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7 Alarms, audio, and voice communications

This section presents general criteria and rules for audio alarms and displays, voice signals and alarms, controls for audio warning devices, and voice communication systems.

7.1 Alarms and alerts

7.1.1 General

- **7.1.1.1 When to use.** If equipment is not regularly monitored, an audio alarm shall be provided to indicate malfunctions or conditions that would cause personnel injury or equipment damage. [Source: Department of Defense (MIL-STD-1472F), 1999]
- **7.1.1.2 Be clear and unambiguous.** Alerting and warning systems shall be unambiguous, with a clear indication of the cause for the alert. [Source: Billings, 1996]
- **7.1.1.3 Alarm system characteristics.** Alarms systems should
 - a. alert the user to the fact that a problem exists,
 - b. inform the user of the priority and nature of the problem,
 - c. guide the user's initial responses, and
 - d. confirm in a timely manner whether the user's response corrected the problem. [Source: Nuclear Regulatory Commission (NUREG-0700), 1981]
- **7.1.1.4 Indicate degree of problem.** Alarms/alerts should indicate the degree of malfunction or emergency. [Source: Wiener & Curry, 1980]
- **7.1.1.5 Alarm in appropriate mode.** When a parameter value represents a fault in some modes and not in others, it should only be alarmed in the appropriate modes. [Source: Nuclear Regulatory Commission (NUREG/CR-6105), 1994]
- **7.1.1.6 Signal loss of redundancy.** When part of a redundant system, unit of equipment, module, or component becomes inoperable, an alarm signaling the loss of redundancy shall be provided to the user immediately. [Source: National Aeronautics and Space Administration (NASA STD 3000A), 1989]
- **7.1.1.7 Allow access to current alarm settings.** When alarm signals are based on user defined logic, the system should allow the users to access current alarm settings that are specified in terms of dimensions (variables) covered and which values (categories) are established as critical. [Source: Smith and Mosier, 1986]

- **7.1.1.8 Provide greater probability of detection.** An alerting and warning system or signal shall provide the user with a greater probability of detecting the triggering condition than his or her normal observation would provide in the absence of the alerting or warning system or signal. [Source: MIL-STD-1472F, 1999]
- **7.1.1.9 Provide help.** When necessary, users shall be able to request help and related information for the operation and processing of critical and non-critical alarms, messages, and signals. [Source: Department of Defense (MIL-STD-1801), 1987]
- **7.1.1.10 Areas with high ambient illumination.** Auditory as well as visual alarms shall be provided when the users work in an area with a high degree of ambient illumination. [Source: Department of Energy (UCRL-15673), 1985]
- **7.1.1.11 Provide redundant visual warning.** All nonverbal audio signals shall be accompanied by a visual signal that defines the condition. [Source: MIL-STD-1472F, 1999]
- **7.1.1.12 Supplement visual displays.** When used in conjunction with a visual display, an audio signal shall be supplementary or supportive, alerting and directing the user's attention to the appropriate visual display. [Source: MIL-STD-1472F, 1999]

7.1.2 Alarm implementation

- **7.1.2.1 Prioritize presentation.** Alarms should be automatically organized and presented to the users in prioritized form, with the most significant alarms receiving the highest priority. [Source: NUREG-0700, 1981]
 - Discussion.** Prioritization of alarms can be based on the immediacy of required action and impact on overall safety. [Source: NUREG/CR-6105, 1994]
- **7.1.2.2 Display by significance.** The display of alarms with higher current operational significance should automatically override the display of alarms with lower current operational significance. [Source: NUREG-0700, 1981]
- **7.1.2.3 Simultaneous alarms.** When two or more incidents or malfunctions occur simultaneously, the one generating a message of higher priority shall be presented first. After presentation of the highest priority message, remaining messages shall be presented in descending order of priority. [Source: MIL-STD-1472F, 1999]
- **7.1.2.4 Limit number of priority levels.** The number of priority levels for alarm messages should be limited to four. [Source: Department of Energy (DOE STD HFAC), 1992]
- **7.1.2.5 Establish priority system.** A message priority system shall be established so that a more critical message shall override the presentation of any message having a lower priority. [Source: MIL-STD-1472F, 1999]

Definition. Caution - A signal that indicates the existence of a condition requiring attention but not immediate action. [Source: Department of Defense (MIL-STD-411), 1991]

Warning - A signal that indicates the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption. [Source: MIL-STD-411, 1991]

Advisory - A signal that indicates a safe or normal configuration, condition of performance, or operation of essential equipment or attracts attention and imparts information for routine action purposes. [Source: MIL-STD-411, 1991]

- **7.1.2.6 Using warning signals.** Warning signals shall be used to indicate the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption. [Source: MIL-STD-411, 1991]
- **7.1.2.7 Using caution signals.** Caution signals shall be used to indicate conditions requiring awareness but not necessarily immediate action. [Source: MIL-STD-1472F, 1999]
- **7.1.2.8 Distinguish caution signals.** Caution signals shall be readily distinguishable from warning signals. [Source: MIL-STD-1472F, 1999]
- **7.1.2.9 Make alarms distinctive and consistent.** Alarm signals and messages shall be distinctive and consistent for each class of event. [Source: Avery, L.W., & Bowser, S.E. (DOE HFDG ATCCS V2.0), 1992; Department of Defense (MIL-HDBK-761A), 1989; MIL-STD-1801, 1987]

