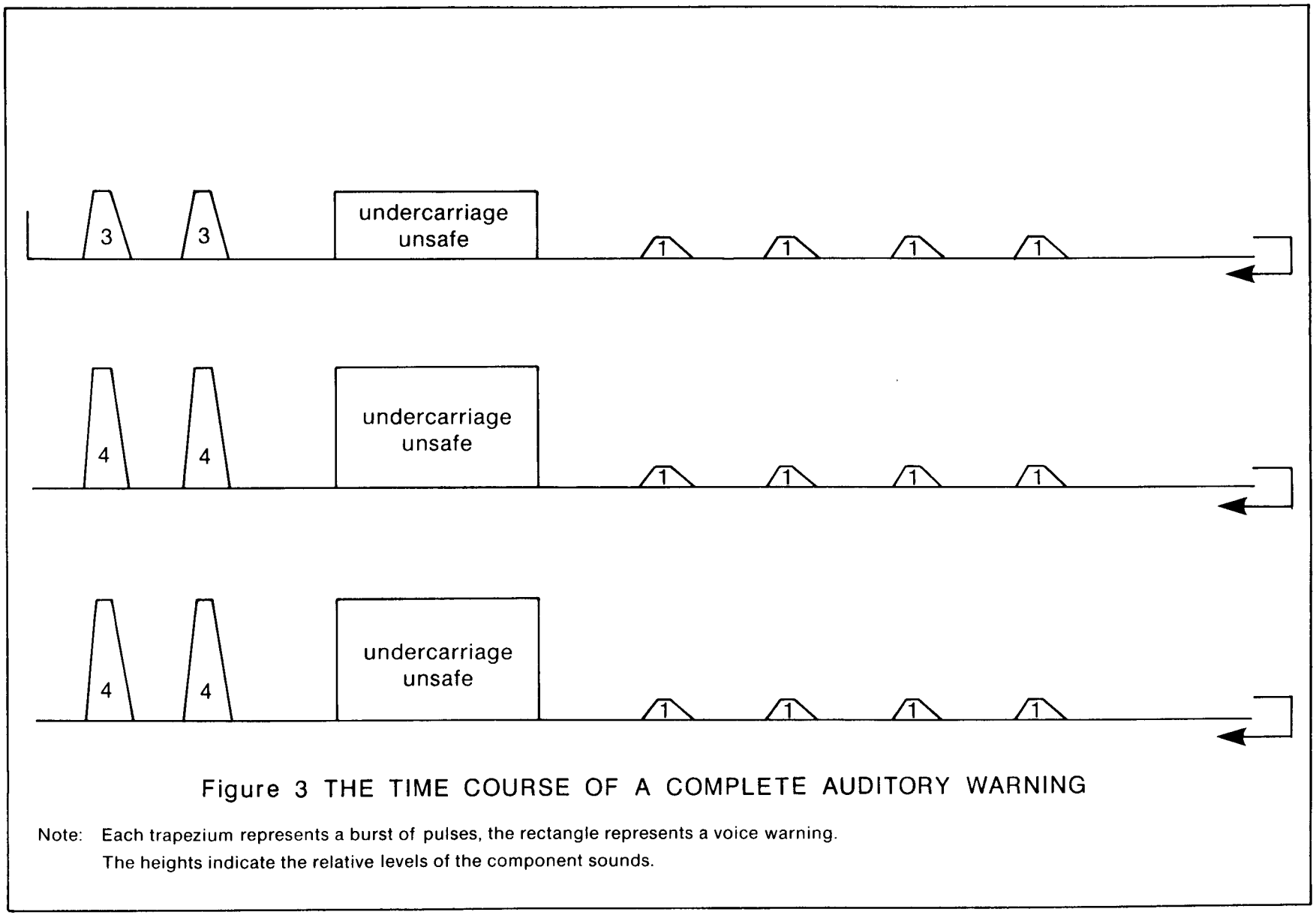

Figure 3 THE TIME COURSE OF A COMPLETE AUDITORY WARNING

Note: Each trapezium represents a burst of pulses, the rectangle represents a voice warning.
The heights indicate the relative levels of the component sounds.