Example. A signal alerting a user to an incoming message would be different from a signal alerting a user to a hazardous condition. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]

- **7.1.2.10 Make information simple and understandable.** Processed alarm information should be simple enough that users can easily evaluate the meaning or validity of the resulting alarm messages. [Source: NUREG-0700, 1981]

Discussion. Complex processing can impact the user's ability to understand the constraints and limitations of alarm processing and the validity of resulting alarms. Users rely on the system's information. Thus, it is essential that the users understand the validity of the data, how they are processed, and the limitations of the system. [Source: NUREG-0700, 1981]

- **7.1.2.11 Status indication.** System status indication generally should be presented on a separate display from the alarm indicators. [Source: NUREG-0700, 1981]

Discussion. Status indication is not intended to alert the user to the need for action. When status indication is presented together with alarm information, it can increase the demands on the user. [Source: NUREG-0700, 1981]

- **7.1.2.12 Alarm filtering.** Filtering should only be used for alarms that have no current operational significance. [Source: NUREG-0700, 1981]

Discussion. Alarm **filtering** is a technique by which unnecessary alarms are eliminated. This differs from alarm **suppression** in which alarm messages are not displayed but are available to the user upon request. [Source: NUREG-0700, 1981]

- **7.1.2.13 Use of suppressed alarms.** When a single alarmed event invariably leads to subsequent alarmed events, the primary alarmed event should be shown with the subsequent events suppressed, as long as it does not interfere with the user's tasks. [Source: NUREG-0700, 1981]
- **7.1.2.14 Access to suppressed alarms.** When an alarm is suppressed, users should be able to access the alarm information that is not shown. [Source: NUREG-0700, 1981]
- **7.1.2.15 Ease of accessing suppressed alarms.** The method for accessing information on suppressed alarms should not be excessively complex. [Source: NUREG/CR-6105, 1994]
- **7.1.2.16 Training for alerts.** Training techniques should be devised to ensure that users are exposed to all forms of alerts and possible combinations of alerts and that they understand how to deal with them. [Source: Wiener & Curry, 1980]

7.1.3 Reliability

- **7.1.3.1 System failure.** In the event of a complete system failure, the system shall integrate messages and report the system failure rather than the failure of components. [Source: MIL-STD-1472F, 1999]
- **7.1.3.2 False alarms.** The design of audio display devices and circuits shall preclude false alarms. [Source: MIL-STD-1472F, 1999]
- **7.1.3.3 Failure.** The audio display device and circuit shall be designed to preclude warning signal failure in the event of system or equipment failure and vice versa. [Source: MIL-STD-1472F, 1999]
- **7.1.3.4 Circuit test.** All audio displays shall be equipped with circuit test devices or other means of testing their operation. [Source: MIL-STD-1472F, 1999]

- **7.1.3.5 Alarm input validation.** Alarm system inputs (such as sensors) should be validated to ensure that spurious alarms are not presented to the user. [Source: NUREG-0700, 1981]
- **7.1.3.6 Noise filtering.** Alarm systems should have the capability to filter out noise signals to eliminate unnecessary alarms. [Source: NUREG-0700, 1981]

Discussion. Spurious alarms can be generated through signals momentarily exceeding the threshold. Time filtering and/or time delay processing can be used to prevent these signals from generating alarms. [Source: NUREG-0700, 1981]

7.2 Audio signals and audio alarms

7.2.1 General

- **7.2.1.1 General.** Audio signals should be provided, as necessary, to warn personnel of impending danger, alert a user to a critical change in system or equipment status, and to remind a user of critical actions that must be taken. [Source: MIL-STD-1472F, 1999]
- **7.2.1.2 Use of auditory signals.** Auditory signals shall only be used when such signals contribute to understanding of and appropriate responses to the operational and task environment. [Source: Ameritech Services, Inc., 1996]
- **7.2.1.3 Avoid negative consequences.** Auditory signals shall not result in user or operator confusion, errors, or inefficiencies in response. [Source: Ameritech Services, Inc., 1996]
- **7.2.1.4 Advantages to audio signals.** An audio signal should be provided when any of the following conditions apply.
 - a. The information to be processed is short, simple, transitory, and requires immediate or time-based response.
 - b. The use of a visual display might be inappropriate because of overburdening of the visual modality, ambient light variability or limitation, user mobility, degradation of vision by vibration, other environmental considerations, or anticipated user inattention.
 - c. The criticality of a response to a visual signal makes supplementary or redundant alerting desirable.
 - d. It is desirable to warn, alert, or cue the user for subsequent or additional responses.
 - e. Custom or usage has created anticipation of an audio display.
 - f. Voice communication is necessary or desirable. [Source: MIL-STD-1472F, 1999]

- **7.2.1.5 Compatible with environment.** The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver. [Source: MIL-STD-1472F, 1999]
- **7.2.1.6 Alarms for normal conditions.** Auditory alarms should not be used to indicate normal conditions. [Source: Wiener, 1988]
- **7.2.1.7 Signal type.** When an audio signal is used, the particular type of signal (tone, complex sound, or speech) should be the best for the intended use as indicated in Exhibit 7.2.1.7. [Source: MIL-STD-1472F, 1999]

Exhibit 7.2.1.7 Characteristics and ratings of audio signals for various uses.

Use	Tones (periodic)	Complex Sounds (non periodic)	Speech
Quantitative Indication	(Poor) Maximum of 5 to 6 tones absolutely recognizable.	(Poor) Interpolation between signals inaccurate.	(Good) Minimum time and error in obtaining exact value in terms compatible with response
Qualitative Indication	(Poor to fair) Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	(Poor) Difficult to judge approximate deviation from desired value.	(Good) Information concerning displacement direction, and rate presented in form compatible with required response.
Status Indication	(Good) Start and stop timing; continuous information if rate of change of input is low.	(Good) Especially suitable for irregularly occurring signals, such as alarms.	(Poor) Inefficient; more easily masked; problem of repeatability.
Tracking	(Fair) Null position easily monitored; problem of signal-response compatibility	(Poor) Required qualitative indications difficult to provide.	(Good) Meaning intrinsic in signal.
General	Good for automatic communication of limited information; must be learned; easily generated.	Some sounds available with common meaning, (e.g., a fire bell); easily generated.	Most effective for rapid, but not automatic, communication or complex, multidimensional information; meaning intrinsic in signal and context, if standardized, minimum learning required

- **7.2.1.8 User evaluation of alarms.** Auditory signals shall be tested and evaluated for usability, operational suitability, and user acceptance using representative users in as near to a realistic operational environment as possible before the signals are incorporated into a system. [Source: Ameritech Services Inc., 1996]

Discussion. All auditory signals, including verbal signals, act as symbols that users must learn and interpret in the light of their operational and task environment. When designers overuse sound, the auditory signals often are ignored and can cause annoyance, interference, or confusion for the system users.

- **7.2.1.9 User setting of alarm parameters.** When appropriate to the task, a system or application should allow a user to set the parameter or condition that results in a software-generated alarm, alert, or status message. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]

Example and discussion. Some examples of parameters or conditions are priorities, percentages, and absolute values or ranges of values. When multiple users are involved with a system, it may be the supervisors who determine the alarm parameters, not the individual users.

- **7.2.1.10 When users should not set alarm parameters.** User setting of parameters should not be allowed when (1) the settings by one user might affect the reception of alarms by another user; (2) the settings might affect the safety of systems, equipment, or personnel; or (3) alarm parameters are determined by functional, procedural, or legal requirements. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]
- **7.2.1.11 Alerting capabilities.** Signals with high alerting capacities should be provided when the system or equipment imposes a requirement on the user for concentration of attention. [Source: MIL-STD-1472F, 1999]
- **7.2.1.12 Avoid startle.** Signals should not be so startling that they preclude appropriate responses or interfere with other functions by diverting attention away from other critical signals. [Source: MIL-STD-1472F, 1999]
- **7.2.1.13 Auditory feedback.** The most common auditory feedback, the system beep, should be used with other forms of notification such as flashing or message dialogs. [Source: Microsoft Corp., 1992]

7.2.2 Number of signals

- **7.2.2.1 Number of audio signals for absolute identification.** When absolute identification is required, the number of signals to be identified should not exceed four. [Source: MIL-STD-1472F, 1999]

Discussion. Research shows that between 4 to 7 alarms can be acquired reasonably quickly, performance decreases dramatically for additional alarms. The meanings associated with up to nine alarms can be retained if the alarms are presented regularly. [Source: Patterson, 1982; Stanton & Edworthy, 1994]
- **7.2.2.2 Number of audio signals for relative identification.** When relative discrimination is required, the number of alarm signals should not exceed 12. [Source: Stanton & Edworthy, 1994]
- **7.2.2.3 Single audio signal.** A single audio signal should be used in conjunction with multiple visual displays only if immediate identification of the appropriate visual display is not critical to personnel safety or system performance. [Source: MIL-STD-1472F, 1999]

7.2.3 Differentiating signals

- **7.2.3.1 Differentiating signals.** Auditory signals that require different user responses should be easily distinguishable from one another. [Source: MIL-STD-1472F, 1999]

Example. Varying frequency, modulation, or both can differentiate signals. One purpose of differentiating the signals is to minimize the user's search of visual displays. [Source: MIL-STD-1472F, 1999]
- **7.2.3.2 Differentiation from routine signals.** Audio alarms intended to attract the user's attention to a malfunction or failure shall be different from routine signals such as bells, buzzers, random noises generated by air conditioning and other equipment and normal operation noises. [Source: MIL-STD-1472F, 1999]
- **7.2.3.3 Multiple audio signals.** When several different audio signals will be used to alert a user to different conditions, the signals shall be distinctive in intensity, pitch, or use of beats and harmonics. [Source: MIL-STD-1472F, 1999]
- **7.2.3.4 Unsuitable auditory signals.** Auditory signals should not be used if they resemble sounds that can occur in the actual operational setting. [Source: National Air Traffic Services, 1999]

Example. Sounds that are similar to navigational signals or radio transmissions and hisses or humming sounds similar to electrical interference would not be good candidates for audio signals.