Section Five. Signal Meaning

23 General

In order to be effective an auditory signal once recognized, must also be understood, ie each auditory signal shall be associated unambiguously with a single meaning. This Section of this Standard provides general guidelines on the reduction of signal ambiguity, and suggestions for the selection of specific auditory signals.

24 Signal Number

The specification of a generally applicable maximum number of auditory signals is beyond practical definition. In order to avoid ambiguity, experience suggests that no more than six, preferably four auditory signals should be used (see Patterson 1982, Coleman 1984, and Wilkins 1981). Designers are advised to use no more than are necessary, and less than the advised maximum whenever possible, unless directly relevant experimental evidence can be provided to the contrary.

24.1 Grouped visual displays should be used to provide specific and detailed information, and master auditory signals to draw attention to them (see Defence Standard 00-970 and US MIL STD 1472 C).

24.2 Attensons and speech supplements shall be used only when the signal length does not impair the reception of other auditory inputs, including voice communication with other personnel.

25 Previous Meanings

Well-known sounds previously associated with an intended meaning should be incorporated in new designs, including the perpetuation of specific frequencies or frequency combinations in the design of signal pulses. Examples for aircraft are given in Defence Standard 00-970 and for ships in Naval Engineering Standard 599, eg submarine diving alarm.

25.1 Specific physical characteristics of well-known auditory signals shall not be incorporated into signals carrying different meanings, whether or not the well-known signal appears in the signal set.

26 Apparent Urgency

The more rapid the repetitions of signal sequences the more urgent they will sound, eg the rate of signal modulation or repetition of pulse sequences in a pulse train. Both apparent urgency and attention gaining characteristics should be matched to the relative priority of each signal in the set.

27 Auditory Displays

When it is necessary for a human operator to monitor changes in a known factor, an auditory display can be preferable to a visual display, particularly when a specialist monitors the display continuously as a primary task. Equipment designed to detect dangerous objects, materials or substances should employ continuous auditory displays, particularly when the detection rate is low. In such cases the auditory signals may be coded

27 (Contd)

for proximity. Increases in signal frequency, in rate of signal modulation or in rate of signal repetition, shall indicate closer approach. For this purpose, designers should avoid using increase in signal level, which can prove unreliable, particularly in the presence of variable background noise. Changes in sensor output should produce corresponding responses in the auditory signal. Direct sensor to signal relationships are preferred. Delays caused by signal processing, for example, are undesirable, and are likely to increase task difficulty and human error.

28 Erroneous Signals

Frequent false auditory signals occurring either as a result of a fault in equipment (a false alert) or of an environmental factor (a false alarm), will degrade user confidence and the meaning of a true signal. The reliability of equipment shall be sufficient to reduce equipment faults to the minimum specified by the sponsor. Designers are encouraged to seek ways of avoiding interactions between equipment and the environment which are known to cause auditory signals. A 'fault warning' shall be treated as either a warning signal or a cautionary signal depending on the criticality of the fault.

Section Six. Requirements for Specific Auditory Signals

29 General

This Section of this Standard provides guidance on the design and selection of suitable attributes for specific auditory signals including: Emergency Evacuation Signal; Warning Signal; Cautionary Signal; Advisory Signal; Confidence Signal; All Clear; Verbal or Voice Signals.

30 Emergency Evacuation Signals (see **B.18)**

30.1 Pending publication of British and International Standards on Emergency Evacuation Signals (EES) the following guidelines are suggested for suitable Defence applications, eg fire alarms in offices, barracks, stores and other buildings:

(a) an EES shall be audible above all other auditory signals and environmental noise in the reception area;

(b) an EES should have high attention gaining characteristics;

(c) an EES may be complemented by visual signals. Reinforcement of signals may be achieved by matching any rate of flashing presented visually with variation in the time pattern of the auditory signal;

(d) equipment shall be designed to permit the sounding of an EES for training purposes. In order to aid the listener(s) to retain signal meaning in memory, it is likely that unexpected practice will be necessary. Rare real emergencies are likely to be insufficient for this purpose;

31 Warning Signals (see **B.39)**

31.1 A warning signal shall have priority over auditory signals in categories three, four and five. It should delete, suppress or obliterate cautionary and advisory signals. Suppressed signals shall be reinstated automatically, when the condition giving rise to the warning signal has been corrected.