- **7.2.3.5 Noninterference.** Audio warning signals shall not interfere with any other critical functions or warning signals or mask any other critical audio signals. [Source: MIL-STD-1472F, 1999]

7.2.4 Signal meaning

- **7.2.4.1 Consistent signals.** The meaning of audio warning signals selected for a particular function in a system should be consistent with warning signal meanings already established for that function. [Source: MIL-STD-1472F, 1999]
- **7.2.4.2 New meanings for standard signals.** Standard signals shall not be used to convey new meanings. [Source: MIL-STD-1472F, 1999]
- **7.2.4.3 Established signals.** Established signals should be used provided they are compatible with the acoustic environment and voice communication systems. [Source: MIL-STD-1472F, 1999]
- **7.2.4.4 Consistent meanings.** The meaning of audio warning signals selected for a particular function in a system should be consistent with warning signal meanings already established for that function. [Source: MIL-STD-1472F, 1999]

7.2.5 Periodicity

- **7.2.5.1 Intermittence.** Auditory signals should be intermittent rather than continuous. [Source: MIL-HDBK-761A, 1989]
 - Discussion.** Continuous tones are the most easily confused signals, even if they vary considerably in pitch. Furthermore, the human auditory system quickly adapts to continuous auditory stimulation. [Source: Merideth & Edworthy, 1994]
- **7.2.5.2 Nature of signals.** Audio warning signals should consist of two elements, an alerting signal and an identifying or action signal. [Source: MIL-STD-1472F, 1999]
- **7.2.5.3 Modulated signals.** Modulated warning signals should either be modulated from 1-8 beeps per second or warbling with a pitch rise and fall of 1-3 cycles per second. [Source: Sanders & McCormick, 1993]

7.2.6 Duration

- **7.2.6.1 Two-element signals.** When reaction time is critical and a two-element signal is used, an alerting signal of 0.5 seconds duration shall be provided followed by an identifying or action signal with all essential information being transmitted in the first 2 seconds of the identifying or action signal. [Source: MIL-STD-1472F, 1999]

- **7.2.6.2 Reaction time critical.** When reaction time is critical, signals shall be of short duration. [Source: MIL-STD-1472F, 1999]
- **7.2.6.3 Single-element signal.** When a single-element signal is used, all essential information shall be transmitted in the first 0.5 seconds. [Source: MIL-STD-1472F, 1999]
- **7.2.6.4 Duration.** Audio warning signal duration shall be at least 0.5 seconds and may continue until the appropriate response is made. [Source: MIL-STD-1472F, 1999]
- **7.2.6.5 Duration limitations.** Signals that persist or increase progressively in loudness shall not be used if manual shutoff may interfere with the corrective action required. [Source: MIL-STD-1472F, 1999]
- **7.2.6.6 Signal termination.** Completion of a corrective action by the user or by other means shall automatically terminate the signal. [Source: MIL-STD-1472F, 1999]

7.2.7 Frequency

- **7.2.7.1 Audibility.** An alarm/warning signal shall provide an audio level in at least one octave band between 200 and 5,000 Hertz such that the signal is at least 10 dBA SPL (sound pressure level) above the ambient noise level, or 20 dBA SPL above the amplitude of the masked threshold, or at such a level that assures personnel are adequately alerted to the danger or status so as to take the appropriate response, when measured within 1 foot of the responder's ear, or at more than 2 feet from the alarm. [Source: MIL STD 1472F, 1999; NASA-STD-3000, 1995]
- **7.2.7.2 Frequency range.** The frequency range of a warning signal shall be between 200 and 5,000 Hz, preferably between 500 and 3,000 Hz. [Source: MIL-STD-1472F, 1999]
- **7.2.7.3 Frequency for long distances.** When a signal must be audible at a distance of 300 m (985 ft) or more, the frequency shall be below 1,000 Hz. [Source: MIL-STD-1472F, 1999]
- **7.2.7.4 Signals around obstacles.** When the signal must be heard around obstacles or through partitions, the frequency shall be below 500 Hz. [Source: MIL-STD-1472F, 1999]
- **7.2.7.5 Frequencies differing from background.** The selected frequency band shall differ from the most intense background frequencies. [Source: MIL-STD-1472F, 1999]
- **7.2.7.6 Spurious signals.** The frequency of a warning tone shall be different from that of the electric power employed in the system to preclude the possibility that a minor equipment failure might generate a spurious signal. [Source: MIL-STD-1472F, 1999]
- **7.2.7.7 Frequencies difficult to localize.** Mid-frequencies (1500-3000 Hz) should not be used for auditory alarms that require localization. [Source: Sanders & McCormick, 1993]

7.2.8 Intensity (loudness)

- **7.2.8.1 Environmental compatibility.** The intensity, duration, and source location of an auditory signal should be compatible with the acoustic environment of the intended receiver as well as with the requirements of other personnel within acoustic range of the signal. [Source: MIL-HDBK-761A, 1989]

Discussion. Avoid the use of loud sounds unless the task requires it (e.g., the environment is loud and it is critical that the user hear the sounds).