31.2 The physical characteristics of warning signals should be chosen to enhance attention gaining characteristics. For preference, complex, interrupted or modulated signals should be used. Interruption rates should produce equal on-off times which lie between 0.5 and 2 seconds. The minimum base frequency for modulated signals should be between lkHz and 1.5 kHz, and the ratio between the maximum and minimum frequency should be at least 1:1.3 and not more than 1:2. Further information is available in ISO 7731: 1986.

32 Cautionary Signals (see **B.15)**

31.1 A cautionary signal shall have priority over auditory signals in categories four and five. A cautionary signal should delete, suppress, or obliterate any advisory signal. Such suppressed advisory signals shall be reinstated automatically when the condition causing the cautionary signal is resolved or the signal is acknowledged or cancelled by the operator (see also **15).**

32.2 Cautionary signals should reduce the need for warning signals, by providing instead an early prompt for corrective action, eg before damage occurs to engines or machinery as a result of overheating or lack of oil.

32.3 The physical characteristics of cautionary signals should provide some attention gaining potential after priority allocation of such characteristics have been made to warning signals in the signals set. Basic frequencies between 400Hz and lkHz are preferred, subject to any limitations in the available auditory communication window (see **10).**

33 Advisory Signals

33.1 Advisory signals are of low priority. They do not normally require high attention gaining characteristics, which shall be reserved for warning and cautionary signals eg square, sawtooth, ramp and similar waveforms. Short soft signals at low audio frequencies, or several harmonically related frequencies are suitable. Although the nature of the task will influence the choice of physical characteristics, frequencies between 250 Hz and 400 Hz are preferred.

33.2 Particular advisory signals are given separate names for convenience, eg Confidence Signals (see **B.17)** or Attensons (see **B.5).**

34 Confidence Signals

34.1 Designs which purport to provide a confidence signal derived solely from the operation of an on-off switch shall be prohibited.

34.2 Confidence signals shall be presented either less frequently than, or at the cylic rate of, successful output from the BITE. When it is necessary to avoid interaction with other auditory signals, presentation rates should be low, yet related to the criticality of the task. The sponsor of an equipment should define the maximum time, between successive presentation of an intermittent confidence signal, and the valid continuous presentation after a successful output from the BITE.

34.3 The physical characteristics of confidence signals should conform to the guidelines for advisory signals. Experience has shown that a suitable signal is formed by a soft intermittent burst of white or pink noise (see Annex B) lasting from 0.5 to 1s and repeated at regular intervals of from 7 to 10s. Precise control and consistency of the repetition rate over the life of the equipment in service and between similar equipment, is far more important than precise specification of signal duration or interval time.

35 All Clear Signals

35.1 An all clear Signal is a category five auditory signal which is complementary to an auditory signal of category one. Pending publication of British and International Standards on this topic, the following guidelines are suggested for suitable Defence applications, eg return to normal duties after an emergency signalled by an EES (see **29).**

35.2 If used, an all clear signal shall be sounded continuously for at least 30s at a constant frequency or harmonically related frequencies.

35.3 An all clear may be complemented by a steady green visual signal.

35.4 Equipment shall be designed to permit the sounding of an all clear for training purposes.

36 Voice Signals

Auditory signals shall not be expected to carry the detailed information that is contained in words until attention has been gained. Once attention has been gained by an initial non-verbal signal or attenson, it is permissible to add spoken words. The detailed information given thus should guide the listener, wherever possible, to information in a visual display, (see Part 7 of this Standard), which is the preferred mode for such purposes. The verbal components in auditory signals can be used not only as a guide to a visual display, but also as a reinforcing supplement to it. This can be very useful when the listener is involved in complex duties with a high workload. All verbal components of auditory signals shall conform to the requirements of Part 9 of this Standard. Words shall be chosen to avoid ambiguity with other words through contrast in pronounced sound as well as in pre-learned meaning (see Defence Standard 00-970 Chapter 105). The following rules apply:

(a) verbal components take a relatively long time to present, and thus the risk of interference with speech communication is greater than with non-verbal signals;

(b) verbal components are usually easy to learn and difficult to forget;

(c) confusion can occur with normal speech communication with other personnel;

(d) voice warnings should be used only to supplement non-verbal warnings;

(e) ambiguity of meaning shall be avoided when the same words are used in visual displays (see Parts 7 and 4 of this Standard);

(f) in either auditory or visual signals, the use of abbreviations shall not lead to ambiguity in either mode;

(g) the information in a verbal signal may be repeated at a more moderate level as a reinforcement, and subsequently at an even lower yet audible level. After a time and in the absence of corrective action, or cancellation, the verbal message can be repeated at the more moderate intensity as a reminder.

Section Seven. Training Aids

37 General

The majority of training aids are produced in the form of handbooks, manuals or simulators and audio-visual aids. The latter have been introduced into training programmes, to an increasing extent. In this context it is possible to make personnel aware of auditory signals, and give them an experience of them. In order to reinforce the link between the perceived sound of an auditory signal and its meaning, there are a number of design actions which can be taken.

38 User Expectancies

In order to reduce training costs, it is important to select auditory signals which are widely recognized, and associated with a specific meaning. In order to ensure that the intended meaning is perpetuated it is necessary to retain the perceived sound. The need for additional training should be considered when synthetic speech is used (Schwab et al 1985, Simpson et al 1985, Slowiaczek et al 1985).

38.1 In order to achieve useful matching with user expectancies for the intended signal, repetitive signal changes and re-testing may be necessary.

39 Consistency in Signal Meaning

For the transfer of training, it is necessary to achieve consistency in the signal meaning associated with given signal characteristics. It is important to recognize that personnel are likely to use several similar types of equipment during their careers due to the replacement of equipment, individual postings or rotation of duties for example between Army units, RN ships or RAF squadrons. In support of this statement E D Schubert (1979) is quoted, "By the very nature of its task the auditory system is most useful if it does not associate a given identifiable signal with a particular fixed loudness. Conversely it is most adaptable if it learns about signals in everyday use, irrespective of their loudness, and recognizes a signal no matter how variable its actual loudness or intensity may be from one time or one environment to another." The perpetuation of well-known signals is already a requirement in NES 599.

40 Reminder Signals

40.1 A sequence of short reminder signals can be generated automatically when an equipment is switched on, or on demand, eg at hand-over to the next watch appropriate important applications are as follows:

(a) signals are sounded in a sequence of increasing urgency and priority. If a confidence signal is used, the sequence should start with it, revert to it at the end, and continue it, if the equipment is functioning correctly;

(b) when Built-In Test Equipment (BITE) is fitted, the BITE shall drive the sequence, start with it, revert to it at the end, and continue it, if the equipment is functioning correctly;

40.1 (Contd)

(c) when BITE is not fitted, the BITE shall drive the sequence of reminder signals after successful completion of the automatic tests;

(d) the above principles for reminder signals may be incorporated into the switching on and checking of individually operated equipment, or of sub-systems in large or complex equipment, eg in the pre-flight checks of aircraft. In this context it is important that reference is also made to the existing single Service standards and learned start-up procedures (see Defence Standard 00-970, NES 599).

Section Eight. Evaluation of Auditory Signals

41 General

41.1 Each auditory signal, and the complete set of auditory signals shall be evaluated when using prototype equipment during development; in a sample of production equipment, if required by the sponsor; and whenever a new or modified auditory signal is introduced into the set.

41.2 Each auditory signal, and the complete set of auditory signals, shall be evaluated according to the principles and test methods set out in ISO 7731: 1986 as well as those summarized in table 1 below.