- **7.2.8.2 Compatibility with clothing and equipment.** When the audio alarms and signals must be heard and understood through equipment or garments (e.g., parka hoods and hearing protective devices covering the ears of a listener), audio signals shall be loud enough to compensate for the attenuation characteristics of the garments without exceeding 115 dB(A) for emergency signals and 90 dB(A) for other signals. [Source: MIL-STD-1472F, 1999]
- **7.2.8.3 Exceeding ambient noise.** Auditory signals shall exceed the prevailing ambient noise level by at least 10 dB(A) or any maximum sound level with a duration of 30 seconds by at least 5 dB(A), whichever is louder, without exceeding 115 dB(A) for emergency signals or 90 dB(A) for other signals. [Source: MIL-STD-1472F, 1999; NUREG-0700, 1981]
- **7.2.8.4 Maximum intensity.** The intensity of evacuation and emergency signals shall not exceed 115 dB(A). The intensity of other signals shall not exceed 90 dB(A). [Source: MIL-STD-1472F, 1999; NUREG-0700, 1981]
- **7.2.8.5 Control of volume.** The user, the sensing mechanism, or both shall control the volume (loudness) of an audio warning signal depending upon the operational situation and personnel safety. [Source: MIL-STD-1472F, 1999]
- **7.2.8.6 Volume limits.** Volume control movement shall be restricted to prevent reducing the volume to an inaudible level or increasing it to an unacceptably high level. [Source: MIL-STD-1472F, 1999]
- **7.2.8.7 Appropriate use.** Auditory coding should be used
 - a. to alert users to critical conditions or operations;
 - b. to supplement visual signals;
 - c. to present information in situations in which visual presentation is not feasible; and
 - d. to provide feedback for control actuation, data entry, or the completion of timing cycles and sequences. [Source: MIL-HDBK-761A, 1989]

- **7.2.8.8 Inappropriate use.** Auditory coding should not be used when ambient noise prevents effective listening. [Source: National Air Traffic Services, 1999]

7.2.9 Acknowledging signals

- **7.2.9.1 Special acknowledgement of critical alarms.** When a user must acknowledge a special or critical alarm in a unique way (e.g., with a special combination of key strokes), this special acknowledgement shall not inhibit or slow the response to the condition initiating the alarm. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989]
- **7.2.9.2 Alarm reset.** A system or application shall provide users with a simple means for turning off non-critical auditory alarms without erasing any displayed message that accompanies the auditory signal. [Source: DOE HFDG ATCCS V2.0, 1992; MIL-HDBK-761A, 1989; MIL-STD-1801, 1987]
- **7.2.9.3 Acknowledging and terminating alarms.** A system or application shall provide users with a means of acknowledging alarms and of turning off alarm signals once the alarms have been acknowledged or the condition generating the alarm has been corrected. [Source: MIL-STD-1801, 1987]
- **7.2.9.4 Procedures for acknowledging alarms.** Procedures for acknowledgment and termination shall not decrease the speed and accuracy of operator reaction to the alerting situation. [Source: MIL-STD-1801, 1987]
- **7.2.9.5 Consistent means of acknowledging.** A simple, consistent means of acknowledging auditory signals shall be provided. [Source: MIL-HDBK-761A, 1989]
- **7.2.9.6 Acknowledging non-critical signals.** When the signal is non-critical, the acknowledgement action shall also turn the signal off. [Source: MIL-HDBK-761A, 1989]
- **7.2.9.7 Acknowledging alarms indicating loss of redundancy.** Users shall be able to acknowledge an alarm signaling the loss of redundancy, with the lack of available redundancy continuously displayed until the redundant system, equipment, module, or component becomes operable again. [Source: NASA STD 3000A, 1989]
- **7.2.9.8 Automatic and manual shutoff.** If an audio signal is designed to persist as long as it contributes useful information, a shutoff switch controllable by the user, the sensing mechanism, or both, shall be provided consistent with the operational situation and personnel safety. [Source: MIL-STD-1472F, 1999]
- **7.2.9.9 Automatic reset.** An automatic reset function for audio signals shall be provided, whether the signals are designed to terminate automatically, manually, or both. The automatic reset function shall be controlled by a sensing mechanism that recycles the signal system to a specified condition as a function of time or the state of the signaling system so that the warning device can

sound again if the condition reappears. [Source: MIL-STD-1472F, 1999]

- **7.2.9.10 Ganging to mode switches.** Volume controls may be ganged to mode switches to provide maximum output during operational phases in which intense noise can occur and to provide reduced volume at other times. This ganging shall not be done if there is a possibility that intense noise could occur in an emergency situation during a phase in which the volume would be decreased below an audible level. [Source: MIL-STD-1472F, 1999]
- **7.2.9.11 Caution signal controls.** Audio caution signals shall be provided with manual reset and volume controls. [Source: MIL-STD-1472F, 1999]

7.2.10 Presentation over headsets

- **7.2.10.1 Headset.** When the user will wear earphones covering both ears during normal equipment operation, the audio warning signal shall be directed to the user's headset as well as to the work area. [Source: MIL-STD-1472F, 1999]
- **7.2.10.2 When not to use headsets.** Binaural headsets should not be used in any operational environment with ambient noise below 85 dB(A) if that environment contains sounds that provide the user with useful information and that information cannot be directed to the user's headset. [Source: MIL-STD-1472F, 1999]
 - Discussion.** Such sounds may include voices, machine noise that indicates wear or malfunctions, and other auditory indications of system performance or mission status. [Source: MIL-STD-1472F, 1999]
- **7.2.10.3 Separate channels.** When feasible, a warning signal delivered to a headset that might mask another essential audio signal should be delivered to one ear and the other signal to the other ear. [Source: MIL-STD-1472F, 1999]
- **7.2.10.4 Dichotic presentation.** When earphones will be worn in an operational environment, a dichotic presentation should be used whenever feasible, with the signal alternating from one ear to the other by means of a dual-channel headset. [Source: MIL-STD-1472F, 1999]

7.3 Voice signals and voice alarms

7.3.1 General

- **7.3.1.1 When to use.** Voice signals should be used
 - a. to supplement visual displays when communication flexibility is necessary,
 - b. when coded signal meanings are numerous or may be forgotten,
 - c. for presentation of complex directions or instructions,
 - d. when ambient noise may mask simple tonal signals,
 - e. in conjunction with tonal signals, and
 - f. for presentation of continuous information when the rate of change is low. [Source: MIL-HDBK-761A, 1989]
- **7.3.1.2 Nature of signals.** Voice signals shall consist of a brief, standardized speech signal (e.g., a verbal message) to identify the specific condition and suggest an appropriate action. [Source: MIL-STD-1472F, 1999]
- **7.3.1.3 Presentation of voice signals.** Verbal signals should be preceded by an initial non-speech alerting signal to attract the users attention if the verbal warning signals are used for other types of information as well as warnings. [Source: Sanders & McCormick, 1993]
- **7.3.1.4 Acknowledging warning signals.** The system should require that users acknowledge spoken warning signals. [Source: MIL-HDBK-761A, 1989]

7.3.2 Intensity

- **7.3.2.1 Intensity.** Verbal signals for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver but shall not exceed 90 dB(A). [Source: NUREG-0700, 1981; MIL-STD-1472F, 1999]

Definition. **Speech interference level** is a measure of the effectiveness of noise in masking speech. It is the arithmetic mean of the same pressure levels of interfering noise (in dB) in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel (dB). [Source: NUREG-0700, 1981; MIL-STD-1472F, 1999]

- **7.3.2.2 Speech intensity.** Speech intensity should be appropriate to the expected ambient noise environment, with a signal to noise ratio of at least 5:1. [Source: MIL-HDBK-761A, 1989]

7.3.3 Word selection

- **7.3.3.1 Word choice.** The words used in verbal signals shall be concise, intelligible, and appropriate to the task and the information presented. [Source: MIL-HDBK-761A, 1989]
- **7.3.3.2 Word characteristic prioritization.** Word selection priority should all be intelligibility, descriptiveness, and conciseness, in that order. [Source: MIL-STD-1472F, 1999]

Discussion. Given the prioritization criteria above, if two word choices are being considered and both are concise, intelligible, and appropriate, but one is more intelligible, the one that is the most intelligible of the two should be used even if the other word choice is more concise.

- **7.3.3.3 Words to avoid.** To the extent possible, words that rhyme with other words or that sound similar in other ways should be avoided if these other words might be used in the same context and, therefore, possibly be confused with the original words. [Source: MIL-HDBK-761A, 1989]
- **7.3.3.4 Formal words.** Formal or correct words should be used; slang, jargon, and colloquial words should be avoided. [Source: MIL-HDBK-761A, 1989]
- **7.3.3.5 Alphabetic information.** Alphabetic information should be presented using a phonetic alphabet that uses words like alpha, bravo, and Charlie rather than the letters A, B, and C. [Source: MIL-HDBK-761A, 1989]

7.3.4 Presentation

- **7.3.4.1 Average talker.** Spoken messages should sound like an average talker from the user country without a regional dialect. [Source: MIL-HDBK-761A, 1989]
- **7.3.4.2 Distinctive voices.** When different categories of voice signals are used, a different, distinctive voice should be used for each category of data. [Source: MIL-HDBK-761A, 1989]

Example. One voice might be used for instructional messages and another for warnings. [Source: MIL-HDBK-761A, 1989]

- **7.3.4.3 Content.** Spoken messages should be brief, informative, and to the point. [Source: MIL-HDBK-761A, 1989]

- **7.3.4.4 Type of voice.** The voice used in recording verbal warning signals should be mature and distinct enough not to be confused with voice communications including radio and intercom communications. [Source: MIL-STD-1472F, 1999]
- **7.3.4.5 Delivery style.** Voice signals shall be presented in a formal, impersonal manner. [Source: MIL-STD-1472F, 1999]
- **7.3.4.6 Repetition.** Critical warning signals shall be repeated with not more than a 3 sec pause between messages until the condition is corrected or overridden by an operator or user. [Source: MIL-STD-1472F, 1999]
- **7.3.4.7 Speech processing.** Verbal warning signals shall be processed only if necessary to increase or preserve intelligibility, for example, by increasing the strength of consonant sounds relative to vowel strength. [Source: MIL-STD-1472F, 1999]

Discussion. When a signal must be relatively intense because of high ambient noise, peak clipping may be used to protect the listener against auditory overload. [Source: MIL-STD-1472F, 1999]