Table 1

Auditory Signal Measurement and Listening Test Methods

Auditory Signal Methods	Criteria and Remarks
Compliance with the requirements of Section Three of this Standard shall be checked by measurements taken at the head location of listeners and in their absence, or at the ear of listeners wearing headphones (Rood 1984) as appropriate.	Sound Level meters shall be at least class 2 as defined in BS 5969: 1981 (see also IS0 266 and IEC 225.)
Until criteria are met, measurements shall be taken for each signal, and the greatest combined ambient and background noise in the following sequence:	As a criterion is met, subsequent criteria become optional.
(a) A-weighted sound level.	That of the signal shall be at least 15dB above that of the noise, and shall be at least 65dB(A)
(b) Frequency analysis in octave bands.	The sound level of the signal shall be at least 15dB greater than that of the noise in at least one octave band. Preferably the maximum octave band level of the signal shall be in a different band from that of the noise.

Continued on page 24

41.2 Table 1 (Concluded)

(c) Frequency analysis in 1/3rd octave bands.	The sound level of the signal shall exceed that of the noise by at least 15dB in at least one, preferably three, 1/3rd octave bands.
(d) Temporal distribution of the A-weighted sound levels.	The temporal distribution of signal energy shall be distinct from that of the noise. The pulse frequency of a signal shall not be identical with any periodic fluctuation in the noise level.
Listening Test Methods	
Compliance with Sections Four and and Five of this Standard shall be checked by sounding an auditory signal in the loudest combination of ambient and background noise, and in all important frequency variants of it.	Noise may vary in level and in frequency content eg the noise on the flight deck of aircraft during descent. Each condition should be checked separately.
Auditory signals shall be sounded unexpectedly to each of a group of 10 listeners, representing the range of age and noise induced hearing loss of the user population. The test shall be repeated on five separate occasions.	If fewer than 10 users exist all should participate. All listeners shall recognize all signal soundings without ambiguity. Instructors should be considered.
The listeners shall wear personal hearing protection if appropriate.	
The listeners shall carry out the tasks or simulated tasks done as their normal duty in the signal reception area.	
Operational clothing and personal equipment should be worn during the tests.	

42 Flexibility in Design

In order to save time and reduce the costs of repetitive testing and redesign, it is important to evaluate auditory signals at an early stage in design, and where possible predict signal effectiveness. Helpful reference may be made to two extensive studies of this kind by Patterson (1982) and Coleman et al (1984). Designers are encouraged to successively refine available data and recognize that at least some adjustment and retesting of auditory signals will probably be necessary. Hence for the purposes of this Part of this Standard, equipment shall be designed to permit easy and rapid replacement at low cost of those components generating or controlling the physical characteristics of auditory signals. Part 11 of this Standard includes guidelines on ease of access and replacement.

Section Nine. Checklist

43 General

A checklist or aide memoire is set out below in the form of a questionnaire. More direct guidelines are given by Coleman et al (1984) although these have been developed specifically for the coalmining industry.

44 Personnel

44.1 Have all the potential listeners been identified? Are special categories of user included, such as older and partially deaf personnel, or instructors as well as operational personnel?

44.2 Are hearing thresholds available including masked thresholds where appropriate? If not, are steps being taken to measure them?

44.3 Are panels of at least 10 listeners, representative of the users, available for participation in tests of early acceptability as well as for final evaluation? If not, what action is being taken to ensure their availability?

44.4 To what extent are vision, hearing and particularly speech communication in active use when auditory signals are to be generated?

45 Signal Meaning

45.1 What information must be transferred to the user? Can this information be classified into a small number of coherent groups? Is the auditory channel used to transfer detailed information? If so, is this avoidable?

45.2 In consultation with the user, has a decision been made on the need for a confidence signal? After the selection of meanings for intended auditory signals, have relative priorities been allocated?

45.3 Are simple or complex auditory signals required? Are verbal components needed? If so, what is the vocabulary used with present equipment, and has an initial list of keywords been selected for tests of compatibility with user expectancies, and for potential ambiguity?

46 The Environment

46.1 Is there any source of ambient acoustic noise in the working environment, or of background acoustic noise generated by the equipment?

46.2 If so, what actions are needed to obtain data on the sound level and spectral composition of each major portion of the mission or duty cycle, which shows a consistently distinct noise characteristic?