7.4 Voice communication systems

7.4.1 Speech intelligibility

- **7.4.1.1 Evaluation method.** If information about the speech intelligibility of a system is needed, the most appropriate of the following methods should be selected.
 - a. The phonetically balanced (PB) word test should be used when the highest accuracy and sensitivity are required. It is difficult to administer accurately and requires a long training time (typically 20-40 hours) before the responses of the listeners have peaked and are stable.
 - b. The modified rhyme test (MRT) described in ANSI 3.2 should be used to measure the communication performance of most military communication systems. It is easy to administer and requires only a short training time of 1-2 hours.
 - c. The articulation index (AI) and/or the speech transmission index (STI) are predictive estimators of intelligibility. They should be used to estimate system performance during the concept and design phase but not as a substitute for intelligibility test when system hardware is available. [Source: MIL-STD-1472F, 1999]

- **7.4.1.2 Intelligibility criteria.** Speech intelligibility shall meet the criterion in Exhibit 7.4.1.2 for the appropriate communication requirement and evaluation method. [Source: MIL-STD-1472F, 1999]

Exhibit 7.4.1.2 Speech intelligibility criteria for voice communication systems

COMMUNICATION REQUIREMENT	SCORE		
	PB	MRT	AI ¹
Exceptionally high intelligibility; separate syllables understood	90%	97%	0.7
Normal acceptable intelligibility; about 98% of sentences correctly heard; single digits understood	75%	91%	0.5
Minimally acceptable intelligibility; limited standardized phrases understood; about 90% sentences correctly heard (not acceptable for operational equipment)	43%	75%	0.3

¹ The Articulation Index (AI) should not be used to measure intelligibility of synthetic speech because some key acoustic features are not present in non-human “speech.” Instead, intelligibility of synthetic speech should be measured using representative panels of talkers and listeners.

7.4.2 Speech transmission equipment

- **7.4.2.1 Frequency range.** Microphones and associated system-input devices shall respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz. [Source: MIL-STD-1472F, 1999]
- **7.4.2.2 Dynamic range.** The dynamic range of a microphone used with a selected amplifier shall be great enough to admit variations in signal input of at least 50 dB. [Source: MIL-STD-1472F, 1999]
- **7.4.2.3 Noise canceling microphones.** In very loud, low frequency noise environments (100 dB overall), noise canceling microphones shall be used and shall be capable of effecting an improvement of at least 10 dB peak-speech to root-mean-square noise ratio as compared with microphones that are not noise canceling, but that have equivalent transmission characteristics. [Source: MIL-STD-1472F, 1999]

- **7.4.2.4 Pre-emphasis.** If necessary, speech system input devices shall employ frequency pre-emphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 Hz, and no greater than 9 dB per octave over the frequency range of 1,500 to 4,800 Hz when no clipping is used. [Source: MIL-STD-1472F, 1999]

Discussion. If speech signals are to be transmitted over channels that have less than 15 dB peak-speech to root-mean-square noise ratios, peak-clipping of 12 to 20 dB may be employed at system input and can be preceded by frequency pre-emphasis. [Source: MIL-STD-1472F, 1999]

- **7.4.2.5 Noise shields.** If the talker is in an intense noise field, the microphone should be put in a noise shield. Noise shields should be designed to meet the following requirements:
 - a. a volume of at least 250 cu cm (15.25 cu in) to permit a pressure gradient microphone to function normally,
 - b. a good seal against the face achieved by pressure of the hand or by tension straps,
 - c. a hole or combination of holes covering a total area of 65 sq mm (0.1 sq in) in the shield to prevent pressure buildup,
 - d. prevention of a standing wave pattern by shape or by use of sound absorbing material, and
 - e. no impediment to voice effort, mouth or jaw movement, or breathing. [Source: MIL-STD-1472F, 1999]

7.4.3 Speech reception equipment

- **7.4.3.1 Frequency range.** Headphones and loudspeakers shall be subject to the same frequency response restrictions as microphones and transmission equipment except that loudspeakers for use in multi-speaker installations and multiple channels fed into headphones (e.g., where several speech channels are to be monitored simultaneously) shall respond uniformly (± 5 dB) from 100 to 4,800 Hz. [Source: MIL-STD-1472F, 1999]

- **7.4.3.2 Use of de-emphasis.** If transmission equipment employs pre-emphasis and peak clipping is not used, reception equipment shall employ frequency de-emphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility, that is, de-emphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range of 140 to 4,800 Hz. [Source: MIL-STD-1472F, 1999]
- **7.4.3.3 Monitoring of speakers.** If several channels are to be monitored simultaneously by means of loudspeakers, the speakers shall be mounted at least 10° apart in the horizontal plane frontal quadrant, from 45° left to 45° right of the user's normal forward-facing position. [Source: MIL-STD-1472F, 1999]
- **7.4.3.4 Filtering of speaker signals.** If additional channel differentiation is required, apparent lateral separation shall be enhanced by applying low-pass filtering (frequency cutoff, $F_c=1,800$ Hz) to signals fed to loudspeakers on one side of the central user position. If there are three channels involved, one channel shall be left unfiltered; a high-pass filter with a 1,000 Hz cutoff shall be provided in the second channel; and a low-pass filter with a 2,500 Hz cutoff shall be provided in the third channel. A visual signal shall be provided to show which channel is in use. [Source: MIL-STD-1472F, 1999]
- **7.4.3.5 Speaker and side tone.** The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset. [Source: MIL-STD-1472F, 1999]
- **7.4.3.6 Use of binaural headsets.** If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. [Source: MIL-STD-1472F, 1999]
- **7.4.3.7 Binaural headsets.** Binaural headsets should be capable of reducing the perceived ambient noise level to less than 85 dB(A). Provisions should be incorporated to furnish the same protection to those who wear glasses. [Source: MIL-STD-1472F, 1999]
- **7.4.3.8 Speaker and side tone.** The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset. [Source: MIL-STD-1472F, 1999]

7.4.4 Design for user comfort and convenience

- **7.4.4.1 Comfort.** Communication equipment to be worn by a user, such as headphones and telephone headsets, shall be designed to preclude user discomfort. Metal parts of a headset shall not come into contact with a user's skin. [Source: MIL-STD-1472F, 1999]
- **7.4.4.2 Hands-free operation.** User microphones, headphones, and telephone headsets shall be designed to permit hands-free operation under normal working conditions. Specialized emergency equipment may be exempt from this criterion. [Source: MIL-STD-1472F, 1999]
- **7.4.4.3 Accessibility of handsets.** When communication requirements necessitate the use of several telephone handsets, the accessibility of their locations when not in use shall be determined by operational priority, that is, the most frequently or most urgently needed handset shall be the most accessible. The handsets may be color coded if the users will be able to perceive the coding under normal working conditions. [Source: MIL-STD-1472F, 1999]

7.4.5 Operating controls for voice communication equipment

- **7.4.5.1 Volume controls.** Accessible volume or gain controls shall be provided for each communication receiving channel, such as loudspeakers or headphones, with sufficient electrical power to drive the sound pressure level to at least 100 dB overall, when using two earphones. The minimum setting of the volume control shall be limited to an audible level, that is, it shall be impossible to inadvertently disable the system using the volume control. [Source: MIL-STD-1472F, 1999]
- **7.4.5.2 Separate controls for power and volume.** Separate controls should be provided for power (ON-OFF) and for volume control. [Source: MIL-STD-1472F, 1999]
- **7.4.5.3 Combined power and volume controls.** If power and volume controls are combined because of space limitations, an easily noticeable detent position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment, and the OFF position shall be labeled. [Source: MIL-STD-1472F, 1999]

- **7.4.5.4 Squelch control.** If communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. A manually operated ON-OFF switch shall be provided to deactivate squelching during the reception of weak signals. [Source: MIL-STD-1472F, 1999]
- **7.4.5.5 Foot-operated controls.** When normal working conditions will permit the operator to remain seated at the working position and require access to "talk-listen" or "send-receive" control switches, or if console operation requires the use of both hands, foot-operated controls shall be provided. [Source: MIL-STD-1472F, 1999]
- **7.4.5.6 Duplicate emergency controls.** Hand-operated controls for the same functions as foot operated controls shall be provided for emergency use and for use when the operator may need to move from one position to another. [Source: MIL-STD-1472F, 1999]

7.4.6 Conventional telephone systems

- **7.4.6.1 General.** In special environments such as control rooms, selection and placement of conventional telephone systems may be more critical than in a normal office environment. Within such specialized environments, systems selected for use shall provide a good frequency response in that portion of the spectrum essential for speech intelligibility. The standard telephone band pass of 200 to 3,300 Hz is acceptable. Handsets shall be compatible with users' hand sizes and mouth-to-ear distances. Again, the standard telephone dimensions are acceptable. Handsets shall provide firm ear contact. [Source: NUREG-0700, 1981]
- **7.4.6.2 Cords.** Cords shall be non-kinking or self-retracting and of sufficient length to permit reasonable user mobility. Cords shall be positioned to avoid entangling critical controls or becoming entangled with passing people or objects. [Source: NUREG-0700, 1981]
- **7.4.6.3 Handset cradles.** Vertically mounted handset cradles shall be designed and located to prevent the handset from being knocked out of the cradle by passing people or objects. [Source: NUREG-0700, 1981]
- **7.4.6.4 Multiple telephones.** If several telephones are located close to each other, they shall be coded to indicate circuit or function. [Source: NUREG-0700, 1981]
- **7.4.6.5 Press-to-talk button.** If a press-to-talk button is used, the button shall be convenient to both left- and right-handed people. [Source: NUREG-0700, 1981]

- **7.4.6.6 Switching.** Switching should be designed and programmed to minimize delay in making desired connections under both normal and emergency conditions. [Source: NUREG-0700, 1981]
- **7.4.6.7 Priority.** Switching shall be programmed to give the control room and critical functions automatic priority of access to the switching system. [Source: NUREG-0700, 1981]
- **7.4.6.8 Noisy environments.** In noisy environments, volume controls should be provided for loudness of ringing and speaker output. [Source: NUREG-0700, 1981]

Glossary

Advisory - A signal that indicates a safe or normal configuration, condition of performance, or operation of essential equipment, or attracts attention and imparts information for routine action purposes.

Alarm filtering - A technique by which unnecessary alarms are eliminated.

Alarm suppression - Alarm messages are not displayed but are available to the user upon request.

Caution - A signal that indicates the existence of a condition requiring attention but not immediate action.

Speech interference level - A measure of the effectiveness of noise in masking speech. It is the arithmetic mean of the same pressure levels of interfering noise in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz, respectively. The unit of speech interference is the decibel (dB).

Warning - A signal that indicates the existence of a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or a service interruption.

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