46.3 In any noise present, are there any periodic fluctuations which will match and therefore mask any temporal patterns intended for auditory signals?

46.4 Do intended signals satisfy criteria to avoid hazards to hearing?

47 Signal Characteristics

47.1 Have signal characteristics been selected to ensure signal detection and recognition including:

(a) cross-system compatibility with functionally similar systems or equipment?

(b) sufficient attention gaining and apparent urgency of signal to conform with allocated priority and meaning?

(c) sufficient discrimination of each signal from all others in the set?

(d) sufficient harmonic components to ensure consistency in perceived sound irrespective of variable degrees of masking by noise?

(e) absence of signal modulations (AM or FM) which are close to periodic fluctuations in environmental noise?

(f) a preference for temporal patterns in which the signal is modulated at between 0.5 and 4Hz (AM or FM) and presented as bursts of sound or pulses separated by relatively long intervals.

48 Tests Trials and Evaluation

48.1 Practical tests, trials and evaluations must form the final basis for evaluation. In this context, are sufficient resources available to ensure that:

(a) a test panel of at least 10 user representative listeners is used?

(b) the ambiguity, attention gaining and urgency aspects of signals are tested on skilled personnel carrying out normal duties?

(c) real or simulated equipment is available for trained personnel to use during tests, trials and evaluations?

(d) all intended auditory signals are tested for mutual compatibility and discrimination?

(e) listener tests are carried out in real or simulated conditions of ambient and background noise, and if appropriate, speech and other auditory signals which are sounded simultaneously or close by?

(f) the design permits easy and relatively low cost changes in the components generating the auditory signals, thus facilitating response to the results of trials and evaluation?

(g) similar flexibility is built into production models to permit adaption to either new or changing operational conditions?

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List of Related Documents

International Standards

IEC 225
Octave, ½ octave + 1/3 octave band filters for the analysis of sound and vibrations, first edition. International Electrotechnical Commission.

ISO 266: 1975
Acoustics - Preferred frequencies for measurements. International Organization for Standardization.

ISO 7731: 1986
Danger signals for work places - Auditory danger signals. International Organization for Standardization.

British Standards

BS 3383: (1961)
Normal equal loudness contours for pure tones and normal threshold of hearing under free-field listening conditions. (Technically equivalent to ISO R226). British Standards Institution, London.

BS 4727: PART 3: GROUP 08: (1985)
British Standard Glossary of Electrotechnical, power, telecommunication, electronics, lighting and colour terms. Part 3. Terms peculiar to telecommunications and electronics. Group 08. Acoustics and electro-acoustics terminology. British Standards Institution, London.

BS 5969: (1981)
Sound Level Meters. British Standards Institution, London.

Defence Standards

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 9 - Voice Communication
Part 10 - Controls
Part 11 - Design for Maintainability
Part 12 - Systems

Defence Standard 00-970: (1983)
Design requirements for Service aircraft: Vol 1: Chapter 105. Crew Stations - General requirements.

NATO Standardization Agreements

STANAG 3370: 21 February 1974. Aircrew station warning, cautionary and advisory signals. North Atlantic Treaty Organization, Military Agency for Standardization.

Naval Engineering Standards

NES 599 (1981)
Policy Requirements for Alarm and Warning Systems.
Sea Systems Controllerate of the Navy.

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Rood G M (1984). Predictions of auditory masking in helicopter noise. Proceedings of the 10th European rotocraft forum August 28-31, The Hague, Netherlands (see also Cogger M K and Chillery J A (1980) Measurement of the acoustic attenuation of flight helmet earshells. Royal Aircraft Establishment Technical Memorandum FS 352).

Schubert E D (1978). History of research on hearing. In: Carterette E C and Friedman M P (Ed). Handbook of perception: Volume IV Hearing. Academic Press, New York.

Schwab E C, Nusbaum H C and Pisoni D B (1985). Some effects of training on the perception of speech. Human Factors 27(4) 395-408.

Simpson C A, McCauley M E, Roland E F, Ruth J C and Williges B H (1985). System design for speech recognition and generation. Human Factors 27(2) 115-141.

Slowiaczek L M and Nusbaum H C (1985). Effects of speech and pitch contour on the perception of synthetic speech. Human Factors 27(6) 701-712.

US Department of Defence (1981). Military Standard: Human engineering design criteria for military systems, equipment and facilities. MIL-STD 1472C.

Wilkins P A (1981). Assessing the effectiveness of auditory warnings. British Journal of Audiology 15 263-274.

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Definitions

For the purpose of this Part of the Defence Standard the definitions given in BS 4727 apply together with the following:

B.1 Advisory Signal

A category four auditory signal (see **B.13).** For aircraft, Def Stan 00-970 states that an advisory signal is "A signal used to indicate aircraft configuration, a condition of performance, the operation of essential equipment or to attract attention for routine purposes". On substitution of 'equipment' for 'aircraft', this definition is acceptable for wider use.

B.2 Alarm

The term 'alarm' is avoided in this Part of this Standard, except when linked to a specific situation, eg, 'Fire Alarm') For ships, NES 599 states that "An ALARM denotes that an emergency situation has arisen, which endangers the ship, its personnel, or essential equipment and for which an immediate decision or action must be taken. An alarm signal may be required when an essential equipment has malfunctioned and the effect of the malfunction is not otherwise readily and immediately apparent".

B.3 Alarm and Warning System

That system which is used to provide a co-ordinated and controlled indication of alarms and warnings, in a ship or submarine, at such positions that the correct decision and/or action can be taken within an appropriate time (NES 599).

B.4 Ambient Noise

Encompassing sound (at a given place), being usually a composite of sounds from any sources, near and far.

B.5 Attenson

The initial, non-verbal and attention gaining component of an auditory signal which subsequently contains speech.

B.6 Audible Signal

An audible sound which is distinct from other sounds in a specified environment and audible to all listeners, who either associate with it a specific meaning, or who may learn to do so.

B.7 Auditory Signal

A sound, the physical characteristics of which are distinct from those of others but which is not necessarily audible to all potential listeners.

B.8 Auditory Signal Systems

That system which is used to provide a co-ordinated and controlled indication of a signal set, at such positions that the correct decision and/or action can be taken within an appropriate time. (NES 599).

B.9 Background Noise

Total of interference from all sources in a system used for the production, transmission, detection, measurement or recording of a signal.

B.10 Category One Auditory Signal

A sound denoting that a critical state exists; emergency action is required of all personnel in the affected locations/environments.

B.11 Category Two Auditory Signal

A sound denoting that immediate danger exists; specific and immediate action is required of selected personnel; for others current operational duties continue.

B.12 Category Three Auditory Signal

A sound denoting that abnormal conditions exist or danger is imminent; immediate awareness is required of selected personnel followed by early but not necessarily immediate action.

B.13 Category Four Auditory Signal

A sound denoting that conditions are within normal limits; awareness is required, but not necessarily action; normal duties continue.

B.14 Category Five Auditory Signal

A sound denoting that conditions have returned to normal; normal duties are to be resumed.

B.15 Cautionary Signal

A category three auditory signal. For aircraft, Defence Standard 970 defines it as "A signal indicating the existence of a hazardous or impending hazardous condition requiring attention and early but not necessarily immediate action". On the inclusion of 'an abnormal condition not covered by a warning signal, or' "after existence of", this definition is suitable for wider use.

B.16 Complex Signal

An auditory signal, usually digitized, which permits easy manipulation of sound level, frequency content, or temporal pattern in an auditory signal system.

B.17 Confidence Signal

An advisory signal driven from repetitively successful outputs from built-in test equipment. BITE is used in a critical situation to indicate that an equipment is on and working correctly, when that information is not available reliably, readily and immediately to the human operator. For example, the Confidence Signal produced by a hand-held mine detector may reduce apprehension and thus potential human errors.

B.18 Emergency Evacuation Signal

A category one auditory signal (see ISO 7731: 1986). It is used to indicate the beginning or the actual occurrence of an emergency involving the possibility of injury and instructing the person(s) to leave the danger zone in the recognized manner.

B.19 Environmental Noise

The total acoustic noise from all sources in the auditory signal reception area, usually the sum of ambient and, if any, background noise.

B.20 Equipment

A generic term used in this Standard to cover all products designed or produced for the MOD, including for example, weapons, vehicles and buildings.

B.21 False Alarm

A term used to indicate an auditory signal correctly generated in response to an environmental factor other than the intended cause for the particular signal.

B.22 False Alert

The sounding of an auditory signal erroneously by an equipment.

B.23 Fault Warning

An auditory signal indicating a fault in the equipment. The criticality of the fault determines the category of signal to be used.

B.24 Listener (Group)

All the Users involved in the reception zone of an auditory signal, or a group of at least 10 subjects chosen to be representative of the age structure, and to include those with the worst hearing acuity encountered in the zone.

B.25 Minimum Audible Field

The effective threshold of audibility in noise which is the level of sound at which an auditory signal is just audible in ambient noise taking into account the hearing deficiencies of the listeners as well as the attenuation of hearing protectors, (see ISO 7731: 1986).

B.26 Master Auditory Signal

An auditory signal used to draw attention to a group of related and closely located visual displays, which provide additional information. Either or both master warning signals and master cautionary signals are acceptable as permitted under Defence Standard 00-970, or a common master auditory signal attracting attention to visual displays of category two and three information, eg in ships as required under NES 599.

B.27 Pink Noise

Noise whose power spectral density is inversely proportional to frequency.

B.28 Pulse

A short burst of acoustic noise.

B.29 Pulse Sequence

A specific pattern of repeated pulses.

B.30 Pulse Train

A pattern of pulse sequence repeated at intervals, into which suitable voice components may be inserted.

B.31 Sequence

See pulse Sequence.

B.32 Set

See signal Set.

B.33 Signal

A detectable oscillation in a medium, in the context of this Part of this Standard an audible sound, which is capable of carrying information.

B.34 Signal Pulse

See Pulse Sequence.

B.35 Signal Category

A class of auditory signals intended for specified groups of listeners.

B.36 Signal Set

Denotes all the auditory signals used to transmit information to a person or a group of personnel.

B.37 Sounder

A device which converts electrical (audio) signals into auditory signals.

B.38 Warning

For ships, Naval Engineering Standard 599 states that, "A warning indicates and draws attention to abnormal conditions not covered by an alarm for which early remedial action is required. In this context it may be used to indicate a condition outside of selected limits". In order to avoid ambiguity in this Part of this Standard the term 'Warning' is not used in lieu of 'Warning Signal' nor in lieu of 'Cautionary Signal'.

B.39 Warning Signal

A sound indicating the existence of an emergency condition requiring immediate decision and/or action to avoid delay or reduce potential loss of life, equipment or operational effectiveness. (A category two auditory signal). For aircraft, Defence Standard 00-970 defines it as "A signal indicating the existence of an imminent catastrophic condition requiring immediate action or a limitation of the flight envelope of the aeroplane".

B.40 White Noise

Noise whose power spectral density is essentially independent of frequency.

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Contract Requirements

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.

MM

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Your reference

Our reference
D/D Stan 328/01/08

Date
March 1989

INTERIM DEFENCE STANDARD IMPROVEMENT PROPOSAL

Defence Standard No: 00-25 Part 8

Title: HUMAN FACTORS FOR DESIGNERS OF EQUIPMENT PART 8 AUDITORY INFORMATION

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.

NAME C D KILLBOURN ..... SIGNATURE ..... BRANCH: STAN ...6d...

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

3. Is the Defence Stardard restrictive:

☐ **YES** ☐ **NO** (if 'yes' in what way)

4. General comment:

5. We agree that this INTERIM Standard (subject to amendments to take account of our comments) when published in final form will cover our requirements. Should you find our comments at variance with the majority, we shall be glad of the opportunity to enlarge upon them before final publication.

Signature . . . . . Representing . . . . . .

Submitted by (print or type name and address):	Telephone number:
	Date:
	Our Ref: