10 COMMUNICATION SYSTEM
10.2 Speech-Based Communication
10.2.4 Portable Radio Transceivers

10.2.4-1 Appropriate Use

Walkie-talkies should be used in both emergency and normal operations for two-way communications beyond the range of installed telephone connections or as a convenient alternative to the sound-powered telephone.
Additional Information: However, each licensee/applicant who intends to use radio communications should determine the extent to which radio interference could adversely affect control room operations.[0700]

10.2.4-2 Sound Quality

Walkie-talkies should realize the same quality desired throughout all of the communications systems within the engineering constraints imposed by radio frequency spectrum availability and by design for easy portability.[0700]

10.2.4-3 Area Coverage

Modulation and a radio frequency should be chosen, as FCC regulations permit, to provide broad-area walkie-talkie communication to the control room.
Additional Information: One consideration for frequency selection should be radio-wave penetration of metal or reinforced concrete barriers, which at certain frequencies, would tend to attenuate or bounce the signal. Use of walkie-talkies should be prohibited in areas close to low-level analog or digital equipment, unless EMI noise susceptibility tests have been conducted that demonstrate that the equipment is not affected by the frequency bands used.[0700]

10.2.4-4 Portability

To the extent permitted by design for effective electrical/radio frequency function, walkie-talkies should be small, light, and easy to carry. The microphone should be integrated into the transceiver package.[0700]

10.2.4-5 Party Identification

Procedures should provide for unambiguous identification of the speaker when there are more than two parties on a channel operating at separate locations.[0700]

10.2.4-6 Battery Replenishment

A supply of fresh replacement batteries should be stowed in an accessible, well-marked space.
Additional Information: The stock should be kept large enough to support long periods of continuous operation in case of emergency.[0700]

10 COMMUNICATION SYSTEM
10.2 Speech-Based Communication
10.2.5 Announcing Systems

10.2.5-1 Intelligibility and Coverage
The system should provide rapidly intelligible messages to all areas where personnel subject to a page may be located.
Additional Information: Adequate coverage requires that speakers should be placed so that they are available in all necessary areas and that there are no "dead spots" within any area.[0700]

10.2.5-2 Microphone Characteristics
If the powered telephone system is used to provide microphone input to the announcing system, the telephone system should contain transmitters of quality compatible with that of the announcing system.
Additional Information: Frequency response should be compatible with that of the rest of the system. Microphones should have high sensitivity to speech signals. Microphone input should be provided within the control room.[0700]

10.2.5-3 Loudspeaker Location
Speakers should be provided in the control room and other areas where personnel might be (e.g., restrooms, eating areas, and locker rooms).
Additional Information: Speakers should be placed to yield an intelligible level of signal throughout the area.[0700]

10.2.5-4 Speech Clarity
Since proper speech over an announcing system differs from normal conversation, users should be familiarized with the proper way to speak on the announcing system.[0700]

10.2.5-5 Loudspeaker Volume
Speaker volume should be adjusted to ensure that speaker communications will not prevent detection of auditory alarms.[0700]

10.2.5-6 Priority
Control room inputs to the plant announcing system should have priority over any other input.
Additional Information: The control room input should be capable of interrupting an announcement in progress, or of bypassing queued announcements.[0700]

10 COMMUNICATION SYSTEM
10.2 Speech-Based Communication
10.2.6 Other Communications Systems

10.2.6-1 Fixed-Base UHF Transceivers
A fixed-base UHF transceiver may be used for normal emergency communications between the control room and the following locations similarly equipped with fixed-base transceivers: Dispatcher, Security, and Utility Headquarters (if within UHF range).
Additional Information: Procedures should be established (and conspicuously posted) for use of the system. Each licensee/applicant who intends to use radio communications should determine the extent to which radio interference could affect control room operations.[0700]

10.2.6-2 Point-to-Point Intercom Systems
Intercom systems should be provided to interconnect the control room with important plant areas and other areas where control room or operating personnel might be.
Additional Information: Areas served by intercoms might include the Shift Supervisor's Office, Plant Security Office, operators' lounge, locker rooms, and restrooms.[0700]

10.2.7-1 Backup Equipment

Provisions should be made to assure complete internal and external communications capabilities during emergencies.[0700]

10.2.7-2 Equipment Usability

Communications equipment should be usable by personnel wearing protective gear without impediment to their tasks.[0700]

10.2.7-3 Voice Communications with Masks

Emergency facemasks should be equipped with diaphragms that are specially designed to transmit speech. *Additional Information:* The diaphragms should be able to separate voice from exhaust valve action. If not equipped with diaphragms, masks should be equipped with electronic speech systems that pick up the voice with an internal microphone and transmit it to a loudspeaker attached outside the mask.[0700]

10 COMMUNICATION SYSTEM
10.3 Computer-Based Communication
10.3.1 General

10.3.1-1 Interactive Communication
Users should be able to communicate interactively with other users who are currently using the same system.[5908]

10.3.1-2 Interaction With Ongoing Tasks
Users should be able to communicate with each other without canceling ongoing tasks.[5908]

10.3.1-3 Functional Integration
Computer-based communications should be integrated with other information handling functions within a system.
Additional Information: A user should not have to log off from the process monitoring system and log on to some other special system in order to send or receive a message. If data transmission facilities are in fact implemented as a separate system, that separation should be concealed in user interface design, so that a user can move from general information handling to message handling without interruption.[5908]

10.3.1-4 Consistent Procedures
Procedures for sending and receiving messages should be consistent from one transaction to another.
Additional Information: Procedures should be the same for handling different kinds of messages and for messages sent to different destinations, although procedures for handling high-priority messages might incorporate special actions to ensure special attention.[5908]

10.3.1-5 Control by Explicit User Action
Both sending and receiving messages should be accomplished by explicit user action.[5908]

10.3.1-6 Automatic Queuing
The computer should provide automatic queuing of outgoing messages pending confirmation of transmission, and incoming messages pending their review and disposition.[5908]

10.3.1-7 Interrupt
Users should be able to interrupt message preparation, review, or disposition, and then resume any of those tasks from the point of interruption.[5908]

10.3.1-8 Message Highlighting
Software capabilities should be provided to annotate transmitted data with appropriate highlighting to emphasize alarm/alert conditions, priority indicators, or other significant information that could affect message handling.
Additional Information: Highlighting will aid the handling and interpretation of messages. Such annotation might be provided automatically by software logic (e.g., a computer-generated date-time stamp to indicate currency), or might be added by the sender of a message to emphasize some significant feature (e.g., attention arrows), or by the receiver of a message as an aid in filing and retrieval.[5908]

10.3.1-9 Automatic Record Keeping
A log of data transmissions should be automatically maintained.[5908]

10.3.2-1 Automatic Message Formatting
When message formats should conform to a defined standard or structure, prestored formats should be provided to aid users in message preparation.
Additional Information: When information must be transmitted in a particular format, computer aids should be provided to generate the necessary format automatically.[5908]

10.3.2-2 Message Composition Compatible with Data Entry
Procedures for composing messages should be compatible with general data entry procedures, especially those for text editing.
Additional Information: A user should not have to learn procedures for entering message data that are different from those for general data entry.[5908]

10.3.2-3 Variable Message Length
Users should be able to prepare messages of any length.
Additional Information: In particular, data transmission facilities should not limit the length of a message to a single display screen or to some fixed number of lines. There will usually be some implicit limit on message length imposed by storage capacity or the amount of time it would take to transmit a very long message. However, a user might sometimes choose to increase storage or accept transmission delays in order to send a long message required by a particular task.[5908]

10.3.2-4 Incorporate Existing Files
Users should be able to incorporate an existing data file in a message, or to combine several files into a single message for transmission.
Additional Information: It should not be necessary for a user to re-enter for transmission any data already entered for other purposes or available in the system. It should be possible to combine stored data with new data when preparing messages for transmission.[5908]

10.3.2-5 Message Editing
Users should be able to save and edit messages prior to transmission.
Additional Information: Users should be able to save draft messages during their preparation. A user should not be forced to recreate a message if its preparation is interrupted for some reason. Users should be able to specify how to save draft messages (i.e., in what file), just as they may decide how to save copies of transmitted and received messages.[5908]

10.3.3-1 Destination Selection
Users should be able to specify the destination(s) to which messages will be transmitted.
Additional Information: Specification of message destination might be in terms of system users, as individuals or groups, or other workstations and terminals (including remote printers), or users of other systems. Standard destinations may be specified as a matter of routine procedure, with special destinations designated as needed for particular transactions. For most applications, it is important that users be able to send a message to multiple destinations with a single transmission action. For multiple recipients, it will usually be helpful to show all addresses to all recipients, so that they will know who else has received the message.[5908]

10.3.3-2 Address Directory
Users should be provided with a directory showing all acceptable forms of message addressing for each destination in the system, and for links to external systems.
Additional Information: In addition to the names of people, users may need to find addresses for organizational groups, functional positions, other computers, data files, workstations, and devices. The directory should include specification of system distribution lists as well as individual addresses.[5908]

10.3.3-3 Aids for Directory Search
Computer aids should be provided so that a user can search an address directory by specifying a complete or partial name.
Additional Information: Users will often remember a partial address, even if they cannot remember its complete form.[5908]

10.3.3-4 Extracting Directory Addresses
Users should be able to extract selected addresses from a directory or select a distribution list for direct insertion into a header in order to specify the destination(s) for a message.
Additional Information: Direct insertion of addresses from a directory will avoid errors that a user might make in manual transcription and entry, and is faster.[5908]

10.3.3-5 Automatic Addressing of Reply
The appropriate address(es) should be provided automatically for users responding to messages.[5908]

10.3.3-6 Assignment of Priority
When messages will have different degrees of urgency, the sender of a message should be allowed to designate its relative priority.[5908]

10.3.3-7 Information About Communication Status
Users should be allowed access to status information concerning the identity of other system users currently on-line, and the availability of communication with external systems.
Additional Information: Such information may influence a user's choice of destinations and choice of communication methods, as well as the decision when to initiate transmission. For example, a user might choose to link directly with another user who is currently on-line, but might compose a message for deferred transmission to an inactive user.[5908]

10.3.3-8 Sender Identification
When a message is sent, the computer should show the sender's address, and the date and time of message creation and/or transmission.[5908]

10.3.3-9 Deferring Message for Automatic Transmission
Users should be able to defer the transmission of prepared messages, to be released by a later action.
Additional Information: A user might wish to defer data transmission until some specified date-time or until a specific event has occurred.[5908]

10.3.3-10 Automatic Feedback
Automatic feedback for data transmission confirming that messages have been sent or indicating transmission failures should be provided to permit effective user participation in message handling.
Additional Information: If message transmission is not successful, the sender should be notified, if possible with an explanation of the problem. It may help a user to know whether transmission has failed because of faulty addressing, communication-link failure, or some other reason, in order to take appropriate corrective action.[5908]

10.3.3-11 Saving Undelivered Messages
If message transmission is not successful, automatic storage of undelivered messages should be provided.
Additional Information: Transmission failure should not cause loss or destruction of messages, and should not disrupt the sender's work in any other way.[5908]

10.3.3-12 Message Cancellation
Users should be able to recall any message whose transmission has been initiated, if it has not yet been received by its addressee(s).[5908]

10.3.3-13 User Review of Data Before Transmission
When human judgment may be required to determine whether data are appropriate for transmission, users (or a system administrator) should be provided some means to review outgoing messages and confirm their release before transmission.
Additional Information: Sometimes message release may require coordination among several reviewers in the interest of data protection.[5908]

10.3.3-14 Saving Transmitted Data Until Receipt is Confirmed
A copy of any transmitted message should be saved automatically until correct receipt has been confirmed.
Additional Information: The primary objective is to prevent irretrievable data loss during transmission. For many system applications, however, the originator of a message will probably want to retain a copy in any case. Any subsequent deletion of that copy should probably be handled as a separate transaction, distinct from data transmission.[5908]

10.3.4-1 Message Notification at Logon
When users log on to a system, they should be notified of any transmissions received since their last use of the system.[5908]

10.3.4-2 Display of Messages
The display of messages from other users should be visually and spatially distinct from the display of system messages.[5908]

10.3.4-3 Nondisruptive Message Notification
Notification of incoming messages should be nondisruptive.
Additional Information: Notification of incoming messages should not interrupt the user's current task and should not automatically overwrite the screen areas where the user is working. For example, the system might indicate message arrival to the user by an advisory notice in a portion of the display reserved for that purpose.[5908]

10.3.4-4 Indicating Priority of Received Messages
Where incoming messages will have different degrees of urgency, recipients should be notified of message priority and/or other pertinent information.
Additional Information: Notification of urgent messages might be routed to a special area of a user's working display for immediate reference, whereas notification of routine messages might be deferred, or perhaps routed to a printer for review at the user's convenience. If incoming messages are queued so that their arrival will not interrupt current user tasks, then users should be advised when an interruption is, in fact, necessary.[5908]

10.3.4-5 Filters for Message Notification
Users should be able to specify "filters" based on message source, type, or content, that will control what notification is provided for incoming messages.
Additional Information: For example, a user might wish the arrival of all messages from a particular source to produce a special notification.[5908]

10.3.4-6 Time-Stamp Messages
Messages should be time-stamped.
Additional Information: The time stamp should provide information needed to manage messages. Some types of time stamps include: date and time of message origin, release, receipt at receiving station, and opening by user.[5908]

10.3.4-7 Indicate Message Size
Some indication of message size should be included at the beginning of each message.
Additional Information: For example, message size might be calculated as number of lines and indicated in its header.[5908]

10.3.4-8 Indication of Message Overflow
The user should be informed when a message has been truncated, such as when a message exceeds the available space.
Additional Information: An end-of-message indicator that is automatically generated when a message is transmitted can help the user verify that the message is complete.[5908]

10.3.4-9 Message Storage and Retrieval
Messages should be stored in a message queue that is available to the user.
Additional Information: For example, the user might be able to scroll through a log file containing the message, time, date, and origin.[5908]

10.3.4-10 Information about Queued Messages
Users should be able to review summary information about the type, source, priority, and size of queued incoming messages.
Additional Information: In some applications, a user might need notification only of urgent messages, and may rely on periodic review to deal with routine messages. Summary information about queued incoming messages should help guide message review.[5908]

10.3.4-11 User Selection of Messages
The user should be allowed to select any message from an ordered queue with a simple action.[5908]

10.3.4-12 Annotating Received Messages
Users should be able to append notes to a received message, and ensure that the annotation will be displayed so that it will be distinct from the message itself.
Additional Information: Users should not be allowed to make changes in received messages. Any such changes would simply provide too much chance for resulting confusion. However, users should be able to append, file, and display their own comments about received messages in some distinctively separate form. If changes are desired in a message itself, then its recipient might make a copy of that message (with appropriate change of its header information) and then edit the copy.[5908]

10.3.4-13 Specifying Device Destination
Users should be able to choose the method of receipt, i.e., what device (file, display, printer) will be the local destination. If a specified receiving device is not operable, such as a printer that is not turned on, the user should be advised.
Additional Information: When messages are received via display, queuing of incoming messages should be provided so that they will not interfere with use of that display for other information handling tasks. Device destination might be specified differently for various types of messages, or for messages received from different sources. Transmitted data might be received directly into computer files. Incoming messages might be routed to an electronic display for quick review, and/or to a printer for hardcopy reference.[5908]

Part III
Workstation and Workplace Design

SECTION 11: WORKSTATION DESIGN

11 WORKSTATION DESIGN

WORKSTATION CONFIGURATION

HSI elements are organized into workstations, where the operators perform their functions and tasks. Types of workstations include sit-stand workstations, stand-up consoles, sit-down consoles, vertical panels, and desks (e.g., used by personnel when performing tasks related to the operation and safety of the plant, such as by a shift supervisor in the main control room). The operators' performance may be affected by design characteristics that affect reach, vision, and comfort. Unique considerations for these types of workstations include the following:

- Workstation height (i.e., for workstations that the operator must see over)
- Benchboard slope, angle, and depth for consoles and sit-stand workstations (i.e., accommodations for reach; provision of writing space)
- Control device location (i.e., placement of highest and lowest controls; distance from front edge of workstation)
- Display device location (i.e., placement of highest and lowest display devices, orientation relative to line of sight, viewing distance, position of frequently and infrequently monitored display devices)
- Lateral spread of control and display devices at a console or workstation
- Clearances for legs and feet.

In addition, the workstation design includes the seating provided for personnel at the consoles or desks. Important considerations include mobility; rests for back, arms, and feet; seat adjustability, and cushioning. Review guidelines for workstation configuration are provided as follows: stand-up consoles in Section 11.1.1, sit-down consoles in Section 11.1.2, sit-stand workstations in Section 11.1.3, vertical panels in Section 11.1.4, desks in Section 11.1.5, and chairs in Section 11.1.6.

CONTROL AND DISPLAY DEVICE LAYOUT

Control and display devices are not usually used in isolation. Often groups of devices are used together to perform a task. Therefore, the following relationships among devices should be addressed:

- Grouping of related controls or displays (i.e., by sequence of use, frequency of use, and importance)
- Control devices (i.e., spacing; interference with access; inadvertent actuation of adjacent controls; simultaneous actuation of controls)
- Display devices (i.e., row arrangement; string length)
- Control-display layout integration (e.g., orientation, proximity, obscuration, and indication of association) for
    - a single control and display pair
    - multiple controls and a single display
    - a single control and multiple displays
- Dynamic control-display relationships (i.e., response compatibility between controls, including rotary and linear devices, and displays, such as linear scales, digital displays, indicator light strings, and circular meter points)

- Between-group and within-group relationships (i.e., control and display modules; repeated groups and functions; mirror-image layouts)

Review guidelines for control and display device layout are provided in Section 11.2.

LABELING AND DEMARCATIONS

Labels and demarcations can help operators find and identify controls, displays, and other equipment.

Labels

Permanent labels may be used for panels, groups of controls and displays, individual items, instructions, control direction, and access openings. In addition, temporary labels may be used for such purposes as tagging-out equipment. The following characteristics of labels are important to operator performance:

- Location (i.e., proximity of adjacent labels; orientation; surface mounting considerations)
- Content (i.e., information content, distinguishability, consistency, and agreement with procedures)
- Lettering (i.e., character height, width, font, spacing, stroke width, and contrast with background)

Demarcation

Demarcation lines are used to identify workstation sections and groups of controls and displays. Important characteristics include contrast, consistency, and permanence. Another important consideration is the rationale that was used in applying them (e.g., the types of controls and displays they enclose). Review guidelines for labels and demarcations are provided in Section 11.3.

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.1 Stand-Up Console Dimensions

11.1.1-1 Console Height to See Over
Console height (with or without annunciator panels) should not exceed 58 inches when it is necessary for a user standing at the console to see over its top.[0700]

11.1.1-2 Control Height
The highest control on a stand-up console should be within the highest reach of the 5th percentile female without stretching or using a stool or ladder, while the lowest controls should be within the lowest reach of the 95th percentile male without bending or stooping, as shown in Table 11.1.
Additional Information: The range of suitable control height on stand-up consoles is defined by the reach radius of the 5th and 95th percentiles. Measurements should be made using shoulder height and functional reach with the shoulder in line with the leading edge of the benchboard, as shown in Figure 11.1. The figure shows the results of two console designs with differing benchboard slope and depth. Controls may be placed somewhat higher on consoles with shallower and/or more steeply angled benchboards, which allow the shoulder reference point to be closer to the back of the benchboard and to the vertical panel.[0700]

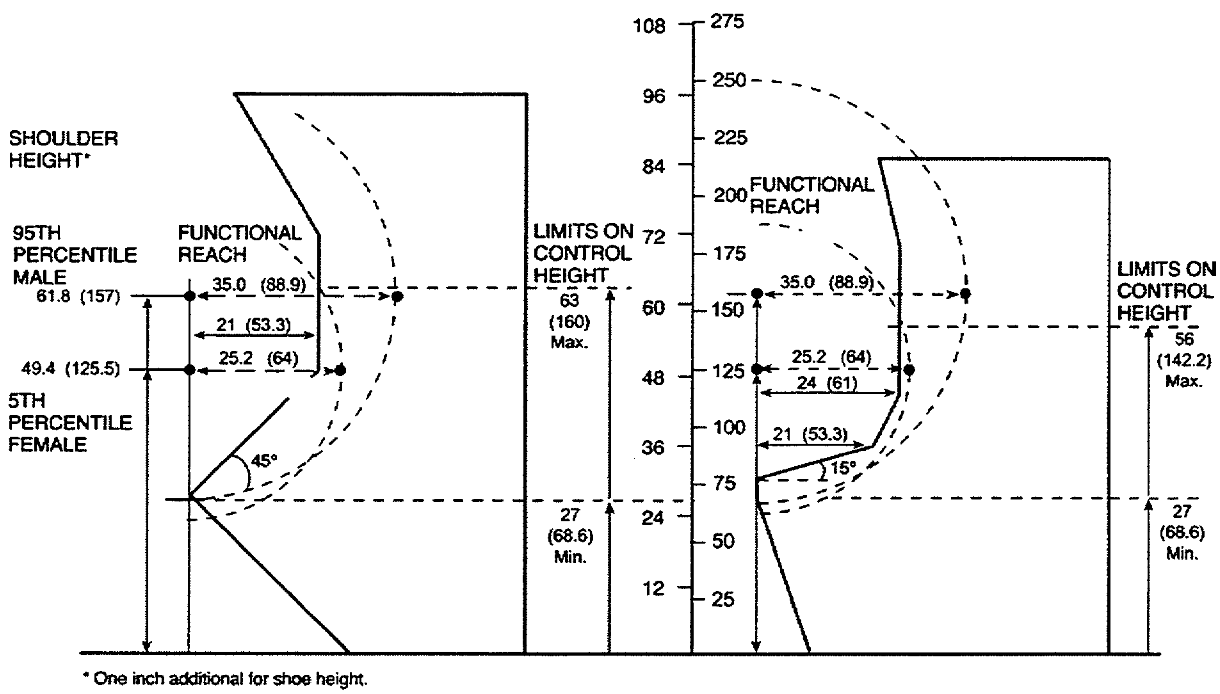


Figure 11.1 Reach capabilities and control height for two stand-up consoles (the console on the right includes a keyboard surface)

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.1 Stand-Up Console Dimensions

Table 11.1 Anthropometric data used to set limits for equipment dimensions

Standing (without shoes)	Bounding Measurements (inches) 5th %-ile Adult Female	Bounding Measurements (inches) 95th %-ile Adult Male[1]
Stature	60.0	73.5
Eye height from floor	55.5	68.6
Shoulder height	48.4	60.8
Elbow height	37.4	46.8
Fingertip height[2]	24.2	28.8
Functional reach[3]	25.2	35.0
Extended functional reach[4]	28.9	39.0
Central axis of body to leading edge of console[5]	5.0	5.3
Eye distance forward of central axis to body[5]	3.0	3.4
Seated	**Bounding Measurements (inches) 5th %-ile Adult Female**	**Bounding Measurements (inches) 95th %-ile Adult Male[1]**
Popliteal height (bend at back of knee)	15.0	19.2
Sitting height above seat surface (erect)	31.1	38.5
Sitting height above seat surface (relaxed)	30.5	37.6
Eye height above seat, sitting erect	26.6	33.6
Shoulder height above seat surface	19.6	25.8
Elbow height above seat surface	6.4	11.3
Functional reach	25.2	35.0
Extended functional reach	28.9	39.0
Thigh clearance height	4.1	7.4
Buttock-popliteal length	17.1	21.5
Knee height	18.5	23.6
Central axis of body to leading edge of console[5]	5.0	5.3
Eye distance forward of central axis of body[5]	3.0	3.4

(Source: MIL-STD-1472D, Section 5.6.)

[1] MIL-STD-1472D gives separate values for male troops and aviators. The two were averaged for presentation here.
[2] Data for male aviators only, 5th and 95th percentiles.
[3] Measured from wall to tip of right index finger, with arm extended horizontal to floor, both shoulders against wall.
[4] Measured as stated above, except right shoulder extended as far as possible with left shoulder against wall.
[5] These measurements are not given in MIL-STD-1472D. Values provided in Seminara et al. are presented although they are based on measures of a different population. Differences in other measurements between the MIL-STD population and the EPRI population are small enough that these EPRI values should provide reasonable approximations.

11 WORKSTATION DESIGN

11.1 Workstation Configuration

11.1.1 Stand-Up Console Dimensions

11.1.1-3 Benchboard Slope
The benchboard slope, in conjunction with its depth, should result in all controls being within the reach radius of the 5th percentile female, as shown in Table 11.1 and illustrated in Figure 11.1.[0700]

11.1.1-4 Minimum Distance of Controls from the Front Edge of the Console
Controls should be set back a minimum of 3 inches from the front edge to protect against accidental activation.[0700]

11.1.1-5 Maximum Distance of Controls from the Front Edge of the Console
Controls should be no more than 25 inches from the front edge of the console.
Additional Information: This accommodates the maximum reach of the 5th percentile female adult as illustrated in Figure 11.1.[0700]

11.1.1-6 Display Height and Orientation
All displays, including alarm indicators, should be within the upper limit of the visual field (75 degrees above the horizontal line of sight) of the 5th percentile female (see Table 11.1), and should be mounted so that the interior angle between the line of sight and the display face is 45 degrees or greater (see Figure 11.2).
Additional Information: The 5th percentile female determines the upper limit. The 95th percentile male determines the lower limit. The principal factors affecting the readability of displays, including annunciator tiles, are: (1) display height and orientation relative to the user's line of sight when standing directly in front of the display; (2) display distance and orientation relative to the user's straight-ahead line of sight when the user must read the display from an off-side position; and (3) the size of display markings relative to the distance at which the display must be read. Character size is addressed in Section 1.3.1, Alphanumeric Characters, and is not considered here. Except as specifically noted, measurements of angles should be made with the eye point in line with the leading edge of the benchboard.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.1 Stand-Up Console Dimensions

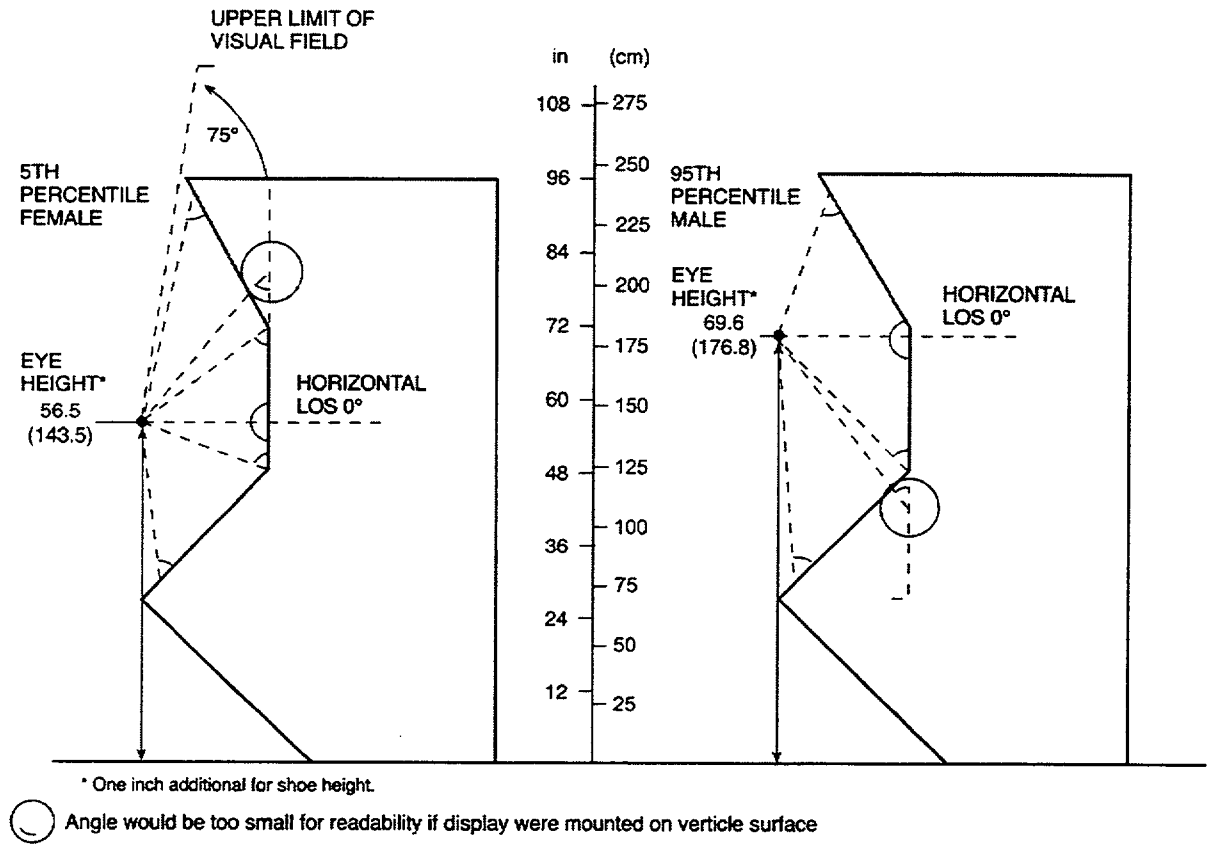


Figure 11.2 Display height and orientation relative to a standing user's line of sight

11.1.1-7 Location of Frequently Monitored Displays
Displays that require frequent or continuous monitoring, or that may display important (e.g., alarm) information, should be located not more than 35 degrees to the left or right of the user's straight-ahead LOS, and not more than 35 degrees above and 25 degrees below the user's horizontal LOS, measured from the normal workstation.[0700]

11.1.1-8 Location of Infrequently Monitored Displays
Displays that do not require frequent or continuous monitoring, and that will not display important (e.g., alarm) information, should be located not more than 95 degrees to the left or right of the user's straight-ahead LOS, as measured from normal workstations.[0700]

11.1.1-9 Lateral Spread of Controls and Displays
The maximum lateral spread of controls and displays at a single-user workstation should not exceed 72 inches.
Additional Information: The user should be able to perform task sequences at a given work station with minimum repositioning. The amount of movement required depends on the arrangement of controls and displays, not simply on the lateral dimensions of the segments of the control board.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.1 Stand-Up Console Dimensions

11.1.1-10 Foot Room

Enough foot room should be provided to allow the user to get close to the board without leaning.
Additional Information: A clearance of 4 inches vertically and horizontally is recommended.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.2 Sit-Down Console Dimensions

11.1.2-1 Console Height to See Over
Console height should be no more than approximately 27 inches above the seat to accommodate the 5th percentile adult female when a seated user must see over the console. Assuming seat height is adjusted to 18 inches, maximum console height therefore should be 45 inches above the floor.
Additional Information: See-over console heights above 45 inches may be acceptable, for example, where the seated user need only monitor (not read) status lights and annunciators beyond the console, if they are at a suitable distance and height.[0700]

11.1.2-2 Control Height
All controls on a sit-down console should be within the reach radius of the 5th percentile female, as shown in Table 11.1 and illustrated in Figure 11.3.
Additional Information: Measurements should be made using seated shoulder height with the shoulder in line with the leading edge of the benchboard.[0700]

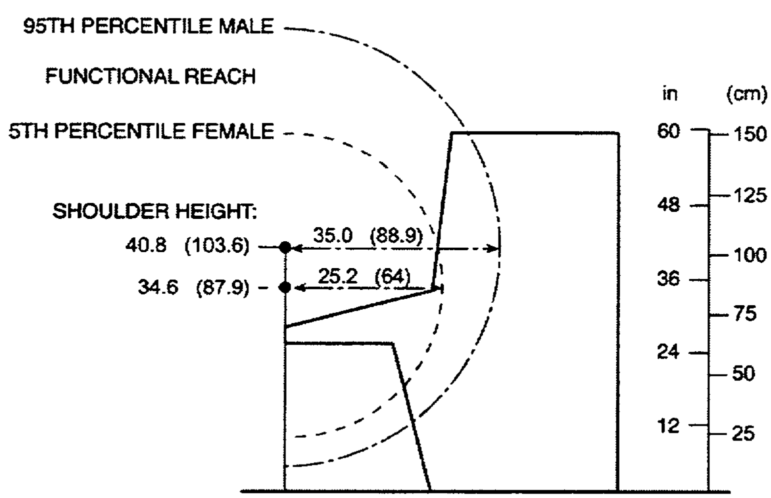


Figure 11.3 Reach capabilities for sit-down consoles

11.1.2-3 Benchboard Slope
The benchboard slope, in conjunction with its depth, should be such that all controls are within the functional reach radius of the 5th percentile female (as shown in Table 11.1 and illustrated in Figure 11.3) and all displays and markings can be read.[0700]

11.1.2-4 Minimum Distance of Controls from the Front Edge of the Console
Controls should be set back a minimum of 3 inches from the front edge to protect against accidental activation.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.2 Sit-Down Console Dimensions

11.1.2-5 Display Height and Orientation
All displays, including alarm indicators, should be within the upper limit of the visual field (75 degrees above the horizontal line of sight) of the 5th percentile female (see Table 11.1), and should be mounted so that the interior angle between the line of sight and the display face is 45 degrees or greater (see Figure 11.4).
Additional Information: The 5th percentile female determines the upper limit. Practically, there is no lower limit for a plausible sit-down console design. The principal factors affecting the readability of displays, including alarm indicators, are: (1) display height and orientation relative to the user's LOS when standing directly in front of the display; (2) display distance and orientation relative to the user's straight-ahead LOS when the user must read the display from an off-side position; and (3) the size of display markings relative to the distance at which the display must be read. Character size is addressed in Section 1.3.1, Alphanumeric Characters, and is not considered here. Except as specifically noted, measurements of angles should be made with the eye point in line with the leading edge of the benchboard.[0700]

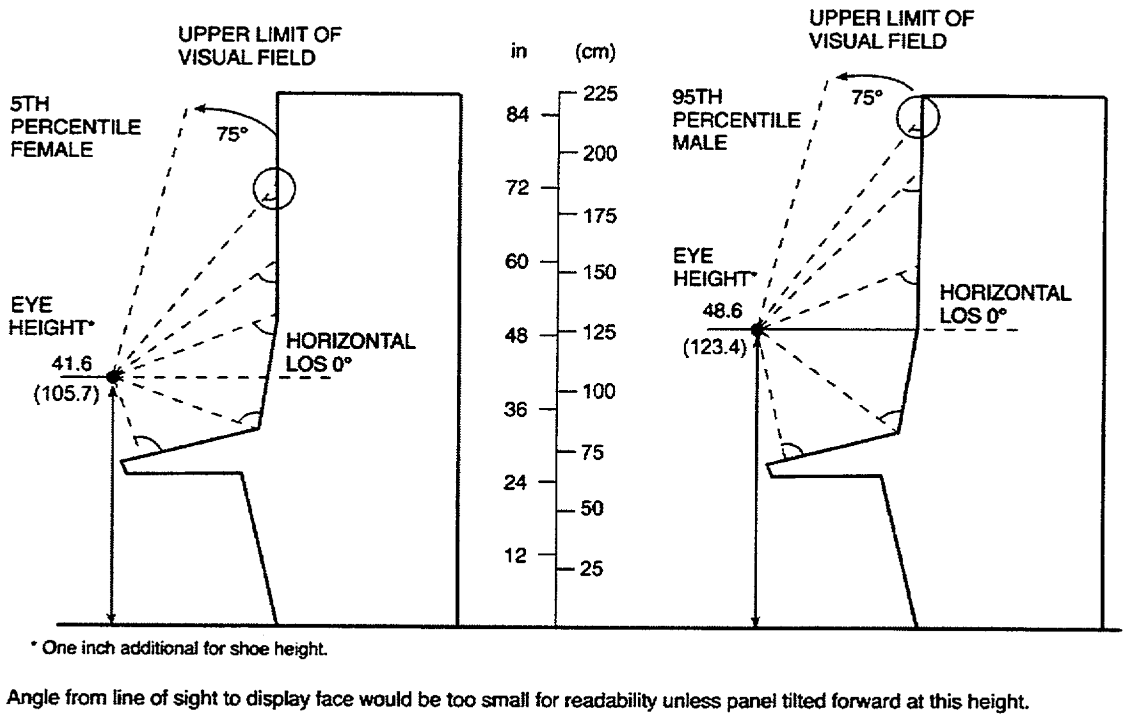


Figure 11.4 Display height and orientation relative to a seated user's line of sight

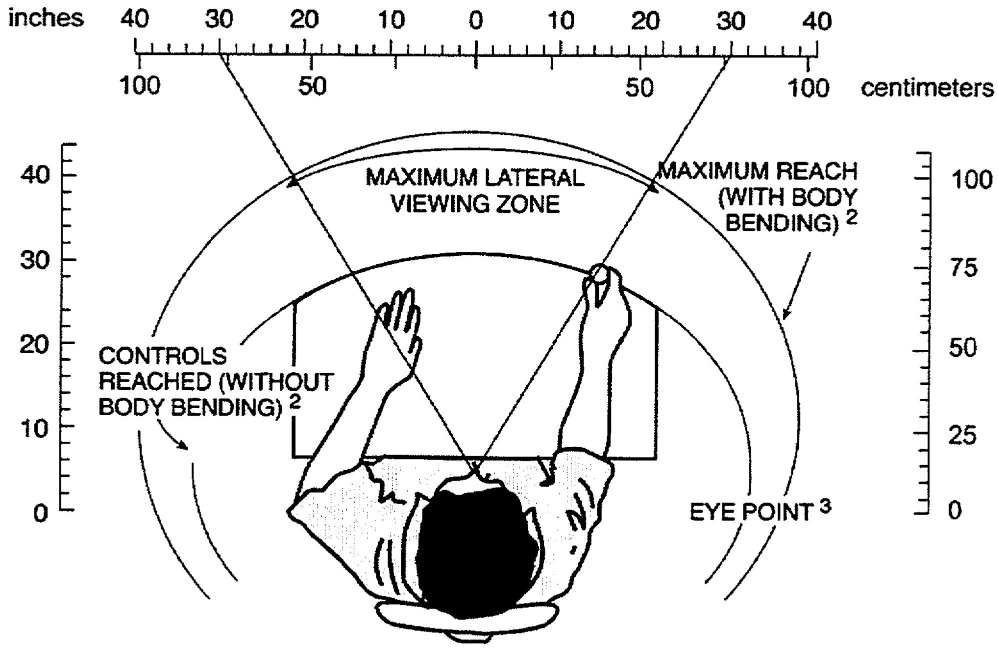
11.1.2-6 Location of Frequently Monitored Displays
Displays that require frequent or continuous monitoring, or that may display important (e.g., alarm) information, should be located not more than 35 degrees to the left or right of the user's straight-ahead LOS, and not more than 20 degrees above and 40 degrees below the user's horizontal LOS, as measured from the normal workstation.[0700]

11.1.2-7 Location of Infrequently Monitored Displays
Displays that do not require frequent or continuous monitoring, and that will not display important (e.g., alarm) information, should be located not more than 95 degrees to the left or right of the user's straight-ahead LOS, as measured from normal workstations.[0700]

11.1.2-8 VDU Viewing Distance
The viewing distance should be 13-30 inches (33 to 80 cm), with 18-24 inches (46-61 cm) preferred.
Additional Information: Display size, symbol size, brightness ranges, line-pair spacing and resolution should be appropriate for the maximum expected viewing distance.[5908]

11.1.2-9 Lateral Spread of Controls and Displays
All necessary controls and displays needed for critical or frequently performed activities should be within the maximum extended reach and viewing range of a seated user from a single reference point as shown in Table 11.1 and illustrated in Figure 11.5.
Additional Information: For sustained or precise control action, the user should be able to reach the controls without having to bend/stretch significantly. The acceptable lateral spread of controls and displays on sit-down consoles depends primarily on the reach of the users, panel orientation, grouping of controls and displays, and the freedom of the user to adjust seat position (center reference point) given task sequence requirements. Figure 11.5 illustrates reach and viewing range related to lateral and forward distance from a center reference point.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.2 Sit-Down Console Dimensions



[1] 28 inches forward of the eye point is the maximum distance for displays when viewing is limited by reach (control-display relationship). Viewing distance may be extended provided display is properly designed. Greater lateral spread of displays would require a wraparound panel.

[2] Based on 5th percentile male data; less for 5th percentile females.

[3] Console edge approximately 4" to 6" forward of eye point for 5th-95th percentile.

Figure 11.5 Reach and visual range related to lateral and forward distance from center point

11.1.2-10 Leg and Foot Room

Sufficient leg and foot room should be provided to enable seated users to avoid awkward and uncomfortable positions. Figure 11.6 shows the dimensions involved and gives minimums and ranges necessary to accommodate the 5th percentile female and 95th percentile male, as defined in Table 11.1.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.2 Sit-Down Console Dimensions

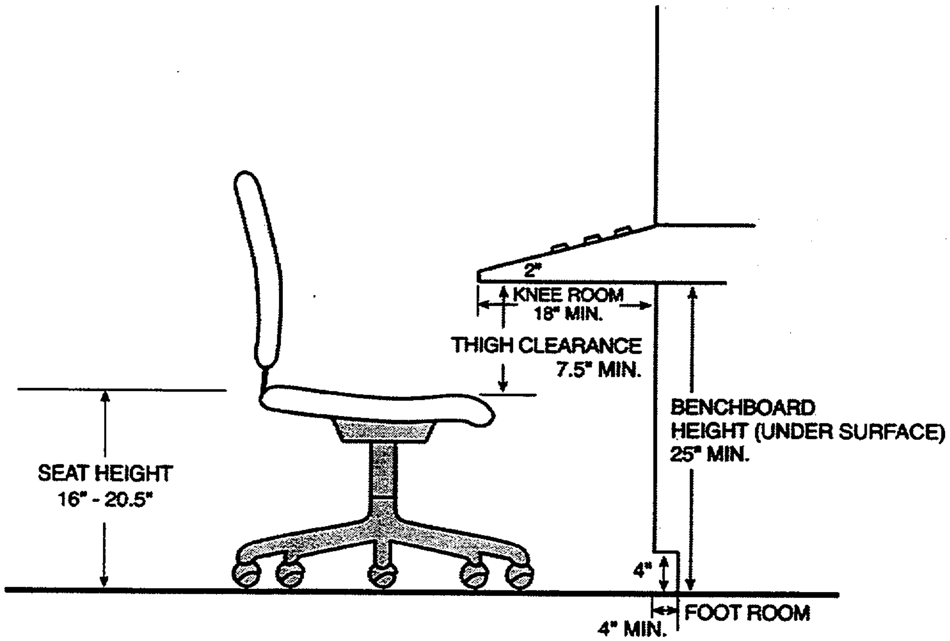


Figure 11.6 Leg- and foot-room dimensions

11.1.2-11 Writing Space on Consoles
If writing space is needed by users working at consoles, an area at least 16 inches deep and 24 inches wide should be provided, where these dimensions in the total configuration would fit users' reach capabilities.
Additional Information: Less space may be adequate considering the frequency and duration of writing requirements at control room consoles. If writing space is provided on the console itself, it should not interfere with viewing and manipulation of controls and displays. If writing is necessary but space on the console is not available, other arrangements such as a nearby desk or table should be provided.[0700]

11.1.2-12 Use of Procedures and Other Reference Materials at Consoles
Provision should be made so that the procedures, manuals, and other reference materials can be consulted easily while task sequences are performed at the consoles.
Additional Information: Lack of space in which to lay down procedures can encourage the poor practice of placing them on the console. A rolling bookcase is a convenient place for storing procedures and manuals and also provides space for laying down procedures during use.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.3 Sit-Stand Workstations

11.1.3-1 Appropriate Use
Sit-stand combinations should be used when users need mobility to monitor large panel areas but also need the stability of seated operation for precise task sequences.
Additional Information: This is especially true when such task sequences go on for fairly long periods and require sustained attention (e.g., reactor startup/shutdown).[0700]

11.1.3-2 Control and Display Positioning
The height and lateral limits for controls and displays should conform to the guidelines given for stand-up consoles (see Section 11.1.1, Stand-Up Console Dimensions).[0700]

11.1.3-3 Seat Height
The user should be provided with a high seat so that the seated eye height is approximately the same as standing eye height.[0700]

11.1.3-4 Knee Room
Knee room and comfortable foot support should be provided.[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.4 Vertical Panels

11.1.4-1 Control Height
Controls should be placed in an area between 34 inches and 70 inches above the floor. Controls requiring precise or frequent operation and emergency controls should be placed in an area between 34 inches and 53 inches above the floor (see Figure 11.7).[0700]

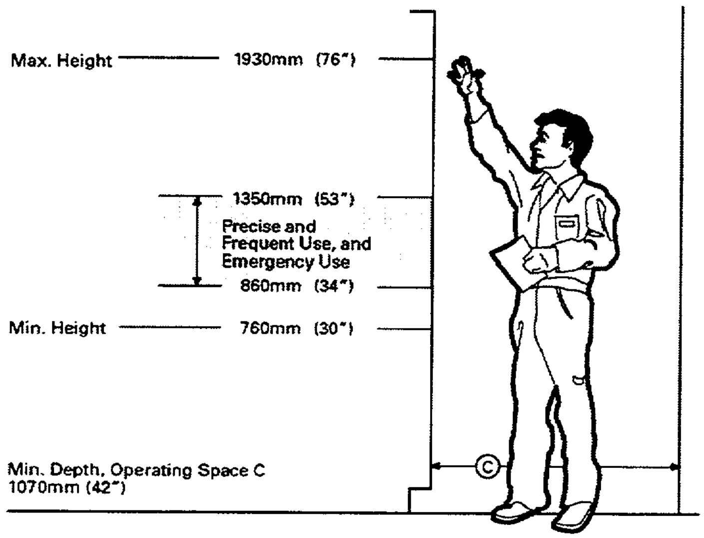


Figure 11.7 Control height

11.1.4-2 Display Height
Displays should be placed in an area between 41 inches and 70 inches above the floor. Displays that must be read frequently or precisely should be placed in an area between 50 inches and 65 inches above the floor (see Figure 11.8).[0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.4 Vertical Panels

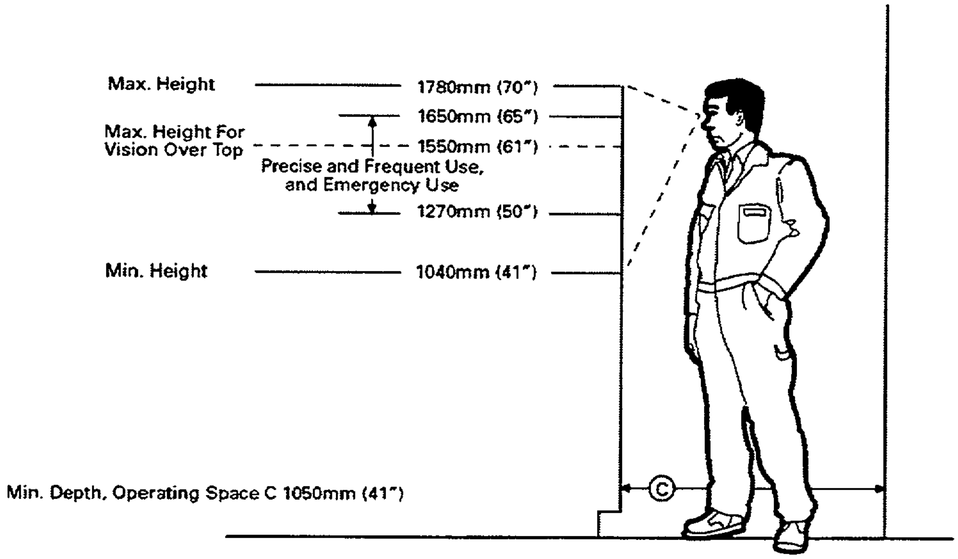


Figure 11.8 Display height

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.5 Desk Dimensions

11.1.5-1 Working Space
Desks should provide enough clear working space for all materials required for task performance.[0700]

11.1.5-2 Chair Positions
The desk should allow for different chair positions as required, with adequate knee space.[0700]

11.1.5-3 Comfort
The relationships of working surface height and area, knee room, and chair height should allow users to work comfortably.[0700]

11.1.5-4 Dimensions
Desk dimensions should conform to those shown in Figure 11.9.
Additional Information: Desk dimensions should be as follows:
- For seated work only, 26 to 31 inches above the floor (29 inches is a standard height)
- For sit-stand desks, 36 to 38 inches above the floor
- Work surface area depth should be 16 inches minimum
- Work surface area width should be 24 inches minimum if tasks involve reading and writing only; 30 inches minimum if other kinds of tasks are required
- For knee room height, a distance of approximately 25 inches from the floor to the under-surface of the desk top should provide adequate clearance for 5th to 95th percentile male and female adults at sit-down-only stations
- For knee room depth, 18 inches minimum
- Knee room width should be 20 inches (an even greater width is preferred) [0700]

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.5 Desk Dimensions

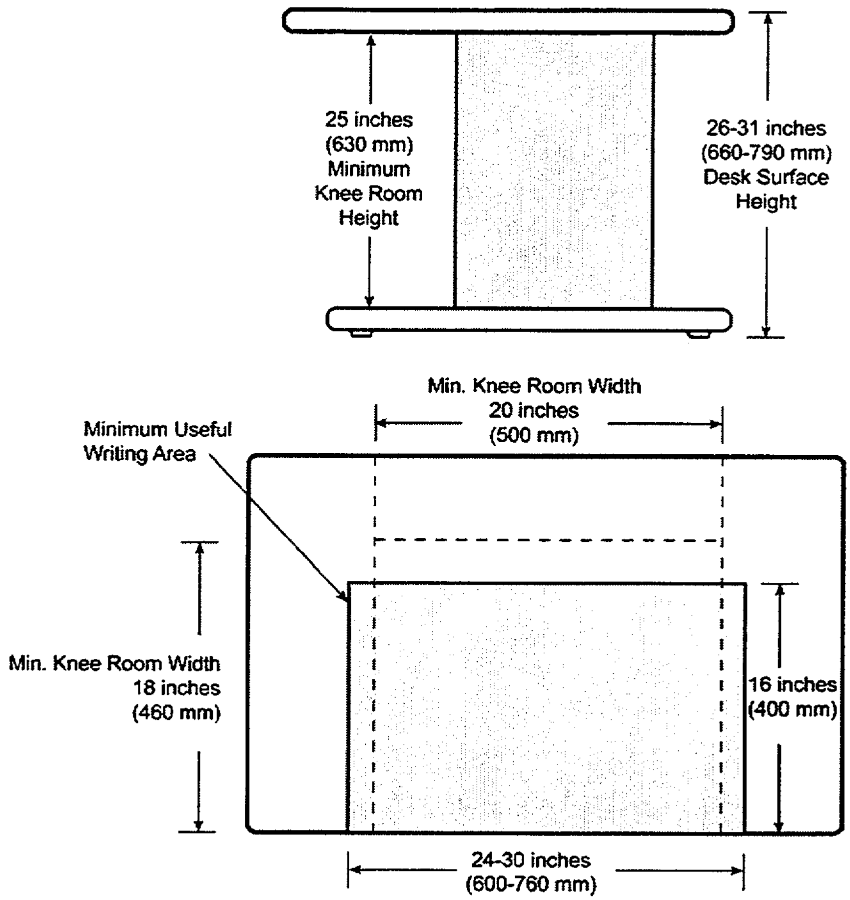


Figure 11.9 Recommended desk dimensions

11 WORKSTATION DESIGN
11.1 Workstation Configuration
11.1.6 Chairs

11.1.6-1 Mobility
Chairs should pivot so that operators can readily adjust position.
Additional Information: Mobile bases (casters) are recommended for chairs at sit-only stations.[0700]

11.1.6-2 Backrests
Chairs should support at least the lower back curvature (lumbosacral region).
Additional Information: The recommended angle between the back and the seat is about 100 degrees for office tasks (such as keyboard tasks). A greater angle is preferred for reading and resting.[0700]

11.1.6-3 Armrests
Where personnel may remain seated for relatively long periods, chairs with armrests should be provided.
Additional Information: Adjustable or retractable armrests may be necessary to allow the elbows to rest in a natural position and for compatibility with a particular desk/console.[0700]

11.1.6-4 Cushioning
The seat and backrest should be cushioned with at least 1 inch of compressible material, enough so that some resilience remains when the chair is occupied.[0700]

11.1.6-5 Seat Dimensions
The seat should be at least 18 inches wide and between 15 and 17 inches deep.
Additional Information: The thighs and the backs of the knees should not be compressed so as to cause fatigue and circulation problems.[5908, 0700]

11.1.6-6 Seat Adjustability
For chairs at sit-down stations, seat height should generally be adjustable from 16 to 20.5 inches. For chairs at sit-stand stations, seat height should be adjustable from 26 to 32 inches.[5908, 0700]

11.1.6-7 Footrests
An adjustable footrest or heel catch should be provided to support the feet at a level no more than 18 inches below the seat surface.
Additional Information: If a footrest is part of the chair, a circular design is recommended, diameter 18 inches. The footrest might be provided on the console base.[0700]

11 WORKSTATION DESIGN
11.2 Control and Display Device Layout
11.2.1 General Layout

11.2.1-1 Proximity
A visual display that will be monitored during control manipulation should be located sufficiently close that a user can read it clearly and without parallax from a normal operating posture.[0700]

11.2.1-2 Obscuration
Controls and displays should be located so that displays are not obscured during control operation. *Additional Information:* To avoid having the user's hand obscure the display, controls should be located below (see 'B' in Figure 11.10) the associated display. When this is not possible, the control should be located to the right of the display (see 'A' in Figure 11.10).

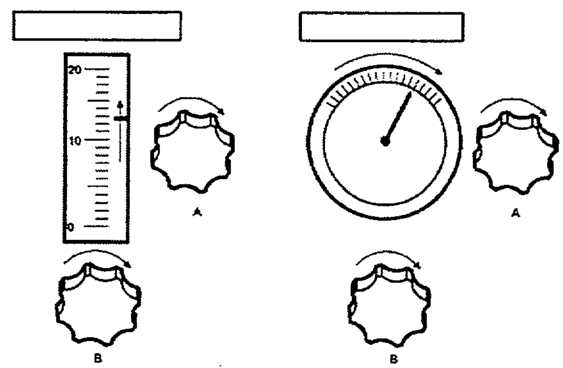


Figure 11.10 Position of control actuator and associated display

11.2.1-3 Association
Related controls and displays should be easily identified as being associated. *Additional Information:* This association can be established (or enhanced) by (1) location, (2) labeling, (3) coding, (4) demarcation, and (5) consistency with user expectations. The following relationships should be immediately apparent to the user: (1) association of displays with controls; (2) the direction of movement of control and display; and (3) the rate and limits of movement of the control and display. See Figure 11.11.[0700]

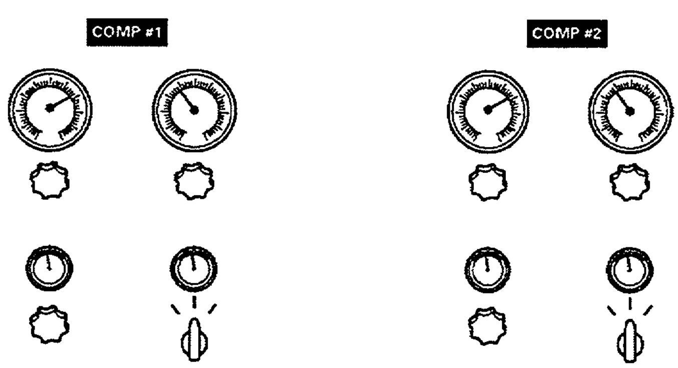


Figure 11.11 Association by grouping

11 WORKSTATION DESIGN
11.2 Control and Display Device Layout
11.2.2 Control-Display Integration
11.2.2.1 Multiple Controls, Single Display

11.2.2.1-1 Controls Mounted Below Display
Multiple controls should be mounted below the single display.[0700]

11.2.2.1-2 Alternative Control Position
If it is not feasible to mount multiple controls directly below the single display, controls should be mounted to the right of the display.[0700]

11.2.2.1-3 Controls Centered on Display
Multiple controls should be centered on the single display.[0700]

11.2.2.1-4 Grouping of Controls
Multiple controls should be grouped in a line or matrix.[0700]

11.2.2.1-5 Arrangement of Controls
Where there is a normal order of use, multiple controls should be arranged for use in left-to-right, top-to-bottom, or other natural sequence.[0700]

11.2.2.1-6 Enhancement of Control Layout
Layout enhancement techniques should be employed where the above techniques cannot apply, or where for other reasons the relationships are not readily apparent.[0700]

11 WORKSTATION DESIGN
11.2 Control and Display Device Layout
11.2.2 Control-Display Integration
11.2.2.2 Single Control, Multiple Displays

11.2.2.2-1 Displays Located Above Control
Multiple displays should be located above the single control.[0700]

11.2.2.2-2 Alternative Position for Displays
If it is not feasible to mount multiple displays above the single control, they should be mounted to the left of the control.[0700]

11.2.2.2-3 Control Centered Below Displays
The single control should be placed as near as possible to the display, and preferably underneath the center of the display array.[0700]

11.2.2.2-4 Grouping of Displays
Multiple displays should be arranged horizontally or in a matrix.[0700]

11.2.2.2-5 Arrangement of Displays
Where there is a normal order of use, multiple displays should read from left-to-right, top-to-bottom, or in other natural sequence.[0700]

11.2.2.2-6 Visibility During Control Manipulation
Multiple displays should not be obscured during control manipulation.[0700]

11.2.2.2-7 Enhancement of Display Layout
Layout enhancement techniques should be employed where the above techniques cannot apply, or where for other reasons the control-display relationship is not clearly apparent.[0700]

11.2.2.2-8 Display Selector Motion
The display selector control should move clockwise from OFF (if appropriate) through settings 1, 2, 3...n.[0700]

11.2.2.2-9 Display Selector Sequence
The display selector control position sequence should conform to the display sequence.[0700]

11.2.2.2-10 Display Selector Labeling
Display selector control position indications should correspond with display labels.[0700]

11.2.2.2-11 Display Selectors Scale
Displays should read off scale, not zero, when not selected, especially if zero is a possible parameter displayed.[0700]

11.2.2.3-1 Rotary Controls

Rotary controls should turn clockwise to cause an increase in parameter value. Associated display movements should be: (1) analog scales, up or to the right; (2) digital displays, increasing in value; (3) strings of indicator lights, bottom-to-top or left-to-right; and (4) circular meter pointers, clockwise.[0700]

11.2.2.3-2 Linear Controls

Linear controls should move up or to the right to cause an increase in parameter value. The associated display relationships should be: (1) analog scales, up or to the right; (2) digital displays, increasing in value; and (3) strings of indicator lights, bottom-to-top or left-to-right.[0700]

11.2.2.3-3 Display Response Time Lag

When there is a time lag between control actuation and ultimate system state, there should be an immediate feedback indication of the process and direction of parameter change.
Additional Information: In some cases, there will be a time lag between the actuation of a control and the resulting change in system condition. That condition should be reflected by displays in real time.[0700]

11.2.2.3-4 Precision of Control

Controls should provide a capability to affect the parameter controlled easily, with the required level of precision.
Additional Information: They should be effective in sufficient time, under expected dynamic conditions, and within the limits of manual dexterity, coordination, and reaction time.[0700]

11.2.2.3-5 Resolution of Display

Displays should provide a capability to distinguish significant levels of the system parameter controlled.[0700]

11.2.2.3-6 Excess Precision

The precision of displays and controls should not greatly exceed that required.[0700]

11.2.2.3-7 Feedback

Feedback from the display should be apparent for any deliberate movement of a control.[0700]

11.2.3-1 Functional Grouping
Multiple controls or displays related to the same function should be grouped together.[0700]

11.2.3-2 Sequence of Use
Sequence of use should be as follows: (1) left to right, (2) top to bottom, or (3) the above combined (normal reading order).[0700]

11.2.3-3 Display Above Each Control
The preferred configuration is with the display above each control.
Additional Information: If this configuration is used, the following should apply: (1) each display should be located directly above its associated control; and (2) the display/control pairs should be arranged in rows.[0700]

11.2.3-4 Controls and Displays in Rows
Displays may be arrayed in rows as the upper portion of a panel, matched to controls arrayed in similar rows below (see Figure 11.12).
Additional Information: Each control should occupy the same relative position as the display to which it is associated. Controls and displays should have corresponding labels.[0700]

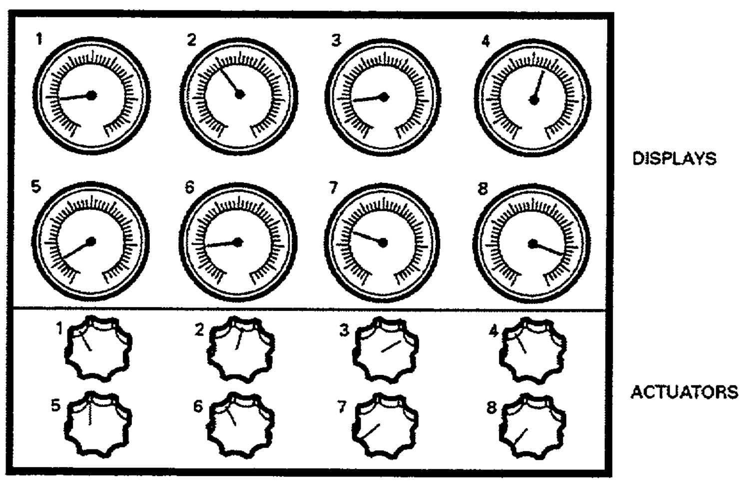


Figure 11.12 Controls and displays in rows

11.2.3-5 Multi-Row Displays with Single-Row Controls
Two or more rows of displays may be arranged above a single row of controls (see Figure 11.13).
Additional Information: Displays should be ordered left to right and top to bottom (in normal reading order), and matched to controls ordered left to right. Controls and displays should have corresponding labels.[0700]

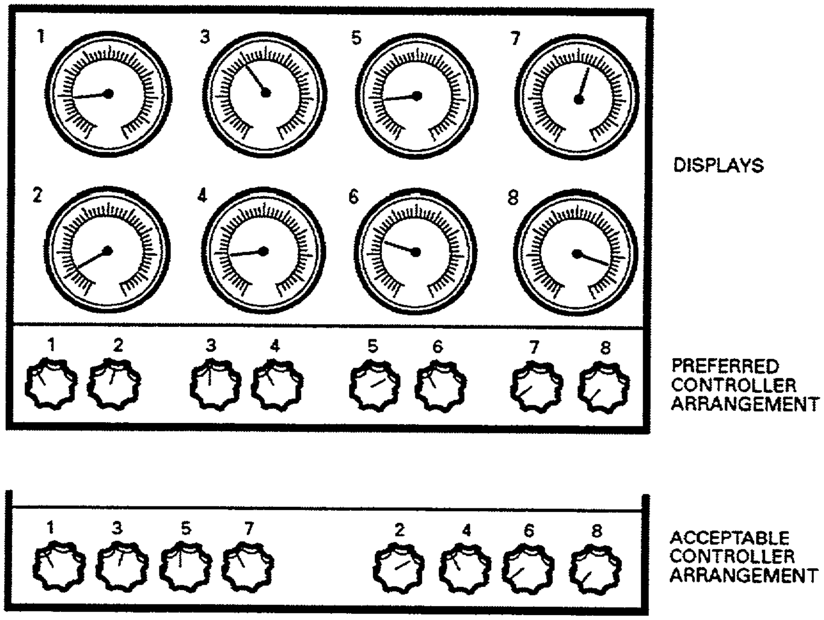


Figure 11.13 Two rows of displays with a single row of controls

11.2.3-6 Consistent Practice
Arrangements of functionally similar controls and displays should conform to the same convention throughout the control room.[0700]

11.2.3-7 Control/Display Packages
Modules should be selected and arranged to achieve maximum conformity with the principles described above.
Additional Information: When controls and related displays are assembled using modular packaged units, the design of the packages will limit the location and arrangement that can be achieved.[0700]

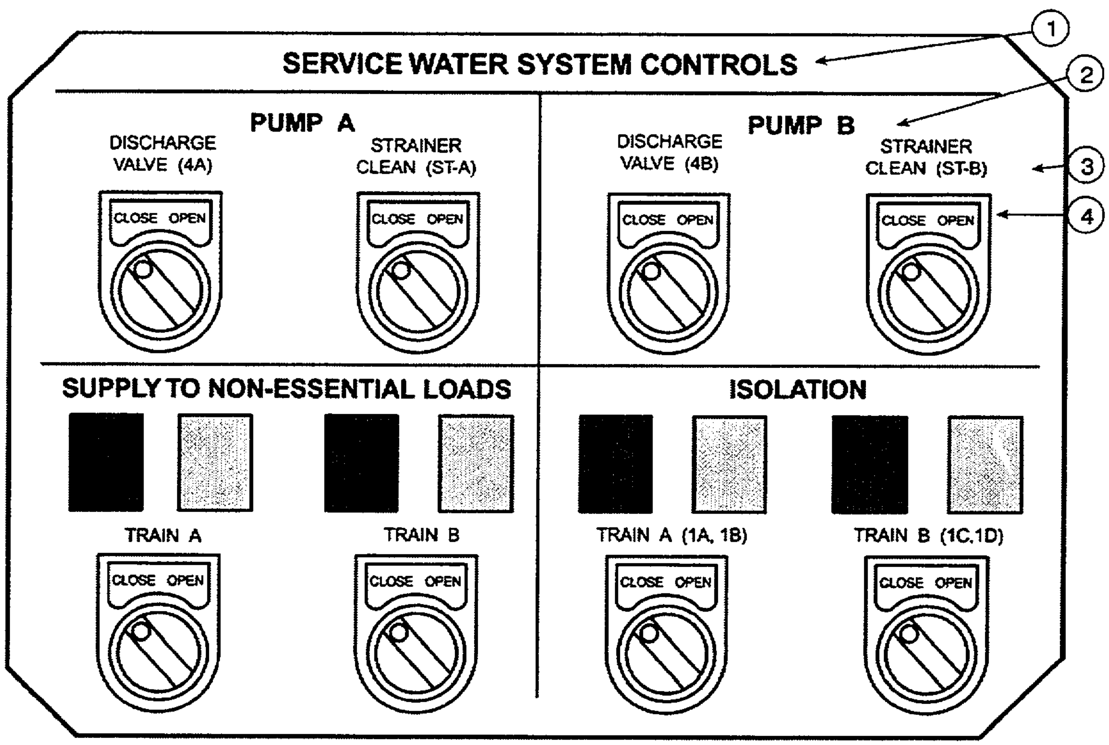
11.2.3-8 Separated Controls and Displays
Where displays are on separated panels, they should be on the adjacent upper panel from their associated controls.[0700]

11.2.3-9 Facing Panels
Related controls and displays should not be located on separate panels that face each other.[0700]

11 WORKSTATION DESIGN
11.3 Labeling and Demarcations
11.3.1 Labels
11.3.1.1 Labeling Principles

11.3.1.1-1 Need for Labeling
Controls, displays, and other equipment items that must be located, identified, or manipulated should be appropriately and clearly labeled to permit rapid and accurate human performance.[0700]

11.3.1.1-2 Hierarchical Scheme
A hierarchical labeling scheme should be used to reduce confusion, search time, and redundancy. *Additional Information:* See Figure 11.14.[0700]



Label Designation and Location

1. System/workstation label, centered near top edge of panel
2. Subsystem/functional label, centered near top of subsection
3. Component label, above component display or control
4. Control position indicator, near control

Figure 11.14 Example of good panel labeling (numerals correspond to numbered items at bottom of figure)

11.3.1.1-3 Content of Hierarchical Labels
Major labels should be used to identify major systems or workstations, subordinate labels should be used to identify subsystems or functional groups, and component labels should be used to identify each discrete panel or console element.
Additional Information: Labels should not repeat information contained in higher-level labels.[0700]

11.3.1.1-4 Letter Size in Hierarchical Labels
Labels should be graduated in letter size such that system/work station labels are about 25 percent larger than subsystem/functional group labels, subsystem/functional group labels are about 25 percent larger than component labels, and component labels are about 25 percent larger than control position labels.[0700]

11 WORKSTATION DESIGN
11.3 Labeling and Demarcations
11.3.1 Labels
11.3.1.2 Label Location

11.3.1.2-1 Normal Placement
Labels should be placed above the panel element(s) they describe.[0700]

11.3.1.2-2 Panel Labeling
The placement of labels on control panels should conform to the principles in Section 11.3.1.1, Labeling Principles.
Additional Information: See Figure 11.12.[0700]

11.3.1.2-3 Labeling Elements Above Eye Level
Labels for elements located above eye level should be positioned to ensure label visibility.[0700]

11.3.1.2-4 Proximity
Labels should be placed close to the panel element.[0700]

11.3.1.2-5 Labels on Controls
Labels should not appear on the control itself when an adjustment or manipulation is required that causes the user's hand to obscure the label for an extended time period.[0700]

11.3.1.2-6 Adjacent Labels
Adjacent labels should be separated by sufficient space so that they are not read as one continuous label.[0700]

11.3.1.2-7 Integrity
Labels should be mounted in such a way as to preclude accidental removal.[0700]

11.3.1.2-8 Surface
Labels should be mounted on a flat surface.[0700]

11.3.1.2-9 Horizontal Orientation
Labels should be oriented horizontally so that they may be read quickly and easily from left to right.
Additional Information: Although not normally recommended, vertical orientation may be used only where space is limited.[0700]

11.3.1.2-10 Curved Patterns
Curved patterns of labeling should be avoided.[0700]

11.3.1.2-11 Other Information Sources
Labels should not cover any other information source or detract from or obscure figures or scales that must be read by the user.[0700]

11.3.1.2-12 Concealment
Labels should not be covered or obscured by other units in the equipment assembly.[0700]

11.3.1.2-13 Controls
Labels should be visible to the user during control actuation.[0700]

11 WORKSTATION DESIGN
11.3 Labeling and Demarcations
11.3.1 Labels
11.3.1.2 Label Location

11.3.1.2-14 Cleaning
Administrative procedures should be in place for the periodic cleaning of labels.[0700]

11 WORKSTATION DESIGN

11.3 Labeling and Demarcations

11.3.1 Labels

11.3.1.3 Label Content

11.3.1.3-1 Principal Function

Labels should describe the function of equipment items.
Additional Information: If needed for clarity, engineering characteristics or nomenclature may also be described.[0700]

11.3.1.3-2 Wording of Instruction Labels

The label should briefly and simply express the intended action.
Additional Information: Words on labels should be concise and still convey the intended meaning. Label text should not be so brief that its meaning is not clear to operating personnel. Instructions should be clear and direct.[0700]

11.3.1.3-3 Commonly Used Terms and Symbols

Terms, abbreviations, and symbols used on panel labels should have commonly accepted meanings for all intended users.
Additional Information: Unusual technical terms should be avoided. Use of Roman numerals should be avoided. Words should be spelled correctly. Abstract symbols should be used only if they have a commonly accepted meaning (e.g., %).[0700]

11.3.1.3-4 Distinguishability

Symbols should be unique and distinguishable from each other.
Additional Information: A commonly accepted standard configuration should be used.[0700]

11.3.1.3-5 Consistency

Labels should be consistent within and across panels in their use of words, acronyms, abbreviations, and part/system numbers.[0700]

11.3.1.3-6 Agreement with Procedures

There should be no mismatch between nomenclature used in procedures and that printed on the labels.[0700]

11.3.1.3-7 Administrative Control

A list of standard names, acronyms, abbreviations, and part/system numbers should be in place and administratively controlled.[0700]

11.3.1.3-8 Label Similarity

Words and abbreviations of similar appearance should be avoided where an error in interpretation could result.
Additional Information: When labels containing similar words, abbreviations, or acronyms are located in close proximity to each other, different words should be selected or means of coding should be used to reduce the probability of selecting the wrong control or reading the wrong display.[0700]

11.3.1.3-9 Functional Relationship

Labels should be used to identify functionally grouped controls or displays.[0700]

11.3.1.3-10 Label Location

Labels should be located above the functional groups they identify.[0700]

11 WORKSTATION DESIGN
11.3 Labeling and Demarcations
11.3.1 Labels
11.3.1.3 Label Content

11.3.1.3-11 Control Position Labels
All discrete functional control positions should be identified.[0700]

11.3.1.3-12 Direction
Direction of motion (increase, decrease) should be identified for continuous motion rotary controls.[0700]

11.3.1.3-13 Visibility
Control position information should be visible to the user during operation of the control.[0700]

11.3.1.3-14 Access Opening Labeling
Access openings should be labeled to identify the functions of items accessible through them.[0700]

11.3.1.3-15 Danger, Warning, and Safety Instruction Labels
All danger, warning, and safety instruction labels should be in accordance with appropriate safety standards.[0700]

11.3.1.4 Temporary Labels and Tagouts

11.3.1.4-1 Necessity
Temporary labels should be used only when necessary.
Additional Information: If used, temporary labels should conform to good human engineering principles (see Guidelines 11.3.1.4-2 to 11.3.1.4-9).[0700]

11.3.1.4-2 Visibility
Temporary labels should not obscure prior permanent labels unless the old label is to be replaced.[0700]

11.3.1.4-3 Identification
Tag-out labels should clearly identify out-of-service components and equipment.[0700]

11.3.1.4-4 Mounting
Tag-outs should be securely affixed.[0700]

11.3.1.4-5 Obscuration
Tag-outs should not obscure the label associated with the non-operable device.[0700]

11.3.1.4-6 Activation
Tag-outs should be designed to physically prevent actuation of a control.[0700]

11.3.1.4-7 Adjacent Devices
Tag-outs should not obscure any adjacent devices or their associated labels.[0700]

11.3.1.4-8 Administrative Procedures
The use of temporary labels should be administratively controlled.[0700]

11.3.1.4-9 Review Procedures
The use and control of temporary labels should be periodically reviewed.
Additional Information: A review procedure should determine:
- when temporary labels are needed
- how they will be used
- content (given human engineering requirements)
- installation
- impact of their use on other system equipment (e.g., annunciators, mimics)
- documentation requirements
- re-training requirements
- their periodic review
- their removal. [0700]

11.3.1.5-1 Character Height

Character height should subtend a visual angle of 15 minutes (viewing distance multiplied by 0.004) as a minimum; a visual angle of 20 minutes (viewing distance multiplied by 0.006) is preferred.
Additional Information: Letter height should be identical for all labels within the same hierarchical level, based on the maximum viewing distance.[0700]

11.3.1.5-2 Contrast

Colors should be chosen for maximum contrast against the label background.
Additional Information: Table 11.2 rates various color combinations in terms of relative legibility. To ensure adequate contrast and prevent loss of readability because of dirt, dark characters should be provided on a light background. If colored print is used for coding purposes, it should conform to the established color coding scheme for the control room (see Section 1.3.8, Color).[0700]

Table 11.2 Relative legibility of color combinations

Legibility Rating	Color Combination
Very good	Black letters on white background
Good	Black on yellow
	Dark blue on white
	Grass green on white
Fair	Red on white
	Red on yellow
	White on black
Poor	Green on red
	Red on green
	Orange on black
	Orange on white

11.3.1.5-3 Character Selection

Labels should be prepared in capital letters with letters and numerals without flourishes or serifs.[0700]

11.3.1.5-4 Character Width

Letter width-to-height ratio should be between 1:1 and 3:5. Numeral width-to-height ratio should be 3:5 except for the numeral "4," which should be one stroke width wider, and the numeral "1," which should be one stroke in width.[0700]

11 WORKSTATION DESIGN
11.3 Labeling and Demarcations
11.3.1 Labels
11.3.1.5 Label Lettering

11.3.1.5-5 Stroke Width
Stroke width-to-character height ratio should be between 1:6 and 1:8.[0700]

11.3.1.5-6 Spacing
The minimum space between characters should be one stroke width. The minimum space between words should be one character width. The minimum space between lines should be one-half of the character height.[0700]

11.3.2-1 Use
Lines of demarcation can be used to enclose functionally related controls and displays, and group related controls and displays (see Figure 11.15).[0700]

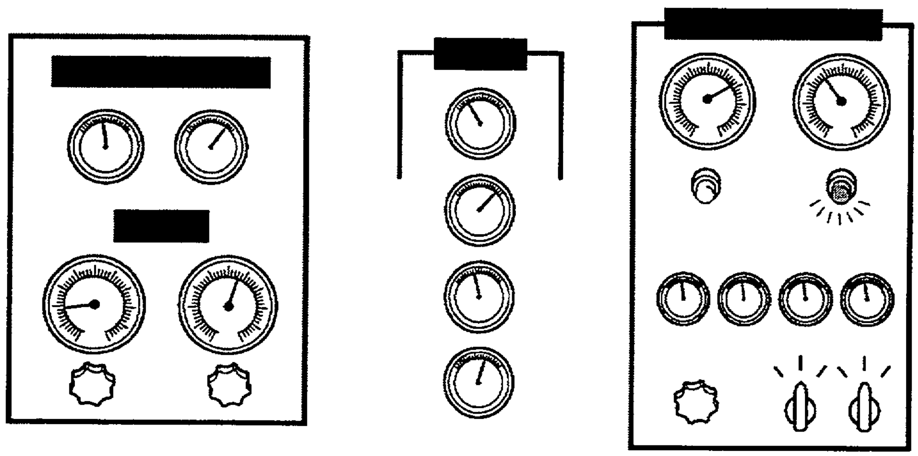


Figure 11.15 Demarcation lines

11.3.2-2 Contrast
Lines of demarcation should be visually distinctive from the panel background.[0700]

11.3.2-3 Permanence
Lines of demarcation should be permanently attached.[0700]

11.3.2-4 Consistency
The color coding scheme should be used consistently throughout the control room.
Additional Information: Refer to the guidelines in Section 1.3.8, Color, for specific recommendations on the use of color.[0700]

11.3.2-5 User Expectations
Color should be dedicated to specific functions or conditions throughout the control room in order for the code to elicit the expected user response.
Additional Information: Refer to the guidelines in Section 1.3.8, Color, for specific recommendations on the use of color.[0700]

11 WORKSTATION DESIGN
11.4 Panel Layout
11.4.1 General Panel Layout

11.4.1-1 Grouping by Task
Controls and displays should be assigned to work stations based on the tasks the user must carry out.
Additional Information: To the extent practical, this assignment should consider both normal and emergency procedures. It should be practical to perform all frequently occurring routine tasks, and time-sensitive emergency tasks, with a minimum of movement from panel to panel.[0700]

11.4.1-2 Grouping by System Function
Within the constraints of grouping by task sequence, controls and displays should be assigned to panels in functional groups related to system structure.
Additional Information: This grouping should promote easy understanding of the relationship between controls and system, and should assist graphic or pictorial display of system relationships.[0700]

11.4.1-3 Grouping by Importance and Frequency of Use
Controls and displays should be assigned to panels depending on their importance and frequency of use, within the constraints of grouping by task sequence and system function.[0700]

11.4.1-4 Less Important Controls/Displays
Controls or displays that are neither important to plant safety nor frequently used should be installed in ancillary panel locations.[0700]

11.4.1-5 Spacing
Spacing between groups should be at least the width of a typical control or display in the group.
Additional Information: Spacing consists of physically separating groups of components on a panel with enough space between groups so that the boundaries of each group are obvious.[0700]

11.4.1-6 Color Shading
When color shading is used, colors should provide adequate contrast and should be consistent with other color coding in the control room.
Additional Information: This practice is also known as 'color padding' or 'color blocking' (see Figure 11.16).[0700]

11.4.1-7 Emergency Controls
Distinctive techniques should be used to enhance the recognition and identification of emergency controls.
Additional Information: For example, a unique style of demarcation or color shading might be applied exclusively to emergency controls.[0700]

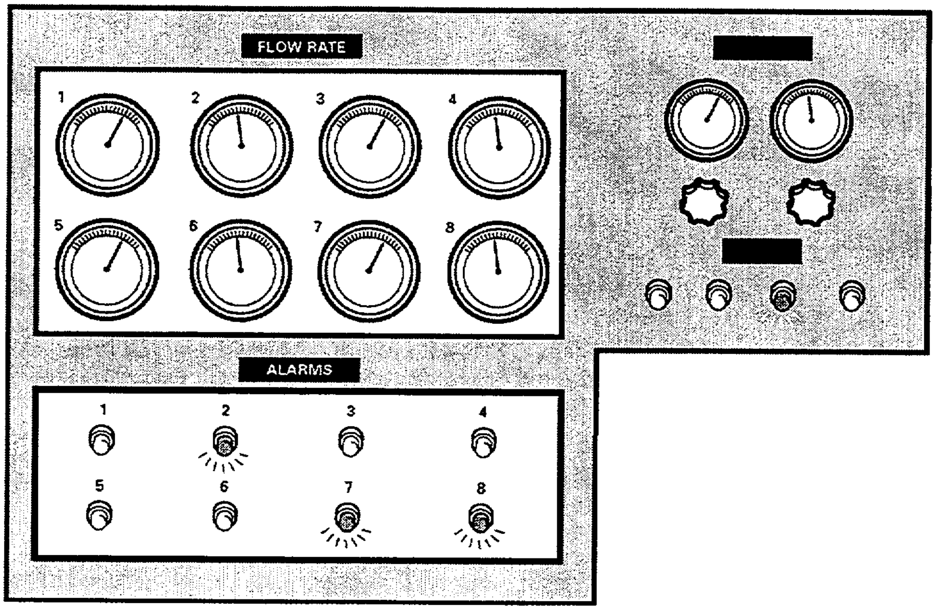


Figure 11.16 Color shading

11.4.2-1 Sequence
Controls and displays should be grouped together when they are observed/operated in a specified sequence.
Additional Information: Controls and displays should be positioned so that they are normally used in a left-to-right, top-to-bottom, or other natural sequence.[0700]

11.4.2-2 Frequency of Use
Frequently used controls and displays should be near the center of the preferred visual and manual areas.[0700]

11.4.2-3 Functional Considerations
Functionally related controls and displays should be grouped together when they are used together to perform tasks related to a specific function or are identical in purpose.[0700]

11.4.2-4 Order and Labeling
Components should be arranged left-to-right and/or top-to-bottom and identified in alphabetic or numeric sequence.
Additional Information: For example, four related displays in a row should be designated A,B, C, D or 1, 2, 3, 4; correspondingly, any controls related to these displays should also be designated A, B, C, D and 1, 2, 3, 4.[0700]

11.4.2-5 Other Expectations
Components should be arranged to match other user expectations when these can be identified.
Additional Information: Well-designed system mimics will help direct and satisfy user expectations.[0700]

11.4.2-6 Inter- and Intra-Panel Consistency
The location of arrangement of recurring functional groups and individual components of those groups should be similar from panel to panel or within a panel.[0700]

11.4.2-7 Repeated Functions
The layout of identical control or display sets should be consistent at all locations.[0700]

11.4.2-8 Mirror-Imaging
Layouts of repeated functions should not be mirror-imaged (see Figure 11.17).[0700]

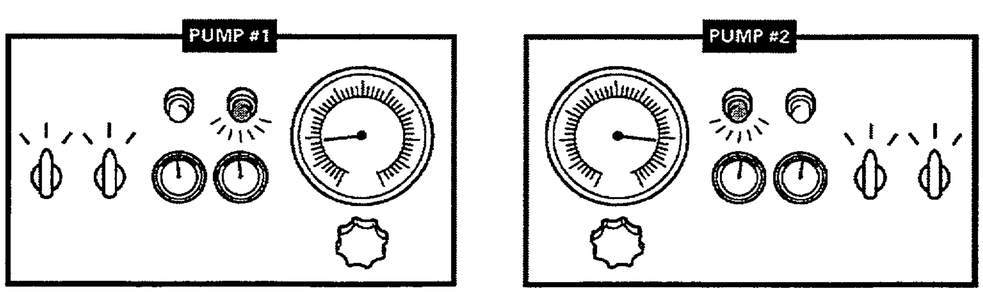


Figure 11.17 Example of a mirror-image arrangement of controls and displays

11.4.2-9 Panel-to-Panel Standardization
Standardization should be maintained where similar functions or panels are located at several workstations or units.[0700]

11.4.2-10 Simulator-to-Control Room Standardization
Standardization should be maintained where simulator or procedures trainers are used that simulate the actual operational equipment.[0700]

11.4.3-1 Access
Control access should not be impeded by any position of an adjacent control.
Additional Information: Recommended minimum separation distances for controls are shown in Table 11.3 and Figure 11.18. In most cases, control room operations will require greater separation.[0700]

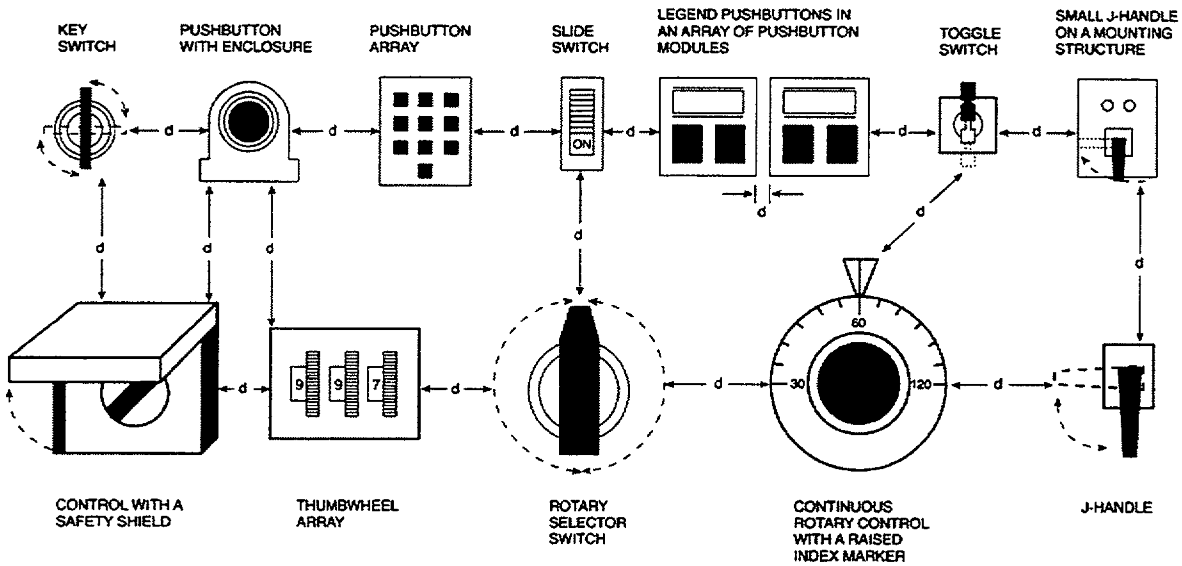


Figure 11.18 Measurement of minimum separation between controls (distances shown in Table 11.3)

11.4.3-2 Inadvertent Actuation
Control actuation should not result in inadvertent actuation of an adjacent control.[0700]

11.4.3-3 Simultaneous Actuation
It should be possible to simultaneously actuate adjacent controls (where required).[0700]

11.4.3-4 Orientation
Horizontal rows of displays should be used rather than vertical columns.[0700]

11.4.3-5 String Length
Strings of similar small displays should not exceed 20 inches on the control board.[0700]

11.4.3-6 Number of Components
No more than five similar components should be laid out in an unbroken row or column.
Additional Information: If more than five similar components must be laid out together, the string or cluster should be broken up by techniques such as physical spacing or demarcation.[0700]

11.4.3-7 Coordinate Axes for Matrices

Large matrices of similar components should have the coordinate axes labeled for identification of any single component within the grid.[0700]

11.4.3-8 Labeling Large Matrices

The left and top sides of large matrices should be used for labeling.[0700]

11.4.3-9 Demarcation of Large Matrices

Large matrices should be subdivided by appropriate demarcation.[0700]

Table 11.3 Minimum separation distances for controls (see Figure 11.18)

Controls	Minimum Separation in inches and (mm)										
	Key-Operated Controls	Pushbuttons	Pushbutton Arrays	Legend Switches	Slide Switches, Rocker Switches	Toggle Switches	Thumb-wheels	Rotary Selector Switches	Continuous Rotary Controls	J-Handles (large)	J-Handles (small)
Key-operated Controls	1.0 (25)	0.5 (13)	1.5 (38)	1.0 (25)	0.75 (19)	0.75 (19)	0.5 (13)	0.75 (19)	0.75 (19)	5.0 (127)	2.0 (50)
Pushbuttons	0.5 (13)	0.5 (13)	2.0 (50)	2.0 (50)	0.5 (13)	0.5 (13)	0.5 (13)	0.5 (13)	0.5 (13)	6.0 (152)	3.0 (76)
Pushbutton Arrays[1]	1.5 (38)	2.0 (50)	2.0 (50)	2.0 (50)	1.5 (38)	1.5 (38)	1.5 (38)	2.0 (50)	2.0 (50)	6.0 (152)	3.0 (76)
Legend Switches[2]	1.0 (25)	2.0 (50)	2.0 (50)	2.0 (50)	1.5 (38)	1.5 (38)	1.5 (38)	2.0 (50)	2.0 (50)	6.0 (152)	3.0 (76)
Slide Switches, Rocker Switches	0.75 (19)	0.5 (13)	1.5 (38)	1.5 (38)	0.5 (13)	0.75 (19)	0.5 (13)	0.5 (13)	0.5 (13)	5.0 (127)	2.0 (50)
Toggle Switches	0.75 (19)	0.5 (13)	1.5 (38)	1.5 (38)	0.75 (19)	0.75 (19)	0.5 (13)	0.75 (19)	0.75 (19)	6.0 (152)	3.0 (76)
Thumbwheels	0.5 (13)	0.5 (13)	1.5 (38)	1.5 (38)	0.5 (13)	0.5 (13)	0.5 (13)	0.75 (19)	0.75 (19)	5.0 (127)	2.0 (50)
Rotary Selector Switches	0.75 (19)	0.5 (13)	2.0 (50)	2.0 (50)	0.5 (13)	0.75 (19)	0.75 (19)	1.0 (25)	1.0 (25)	5.0 (127)	2.0 (50)
Continuous Rotary Controls	0.75 (19)	0.5 (13)	2.0 (50)	2.0 (50)	0.5 (13)	0.75 (19)	0.75 (19)	1.0 (25)	1.0 (25)	5.0 (127)	2.0 (50)
J-Handles (large)	5.0 (127)	6.0 (152)	6.0 (152)	6.0 (152)	5.0 (127)	6.0 (152)	5.0 (127)	5.0 (127)	5.0 (127)	3.0 (76)	5.0 (127)
J-Handles (small)	2.0 (50)	3.0 (76)	3.0 (76)	3.0 (76)	2.0 (50)	3.0 (76)	2.0 (50)	2.0 (50)	2.0 (50)	5.0 (127)	1. 0

[1] Pushbuttons within an array, 0.75 inches center-to-center.

[2] Legends switches within an array, no minimum distance, but should be separated by a barrier. Barrier should be at least 0.125 inches wide, 0.183 inches high, with rounded edges. Legend switches manufactured as elements of a module or modular array may be mounted as closely as engineering consideration permit. Toggle switches arrayed in a horizontal line, 0.75 inches center-to-center.

SECTION 12: WORKPLACE DESIGN

12 WORKPLACE DESIGN

Workplaces are facilities that house workstations and other task-support equipment and provide the environment in which personnel perform their tasks, e.g., the main control room, remote shutdown station, and local control stations.

CONTROL ROOM

Two important aspects of a control room are its configuration (i.e., the arrangement of workstations and other equipment within it) and its environment. The important characteristics of each are described below. Many of these characteristics are also applicable to other workplaces, such as the remote shutdown station, technical support center, and emergency operations facility.

Control Room Configuration

Control room configuration refers to the overall layout and arrangement of the control room; it comprises the following factors:

Accessibility of instrumentation/equipment

Accessibility refers to the ease with which control room personnel can gain access to needed instrumentation and equipment. Any instrumentation and equipment needed by control room personnel for detecting abnormal conditions and shutting down the plant, but which are not located inside the control room, should be identified. Similarly, the controls and displays required for continuous monitoring and the timing of control actions that are not located in the primary operating area of the control room should be identified. Review guidelines are provided in Section 12.1.1.1.

Consistency of staffing with equipment layout

This refers to factors that may affect the adequacy of personnel staffing levels, including: the ability of control room personnel to monitor and operate all necessary controls, displays, and other equipment during all modes of plant operation (e.g., consistency of the control room layout with staffing levels and task assignments); the ability of additional onsite or offsite personnel to augment the normal crew complement under certain unusual conditions, such as refueling (e.g., consistency of control room layout with anticipated activities and task assignments); the ability to limit access and movement of nonessential but authorized personnel to prescribed areas within the control room (e.g., adequate designations of prescribed areas; doors, gates, and other physical barriers). Review guidelines are provided in Section 12.1.1.2.

Furniture, instrumentation and equipment layout

The arrangement of furniture, instrumentation, and equipment in the control room that might affect the operators' requirements for viewing, communication, accessibility, and movement. Review guidelines are provided in Section 12.1.1.3.

Document organization and storage

Review guidelines are provided in Section 12.1.1.4 for the availability, storage, and accessibility of procedures and other documents needed for ready reference.

Spare parts, operating expendables, and tools

Guidelines provided in Section 12.1.1.5 address the availability, storage, and accessibility of spare parts, operating expendables, and tools needed by personnel.

Supervisor access

The accessibility of the shift supervisor's office by walking and communication links is addressed by review guidelines in Section 12.1.1.6.

Multiunit control rooms

The characteristics of multi-unit control rooms that may affect personnel performance include whether or not the control room has a mirror-image design, design factors that distinguish the operating units, equipment layout that might affect personnel movement and communication. Review guidelines are provided in Section 12.1.1.7.

Emergency equipment and protective clothing

If personnel are required to wear protective clothing in the workplace, then this clothing should be considered, along with warning systems that signal the need for its use, and storage for protective clothing. Review guidelines are provided in Section 12.1.1.8.

Personal storage

Provisions for storing personal items (e.g., coats and other belongings) can help maintain a clutter-free work environment. Storage places, including those located outside on the control room such as lockers, should be addressed. Review guidelines are provided in Section 12.1.1.9.

Ambience and comfort

Eating, restroom, and lounge facilities contribute to the operators' comfort, health, and performance. Review guidelines are provided in Section 12.1.1.10.

Control Room Environment

Environmental factors that can have important effects on operators' performance include thermal comfort, illumination, the auditory environment, and facility layout.

Thermal comfort

Thermal comfort includes temperature, humidity, and ventilation. Guidelines for these topics are provided in Sections 12.1.2.1 and 12.1.2.2.

Illumination

Illumination encompasses general illumination levels (i.e., for the main operating area and auxiliary areas) and specific levels for particular areas, such as workstations, individual control and display devices, and areas used for reading and writing; emergency lighting systems intended for special operating conditions are also included. Review guidelines for general control room illumination are provided in Section 12.1.2.3; guidelines for emergency lighting are in Section 12.1.2.4.

Auditory environment

The auditory environment includes the background noise level and the reverberation and sound absorption characteristics of the workplace. Review guidelines for the control room environment are provided in Section 12.1.2.5.

LOCAL CONTROL STATIONS

A local control station is a place outside of the main control room where operators interact with the plant. Local control stations may include multifunction workstations and panels, as well as operator interfaces, such as controls (e.g., valves, switches, and breakers) and displays (e.g., meters and VDUs). They have many characteristics in common with the main control room. However, they may also have unique characteristics when located in environments that are not as controlled as the main control room. For example, local control stations may have higher levels of background noise and more demanding conditions for use than the main control room. Accordingly, they may have a diverse range of communication media, such as loudspeakers, public address/pager stations, and two-way communication systems (e.g., telephones and walkie-talkies). In addition, these media may have special administrative controls that regulate their use. Review guidelines for local control stations are provided in Section 12.2.

12 WORKPLACE DESIGN

12.1 Control Room

12.1.1 Control Room Configuration

12.1.1.1 Accessibility of Instrumentation/Equipment

12.1.1.1-1 Present in the Control Room
Control room instrumentation and equipment should include all controls and displays needed for (1) detection of abnormal conditions, and (2) bringing the plant to a safe shutdown condition.[0700]

12.1.1.1-2 Arranged to Facilitate Coverage
Users should not have to leave their principal work areas to attend to instrumentation on back panels during operational sequences in which continuous monitoring or the timing of control actions may be critical.[0700]

12 WORKPLACE DESIGN

12.1 Control Room

12.1.1 Control Room Configuration

12.1.1.2 Consistency of Staffing with Equipment Layout

12.1.1.2-1 Coverage
Control room staffing and task assignments should ensure complete and timely coverage of controls, displays, and other equipment required during all modes of operation.[0700]

12.1.1.2-2 Utilization of Additional Personnel
When additional onsite or offsite personnel are needed to augment the normal crew complement under certain conditions (e.g., refueling), activities, and task assignments should be planned to ensure proper coordination.
Additional Information: Special training for this situation may be required.[0700]

12.1.1.2-3 Nonessential Personnel
Provision should be made to limit the access and movement of nonessential but authorized personnel to prescribed areas within the control room.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.3 Furniture and Equipment Layout

12.1.1.3-1 Viewing
Desks and consoles should permit users at those desks and consoles full view of all control and display panels (including alarm displays) in the main control room.
Additional Information: Placement and spacing of equipment depends on control room configuration, staffing, and other design features. Thus, guidelines are stated in terms of minimum spacing considerations for common equipment arrangements and use situations. Maintenance and testing of equipment has not been considered, and may require larger clearances than the minimums suggested.[0700]

12.1.1.3-2 Communications
Desk and console placement should facilitate voice communications from users seated at those workstations to any point in the main operating area.[0700]

12.1.1.3-3 Access to Workstations
Users should be able to get to any workstation without having to overcome obstacles such as tripping hazards, poorly positioned filing cabinets or storage racks, and maintenance equipment.
Additional Information: Users should be able to position themselves conveniently for performing task actions at any work station.[0700]

12.1.1.3-4 Circulation Patterns
The control room arrangement should facilitate efficient, unobstructed movement and communication.
Additional Information: The control room arrangement should minimize interference between the members of the operational crew.[0700]

12.1.1.3-5 Maneuvering Space
Adequate space should be allowed between the back (user's position) of a desk or console and any surface or fixed object behind the user for the user to get into and out of a chair freely or to turn in the chair to view the equipment behind.
Additional Information: A minimum separation of 36 inches from the back of any desk to any opposing surface is suggested as the minimum (see Figure 12.1). A greater separation is preferable. Lateral space for a seated user should be no less than 30 inches; greater latitude is preferable. Placement and spacing of equipment depends on control room configuration, staffing, and other design features. Thus, guidelines are stated in terms of minimum spacing considerations for common equipment arrangements and use situations. Maintenance and testing of equipment has not been considered, and may require larger clearances than the minimums suggested.[0700]

12.1.1.3-6 Equipment-to-Opposing-Surface Distance
Enough space should be allowed so that personnel can perform all required tasks.
Additional Information: The space should accommodate kneeling and bending, simultaneous work by more than one person, and simultaneous performance of operational and maintenance tasks as required. Recommended minimum separations are illustrated in Figure 12.2. A minimum separation of 50 inches is recommended between a single row of equipment/panel and a wall or other opposing surface. A minimum separation of 50 inches is also recommended between two rows of facing equipment if both rows are worked by a single person. A minimum separation of 8 feet is recommended between opposing rows of equipment where more than one person must work simultaneously on operational or maintenance tasks, and kneeling, bending, or use of test equipment may be necessary.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.3 Furniture and Equipment Layout

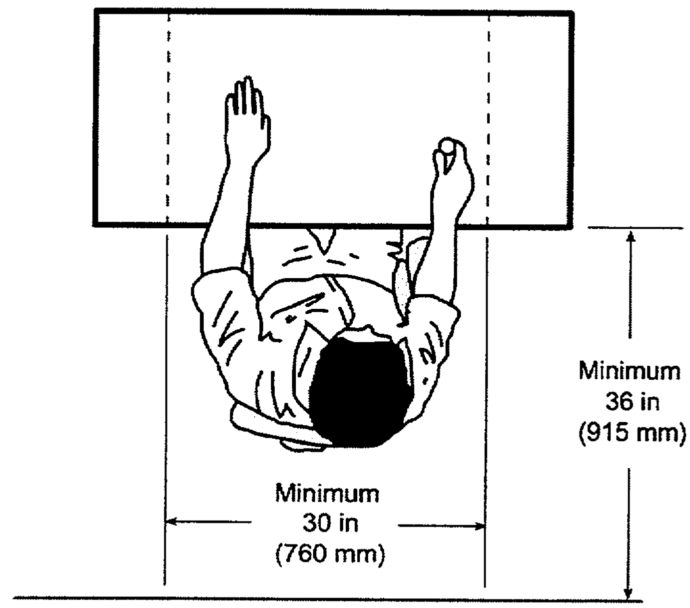


Figure 12.1 Spacing of equipment to accommodate seated users

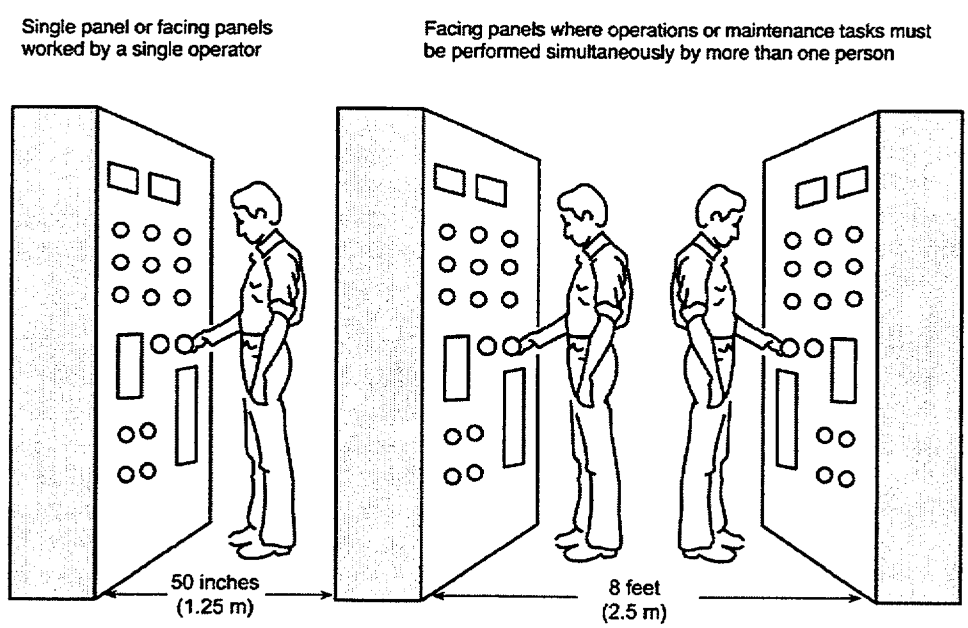


Figure 12.2 Equipment-to-equipment distances: single person and more-than-one-person spaces

12 WORKPLACE DESIGN

12.1 Control Room

12.1.1 Control Room Configuration

12.1.1.3 Furniture and Equipment Layout

12.1.1.3-7 Openings

Panels should be laid out and maintained, and equipment enclosures designed, so that there are no unguarded openings through which unwanted objects can be introduced.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.4 Document Organization and Storage

12.1.1.4-1 Accessibility
All procedures and other documents that may be needed for ready reference should be kept in the control room in places where they are easy to locate and extract for use.
Additional Information: Reference documents should not be locked up, or stored in places too low or too high for large or small personnel to access easily, in cramped spaces, or where poor illumination exists.[0700]

12.1.1.4-2 Location Aids
Clearly visible title labels should be provided to identify specific documents. Labels should distinguish documents as much as possible.
Additional Information: Putting many volumes in one location creates a search problem, especially if titles are similar. One means of reducing search time would be to put operational documentation in one location and other documentation in a secondary location.[0700]

12.1.1.4-3 Convenience of Use
Documents should not be fixed in racks; it should be possible to remove documents for use.[0700]

12.1.1.4-4 Bound Documents
Documents should be bound so that they can be opened fully and will remain open at the desired place without holding.[0700]

12.1.1.4-5 Protection
Documents should be protected from wear so that they do not become dog-eared, dirty, loose, torn, and difficult to read.[0700]

12.1.1.4-6 Dedicated Sets of Procedures
Sets of procedures should be stored separately for each unit in a multiunit control room.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.5 Spare Parts, Operating Expendables, and Tools

12.1.1.5-1 Supply
There should be an adequate supply of expendables and spare parts (e.g., fuses, bulbs, ink and inking pens, recorder charts, and printer paper).
Additional Information: Spare parts, such as indicator lamps, and any tools that are needed by operating personnel should be stored in suitable, designated space(s) within the control room.[0700]

12.1.1.5-2 Accessibility
Expendables and spare parts should be readily accessible.[0700]

12.1.1.5-3 Tools
All necessary or special replacement tools should be available as needed to install expendables and spare parts.[0700]

12.1.1.5-4 Storage Space
There should be adequate storage space for expendables and spare parts.[0700]

12.1.1.5-5 Coding
When different types, sizes, or styles of expendables and spare parts are required, they should be clearly and distinctively marked to avoid misapplication.[0700]

12.1.1.5-6 Inventory
Records should be kept as to the status of expendables and spare parts.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.6 Supervisor Access

12.1.1.6-1 Access
The shift supervisor's office should be located so as to permit prompt physical access to the control room under all conditions, including control room isolation.
Additional Information: The preferred location is within the control room isolation boundary, with placement to permit good visual and voice contact with the main operating area.[0700]

12.1.1.6-2 Communications
Dedicated communications links should be provided between the main operating area and the shift supervisor's office when the shift supervisor's office is not within the control room boundary.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.7 Multiunit Control Rooms

12.1.1.7-1 Equipment Arrangement
Equipment should be arranged with movement and communication patterns in mind so that unit operations do not interfere with each other.[0700]

12.1.1.7-2 Senior Operator Station
Senior operators who supervise and assist operations of more than one unit should be stationed so that they can communicate effectively with operators in each unit and have an unobstructed visual path to the control boards of each unit.[0700]

12.1.1.7-3 Sharing of Personnel
Where operators may assist those of another unit, potential task loading should be evaluated to assure that each unit can be covered adequately in all situations.[0700]

12.1.1.7-4 Sharing of Procedures
Each unit should have its own set of procedures and other reference documents as required to make sure that references are easily available to personnel in each unit, and to avoid conflicting needs for the same reference.[0700]

12.1.1.7-5 Shared Equipment
When control of some plant equipment is shared by the control rooms of multiple-unit nuclear power plants, care must be taken to ensure that status and availability data for this equipment are available in each control room, and that equipment operation from the control room for one unit will not affect other unit operations.
Additional Information: Control of plant equipment from one control room should not affect the ability of operators of other control rooms to maintain control of their respective units. The status of plant equipment under the control of one control room should be displayed in all control rooms capable of controlling that equipment. If control of plant equipment from one control room renders that equipment unavailable to other control rooms, availability status indications should be displayed in all control rooms. A single, centrally located control panel/console may be used for dual-unit control rooms within the same isolation boundary when this design does not conflict with the panel layout and control-display integration guidelines of Section 11.2. Administrative procedures should be in place that assign responsibility for allocation of use of controls of shared plant equipment to a single control room.[0700]

12.1.1.7-6 Dedicated Crews
When mirror image control rooms exist, operational crews should be committed to one or the other unit and should not be allowed to alternate between the two mirrored units.
Additional Information: This includes crews staffing a single center-desk station. Some control rooms are designed with the control boards of two units laid out symmetrically, side-by-side, so that one is a complete or nearly complete reversal of the other. Operators who work both units have to deal with two opposite patterns of controls and displays, and must reorient their expectations completely when they switch from unit to unit. This requirement violates the principle of positive transfer of training and is highly unfavorable for task performance reliability. The potential for confusion is greater when the reversal is incomplete (e.g., control boards mirror imaged, but annunciator panels arranged identically in both units).[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.7 Multiunit Control Rooms

12.1.1.7-7 Accentuate Differences
The distinction between the mirrored units should be heightened as much as possible so that there will be no confusion about where one unit ends and the other begins.
Additional Information: In addition to using labeling, distinctiveness can be increased by using a different color scheme for the elements of each unit, including carpeting, desks, and other work station equipment, as well as the board surface areas.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.8 Emergency Equipment

12.1.1.8-1 Types of Equipment
Protective equipment should include protective clothing and breathing apparatus.[0700]

12.1.1.8-2 Anthropometry
Protective clothing and breathing equipment should be compatible with users' body sizes and tasks to provide adequate tactile sensitivity and ability to see, reach, move, communicate, and hear.[0700]

12.1.1.8-3 Periodic Checks
Protective equipment should be periodically checked to determine if it is in good condition.[0700]

12.1.1.8-4 Quantity
There should be protective equipment available in sufficient quantities and sizes for the required number of users.[0700]

12.1.1.8-5 Marking
Protective clothing sizes should be clearly identifiable.[0700]

12.1.1.8-6 Expendables
There should be an adequate supply of personal protection equipment expendables, such as filters.[0700]

12.1.1.8-7 Accessibility
All protective equipment should be easily and readily accessible.[0700]

12.1.1.8-8 Training
Personnel should be well practiced in donning protective equipment.[0700]

12.1.1.8-9 Procedures
Instructions for donning, doffing, and controlling personal protective equipment should be provided.[0700]

12.1.1.8-10 Periodic Checks
All equipment should be periodically checked to determine if it is in good condition.[0700]

12.1.1.8-11 Accessibility
All equipment should be easily and readily accessible.[0700]

12.1.1.8-12 Training
Personnel should be trained in the use of all emergency equipment.[0700]

12.1.1.8-13 Procedures
There should be a written, administratively approved procedure for each type of emergency or combination of emergencies.[0700]

12.1.1.8-14 Automatic Warning System
There should be an automatic fire warning system for control room fires.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.8 Emergency Equipment

12.1.1.8-15 Proper Storage

Provision should be made for the orderly storage in the control room of emergency equipment that is needed by control room personnel.[0700]

12.1.1.8-16 Storage Locations

The storage location(s) may be away from the main operating area but should be accessible, clearly marked, and known to all personnel.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.9 Personal Storage

12.1.1.9-1 Storage Locations
There should be a suitable, out-of-the-way, but secure place in which control room personnel may keep their coats and other personal belongings.[0700]

12.1.1.9-2 Storage Suitability
If lockers are provided, they should be large enough to hold the items that might reasonably be expected to require storage.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.10 Ambience and Comfort

12.1.1.10-1 Decor
Decor should create a pleasant working environment in the control room.
Additional Information: Features to be considered include:
- Color coordination
- Use of color and lighting to create a cheerful atmosphere (without introducing glare and brightness to a degree that causes eye fatigue or an overly intense atmosphere)
- Visual relief from arrays of instrumentation
- Comfortable seating
- Carpeting to lessen the fatigue of standing and walking. [0700]

12.1.1.10-2 Restroom and Eating Facilities
A restroom and kitchen or eating area should be provided within (preferably) or near the control room isolation boundary.
Additional Information: Since formal breaks are not scheduled in most control rooms, it is important that personnel have access to these facilities without delay. It is preferable that they be used only by control room personnel. Provision should be made for communication if facilities are out of voice contact, so that an operator taking a break can be contacted as necessary by personnel in the control room (see Guideline 10.2.6-2).[0700]

12.1.1.10-3 Rest Area/Lounge
Consideration should be given to providing a rest area (possibly in conjunction with the eating area) conducive to relaxation and revitalization, especially where shifts are long.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.11 Crew Coordination

12.1.1.11-1 Shared Information and Control Functions
The HSI design should maximize the ability of users to share information and control functions among crew members if users are required to share the responsibilities for monitoring and control.[6546]

12.1.1.11-2 Indication of Shared Control Capability
If a control function is shared among users but only one user can operate it at a time, then a clear, unambiguous indication should be provided identifying which user has the control capability.[6546]

12.1.1.11-3 Indication of Override of Shared Control Capability
A clear, unambiguous indication should be provided prior to overriding the use of a shared control.
Additional Information: An override capability allows one user to take the control capability of a shared control from another user. If such an override capability exists, then a clear indication should be provided prior to each override so that users are aware of the pending change.[6546]

12.1.1.11-4 Shared Display Devices
When a display device is viewed by more than one person, its use should be regulated.
Additional Information: The system should not permit one user to remove a display that is still needed by another user, or to present a display that may interfere with another user's activities.[6546]

12.1.1.11-5 User-Configured Displays
When a display device can be configured by more than one user, the system should support the coordinated use of the displays.
Additional Information: Users may modify display pages to address particular task needs or personal preferences. For example, a user may be able to select plant variables to be included in or excluded from the display page, define coding for displayed items, and define axes and scales for plots. When multiple users can manipulate the same displays, coordination may be needed to ensure that they are aware of the current content. In addition, mechanisms are needed to ensure that displays created by one user are not changed or eliminated by other users. Possible solutions include password protection, special directories for storing these displays, and administrative procedures.[6546]

12.1.1.11-6 Soft Controls with Multiple Access
The system should make each user aware of control inputs made by others, and ensure that the control actions of one user are not unknowingly reversing another user's actions.
Additional Information: Some input interfaces for controlling plant variables can be accessed from multiple locations in the HSI. Some process plants with computer-based HSIs address this problem by assigning control capabilities for a plant variable to a particular control console. Users at other consoles can observe the control setting but cannot initiate changes.[6546]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.1 Control Room Configuration
12.1.1.12 HSI Upgrades

12.1.1.12-1 Consistent System Response
The system's interpretation of a user input should not change as a result of an upgrade.
Additional Information: For example, a given keystroke should not produce a benign action in one version of the system software and a destructive action, such as erasing data, in a subsequent version.[6546]

12.1.1.12-2 Existing Skills Preserved
Changes to HSI hardware or software should not force users to have to unlearn existing skills.
Additional Information: It is better for an upgrade to require the user to learn additional skills rather than expect the user to change existing ones. Thus, changes in the information presented by the system (e.g., messages, graphic symbols) are less difficult to adapt to if they do not require users to modify their skills or strategies. For example, changes limited to physical appearance do not typically serious disrupt users' performance, whereas changes in the operation of the system almost certainly will. However, sometimes the appearance of a system is strongly linked to user skills. For example, the layout of tools on the palette of a drawing program should not be changed in subsequent versions. Users who rely on spatial memory for retrieving tools from the palette will find that this skill leads them to select the wrong tool.[6546]

12.1.1.12-3 Salient Changes
If changes must be made to the HSI, they should be salient.
Additional Information: Drawing the user's attention to characteristics that have changed can help them to adapt their skills. For example, injecting a single new word into a message is not recommended. Adding the word 'not' to a question, such as "Do you want to save these settings?" will change the meaning of the message. However, it may not be detected by the user until an error occurs. Many actions become automatic as users become skilled in using the interface. If HSI changes are obvious, users may be able to block their automatic responses and develop new ones.[6546]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.2 Control Room Environment
12.1.2.1 Temperature and Humidity

12.1.2.1-1 Comfort Zone

The climate control system should maintain temperatures of 68-75°F in winter and 73-79°F in summer and relative humidity levels between 30% and 60%.

Additional Information: The temperature ranges given are based on the ASHRAE summer and winter comfort zones as specified in ASHRAE 55-1992. In the summer comfort zone, workers wearing light clothing will be comfortable; in the winter comfort zone, workers wearing heavy indoor clothing (e.g., sweaters) will be comfortable. The range of relative humidity given is based on ASHRAE 62 and is narrower than that currently specified in ASHRAE 55. The comfort zones assume sedentary work; personnel performing 'light work' (e.g., actively monitoring spatially distributed equipment, or retrieving procedures or manuals) will be comfortable at lower temperatures. Air movement rates less than 50 ft/min are also assumed.[0700, 5680]

12.1.2.1-2 Temperature Differential

Air temperature at floor level and at head level should not differ by more than 10°F.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.2 Control Room Environment
12.1.2.2 Ventilation

12.1.2.2-1 Air Quantity
The ventilation system should be capable of introducing fresh air into the control room at a rate of at least 20 cubic feet per minute per occupant.[0700, 5680]

12.1.2.2-2 Air Velocity
Air velocities in the main operating area should not exceed 45 feet per minute measured at head level and should not produce a noticeable draft.[0700]

12 WORKPLACE DESIGN
12.1 Control Room
12.1.2 Control Room Environment
12.1.2.3 Illumination

12.1.2.3-1 Illumination Levels
The illumination levels should be consistent with those listed in Table 12.1.
Additional Information: The values in the table are preferred levels based on conservative assumptions about the reflectance of the task background, the age of the operator, and the criticality of the task being performed. Lower illuminances may be justified for more favorable visual conditions or where the need to perform critical tasks can be ruled out.[0700, 5680]

Table 12.1 Nominal illumination levels for various tasks and work areas

Work Area or Type of Task	Task Illuminance, footcandles
Panels, primary operating area	50
Auxiliary panels	50
Scale indicator reading	50
Seated operator stations	100
Reading:	
- handwritten (pencil)	100
- printed or typed	50
- VDU	10
Writing and data recording	100
Maintenance and wiring areas	50
Emergency operating lighting	10

(Source: adapted from NUREG/CR-5680, Tables 6.2 and 6.3)

12.1.2.3-2 Uniformity
The level of illumination should not vary greatly over a given work station.[0700]

12.1.2.3-3 Supplemental Light
Supplemental lighting should be provided for personnel performing specialized visual tasks in areas where fixed illumination is not adequate.[0700]

12.1.2.3-4 Task Area Luminance Ratios
To ensure effective visual performance, the task area luminance ratios in Table 12.2 should not be exceeded.
Additional Information: To determine task lighting requirements, it is necessary to consider the levels of lighting that surround a task. Great disparities between task and background lighting can lead to adaptation problems.[0700]

Table 12.2 Maximum task area luminance ratios

Areas	Luminance Ratio
Task area versus adjacent darker surroundings	3:1
Task area versus adjacent lighter surroundings	1:3
Task area versus more remote darker surfaces	10:1
Task area versus more remote lighter surfaces	1:10
Luminaires versus surfaces adjacent to them	20:1
Anywhere within normal field of view	40:1

12.1.2.3-5 Shadows
To reduce fatigue and eyestrain, shadows should be avoided.
Additional Information: Ambient illumination should be provided via indirect or diffuse lighting. Labels, instructions, and other written information should not be in shadowed positions.[0700]

12.1.2.3-6 Glare
Glare should not interfere with the readability of displays, labels, or indicators.
Additional Information: Glare increases the probability that an individual will misread a display or will fail to notice displayed information. Glare can also produce discomfort. Direct sources of glare include light emitted from luminaires, indicators, and displays. Indirect sources of glare include reflected light from all surfaces, e.g., paint, metal, and glass. The surface of a VDU screen should reduce reflections. Positioning of VDUs relative to light source affects glare as can use of a shield or filter on the VDU or light source. If glare reduction or contrast enhancement techniques are used, they should not violate the requirements of luminance, contrast, and resolution as stated in this document.[0700, 5908]

12.1.2.3-7 Reflectance
Reflectance should conform to the recommendations shown in Table 12.3.
Additional Information: The amount of light reflected from a surface depends on its color; typical reflectance values for various colors are given in Table 12.4. Surfaces adjacent to a VDU should have a dull matte finish to reduce glare. The luminance range of surfaces immediately adjacent to VDUs should be between 10 percent and 100 percent of screen background luminance.[0700, 5908]

12.1.2.3-8 Color
Surface colors should be recognizable under both normal and emergency lighting conditions.
Additional Information: Some types of lamps (e.g., mercury or sodium lamps) have very poor color rendering properties. Such lamps should not be used for normal or emergency lighting if the ability to distinguish among colors may be important.[0700, 5680]

12.1.2.3-9 Ambient Illumination and VDUs
The ambient illumination in the VDU area that is necessary for other visual functions (e.g., setting controls, reading instruments) should not degrade the visibility of signals on the VDU.[5908]

Table 12.3 Recommended workplace reflectance levels

	Reflectances	
Surface	**Preferred**	**Permissible**
Ceiling[a]	80%	60-95%
Upper Wall	50%	40-60%
Lower Wall	15-20%	
Instruments/Displays	80-100%	
Cabinets/Consoles	20-40%	
Floor	30%	15-30%
Furniture	35%	25-45%

[a] Recommended reflectances are for finish only. Overall average reflectance of acoustic materials may be somewhat lower. The upper walls (one to two feet below the ceiling) may be painted with the same paint as is used on the ceiling.

12.1.2.3-10 Use of Colored Ambient Illumination
Colored ambient illumination should not be used if color coding is used in the workplace.
Additional Information: Colored lighting will interfere with color-coded VDU displays and other color coding. Some types of lamps (e.g., mercury or sodium lamps) have very poor color rendering properties. Such lamps should not be used for normal or emergency lighting if the ability to distinguish among colors may be important.[5908, 5680]

12.1.2.3-11 Illuminance of Areas Immediately Surrounding VDUs
There should be no light source (direct or reflected) in the immediate surrounding area of the VDU that is of greater luminance than the VDU.[5908]

Table 12.4 Surface color reflectance values

Color	Reflectance
White	85
Light::	
Cream	75
Gray	75
Yellow	75
Buff	70
Green	65
Blue	55
Medium:	
Yellow	65
Buff	63
Gray	55
Green	52
Blue	35
Dark:	
Gray	30
Red	13
Brown	10
Blue	8
Green	7
Wood Finish:	
Maple	42
Satinwood	34
English Oak	17
Walnut	16
Mahogany	12

12 WORKPLACE DESIGN
12.1 Control Room
12.1.2 Control Room Environment
12.1.2.4 Emergency Lighting

12.1.2.4-1 Automatic Action
A control room emergency lighting system should be automatically activated and immediately available upon failure of the normal control room lighting system.
Additional Information: This system should be independent of any other plant lighting system that is available in the control room.[0700]

12.1.2.4-2 Operability
Failure of the normal control room lighting system should not degrade operability of the emergency lighting system.[0700]

12.1.2.4-3 Emergency Lighting Levels
The control room emergency illumination system should be designed to provide a minimum illumination level of 10 footcandles at all work stations in the main operating area.
Additional Information: Higher levels of illumination are preferred if the room's surfaces are of low reflectivity or the occupants of the room are over 40 years of age.[0700]

12.1.2.5-1 General

The acoustic design of the control room should ensure that verbal communications among personnel are not impaired; auditory signals are readily detected; and auditory distraction, irritation, and fatigue are minimized.[0700]

12.1.2.5-2 Background Noise

Background noise should not impair verbal communication between any two points in the main operating area.

Additional Information: Verbal communications should be intelligible using normal or slightly raised voice levels. Figure 12.3 shows the voice levels needed for spoken communication over specified distances in the presence of different levels of background noise. Intelligibility of speech in noise is affected by the frequency spectra of the noise and of the speakers' voices and by the speakers' hearing sensitivity.[0700, 5680]

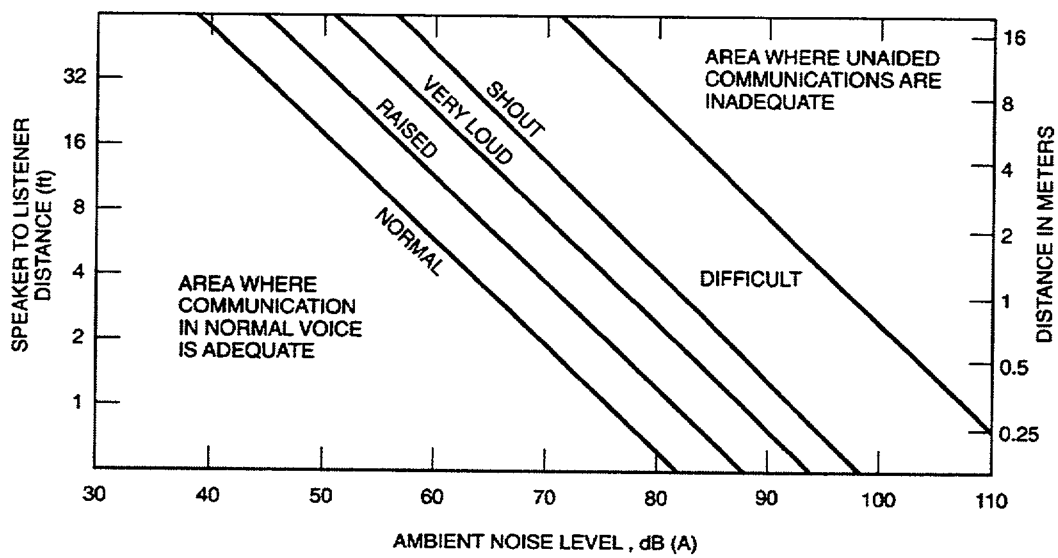


Figure 12.3 Voice level as a function of distance and ambient noise level

12.1.2.5-3 Background Noise Level

Background noise levels should not exceed 65 dB(A).

Additional Information: Operators eight feet apart will have to speak loudly to be heard in the presence of a 65 dB(A) background noise. Therefore, if workstations, display panels, or control interfaces are widely separated in the control room, the background noise limit should be reduced.[0700]

12.1.2.5-4 Further Reductions

Where communications between the main operating area and other control room locations are necessary, and voice transmission systems are not provided, further reductions in background noise should be implemented.[0700]

12.1.2.5-5 Noise Distractions

Noise distractions generated either inside or outside the control room should be minimized.[0700]

12.1.2.5-6 Reverberation Time and Sound Absorption

The acoustical treatment of the control room should limit reverberation time to 1 second or less.[0700, 5908]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.1 Labeling
12.2.1.1 Placement of Labels

12.2.1.1-1 Labeling of Equipment
Labels should appear on all components and systems with which personnel may interact.[6146]

12.2.1.1-2 Replacement of Labels
When labels are affixed, earlier markings (such as labels applied during construction or acceptance, or informal labels) should be removed.[6146]

12.2.1.1-3 Viewing Direction
When equipment may be approached from more than one direction, labels should be placed on surfaces so that they are visible from each direction.[6146]

12.2.1.1-4 Label Visibility
Identifying labels should be placed so that they are readily visible at typical viewing distances and orientations.
Additional Information: Labels should be placed so as to be visible to plant personnel of both short and tall stature. Recommended character sizes are given in Guideline 12.2.1.2-3.[6146]

12.2.1.1-5 Locator Labels
Readily visible markings should be placed nearby to indicate the location and identity of components that are partially blocked from view.
Additional Information: The location of overhead valves can be indicated by labels on floors or walls directly below them.[6146]

12.2.1.1-6 Label Orientation
Labels should be designed and mounted so that text is oriented horizontally for ease of reading.
Additional Information: Requiring operators to manipulate and re-orient the label is inconvenient (especially when their hands are full), and may lead to misreading.[6146]

12.2.1.1-7 Label Positioning
Labels should be attached or positioned so as to unambiguously indicate the item being identified.[6146]

12.2.1.1-8 Redundant Labels
When labels are placed on the doors of equipment cabinets, redundant labels should be placed inside so that they are visible when the door is open.[6146]

12.2.1.1-9 Label Placement Conventions
Specific conventions for label placement should be employed for each type of equipment (e.g., valves, motors).[6146]

12.2.1.1-10 Label Mounting
Tags should be attached to components so as not to cause damage or interfere with operation.
Additional Information: Valve labels should not be connected to handwheels or operating chains. The wire used to attach a label to a valve should be passed through the yoke in a manner that will not damage the stem. For chain-operated valves, the label should be wired to a small piece of plastic pipe through which the operating chain passes freely.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.1 Labeling
12.2.1.1 Placement of Labels

12.2.1.1-11 Label Replacement after Maintenance
Maintenance procedures should require personnel to check that labels are in place after components are reassembled or replaced.[6146]

12.2.1.1-12 Means of Label Attachment
Labels and tags should be securely attached in a manner appropriate to the equipment and environmental conditions.
Additional Information: The method chosen to attach a label should take into account the possibility of exposure to heat, corrosive substances, oil, or solvents.[6146]

12 WORKPLACE DESIGN

12.2 Local Control Stations

12.2.1 Labeling

12.2.1.2 Label Design

12.2.1.2-1 Label Material

The material from which labels and tags are made should be appropriate to the equipment and environmental conditions.

Additional Information: The material chosen should take into account the possibility of exposure to heat, corrosive substances, oil, or solvents. A single label material may not be appropriate in all environments. If different label material is required at different locations in the plant, an effort should be made to keep the content and format of the labels constant.[6146]

12.2.1.2-2 Label Contrast

Lettering and background colors should provide high contrast and high legibility.

Additional Information: Dark letters on a light background are preferred. Table 11.2 provides examples of color combinations and their relative legibility. Stamped metal tags (brass, stainless steel, and color anodized aluminum) often are illegible under less-than-optimal conditions.[6146]

12.2.1.2-3 Character Height

Characters used on labels should be sized to take into account viewing distances and illumination conditions.

Additional Information: The character height recommendations in Guideline 11.3.1.5-1 should be observed. Character heights required for various viewing distances are given in Table 12.5. Under less-than-optimal viewing conditions, the preferred values should be used as minimums. The preferred values should also be used for critical markings associated with safety-related systems.[6146]

12.2.1.2-4 Stenciled Labels

Stenciled labels should not be used.

Additional Information: The gaps in stenciled characters render them less legible than other forms of labeling.[6146]

12.2.1.2-5 Label Reflectance

Surfaces of labels should have a non-reflective (i.e., matte) finish.

Additional Information: Reflective materials may be added to labels to aid locating equipment when normal lighting is lost. Such labels should be designed so that legibility is not impaired under normal lighting conditions; e.g., a reflective border may be placed around the contents of the label.[6146]

Table 12.5 Minimum and preferred character heights for various viewing distances

Viewing Distance	Minimum Character Height		Preferred Character Height	
	inches[1]	points[2]	inches[3]	points[2]
28 inches	0.112	8	0.168	12
3 feet	0.144	10	0.216	16
4 feet	0.192	14	0.288	21
5 feet	0.240	17	0.360	26
6 feet	0.288	21	0.432	30
10 feet	0.480	35	0.720	50
20 feet	0.960	70	1.440	100
30 feet	1.440	100	2.160	150
40 feet	1.920	140	2.880	200
50 feet	2.400	175	3.600	250

[1] minimum character height (15 minutes of arc) = distance multiplied by .004
[2] character heights in points (1 point = 1/72 inch) are approximate
[3] preferred character height (20 minutes of arc) = distance multiplied by .006

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.1 Labeling
12.2.1.3 Label Content

12.2.1.3-1 Label Information
Labels should contain concise, descriptive noun names along with alphanumeric system and component identification codes.
Additional Information: Labels should provide sufficient descriptive information to allow the least experienced operator to recognize the equipment. The following additional items may be considered for inclusion on labels: unit/train/channel designations, power supply information, operational characteristics, and flow direction.[6146]

12.2.1.3-2 Labeling Conventions
Labeling conventions should be employed to ensure consistency of plant labeling with drawings and procedures.[6146]

12.2.1.3-3 Standard Label Format
The format of presentation (e.g., order, position) of information should be consistent on all labels.[6146]

12.2.1.3-4 Abbreviations
Abbreviations used on labels should be standardized and easily recognized.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.2 Information Display
12.2.2.1 Gauges/Meters

12.2.2.1-1 Design

The design of gauges and meters should conform to the relevant portions of Section 1.6.4, Meters.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.2 Information Display
12.2.2.2 CRT Displays

12.2.2.2-1 Design
If CRT displays are employed, they should conform to the relevant portions of Section 1, Information Display.[6146]

12.2.2.3-1 Alignment Marks
Alignment marks should be used to indicate open and closed status of important manual valves.[6146]

12.2.2.3-2 Visibility of Position Indication
The location and size of the alignment marks should reflect the normal viewing distance, location, and ambient lighting.[6146]

12.2.2.3-3 Indication of Full Open/Closed Positions
Alignment marks should show both the valve's fully open and fully closed positions.[6146]

12.2.2.3-4 Design of Position Indication
Alignment marks should be located to minimize parallax error.
Additional Information: Parallax refers to the apparent change in the relative positions of objects depending on the position of the viewer. Error will be minimized if the distance between the indicator and the marks against which it is to be read is small, and if the indicator is located so that it can be viewed "straight-on," i.e., with the observer's LOS perpendicular to the plane of the alignment marks.[6146]

12.2.2.3-5 Indication of Direction of Rotation
The direction of rotation for opening and closing of a valve control wheel should be indicated in cases where the direction is not obvious.[6146]

12.2.2.3-6 Precision of Indication
Alignment marks should be precise enough that the observers can tell when a valve is fully opened or closed.[6146]

12.2.2.3-7 Alternate Means of Local Position Indication
Indicators that are activated by valve limit controls should be used when alignment marks would not be appropriate.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.3 Controls
12.2.3.1 General

12.2.3.1-1 Design of Controls
The design and operation of controls should conform to the guidelines in Section 3, Controls.[6146]

12.2.3.1-2 Inadvertent Activation
Controls should be protected against inadvertent actuation.
Additional Information: See Guideline 3.1.1-4. The danger of inadvertent actuation of controls may be greater outside the control room due to ongoing construction, maintenance, calibration, and outage-related activities. Controls can be affected by personnel or equipment moving by, radio transmissions, or vibration.[0700]

12.2.3.1-3 Suitability for Use
The operation of controls should be compatible with the use of protective clothing, if it may be required.
Additional Information: See Guideline 3.1.1-12. The likelihood of operators requiring protection (e.g., against heat or radiation) is greater outside the control room.[0700]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.3 Controls
12.2.3.2 Manual Valves

12.2.3.2-1 Operating Labels

Handwheels should be provided with double-ended arrows showing the direction of operations and labeled at each end to indicate the functional result (i.e., open and close).[6146]

12.2.3.2-2 Turning Aids

Knurling, indentation, high-friction covering, or a combination of these should be built into the handwheel to allow the application of the required torque.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.4 Communication
12.2.4.1 Loudspeakers

12.2.4.1-1 Range of Coverage of Loudspeakers
Loudspeaker coverage should be such that members of the work force can be alerted under all plant conditions.[6146]

12.2.4.1-2 Coverage Areas of Loudspeakers
Loudspeaker coverage should be provided in all areas where the work force may be.[6146]

12.2.4.1-3 Locations and Amplitudes of Loudspeakers
Speakers should be placed within a space so that their number, location, and volume provide an intelligible signal to all workers therein.
Additional Information: Room size and configuration, and ambient noise levels should be taken into account.[6146]

12.2.4.1-4 Echoes
Loudspeaker systems should not echo.
Additional Information: Sufficient numbers of loudspeakers should be provided in containment and other large volumes to avoid excessive echoing. Maximum speaker range in these reverberant spaces should not exceed 50 feet.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.4 Communication
12.2.4.2 Public Address/Pager Stations

12.2.4.2-1 Locations of Page Stations
Page stations should be located so that time required for access by personnel does not exceed 30 seconds.[6146]

12.2.4.2-2 Shielding of Page Stations
Sound shielding should be provided where ambient noise levels exceed 90 dB(A).[6146]

12.2.4.2-3 Control of Page System
Design features or administrative controls should limit unauthorized or excessive paging.[6146]

12.2.4.2-4 Variable Amplitude Speakers
A means of varying speaker amplitude should be provided when ambient noise levels may vary by more than 20 dB.
Additional Information: Features should be provided to allow the volume setting to be monitored. Administrative controls should be established to ensure that speaker amplitude is restored after having been reduced, e.g., during an outage.[6146]

12.2.4.3-1 High Noise Environments
Communications equipment should conform to guidelines in Section 10.2.1, General Requirements, relevant to high noise environments (i.e., Guidelines 10.2.1-5, 10.2.1-6, 10.2.1-9).[6146]

12.2.4.3-2 Portable Alerting Devices
Personal page devices should be provided and should be suitable for high-noise or remote areas.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.4 Communication
12.2.4.4 Two-Way Communication Systems

12.2.4.4-1 Capacity Requirements
A minimum of five communications channels should be provided to avoid excessive waiting for a free channel.[6146]

12.2.4.4-2 Dedicated Emergency Circuits
Dedicated lines should be provided for frequent or emergency communications.
Additional Information: Sound-powered lines are a cost-effective method of providing this capability.[6146]

12.2.4.4-3 Signal Characteristics
The signal transmission characteristics of the system should support good intelligibility.[6146]

12.2.4.4-4 System Access Locations
System stations should be located so that time and effort required for access by personnel is not excessive and so that stations are in areas of relative quiet.[6146]

12.2.4.4-5 Portable Communication Devices
Portable systems should be available to supplement installed systems.
Additional Information: Guidelines for the use of portable radio transceivers (walkie-talkies) are given in Section 10.2.4, Portable Radio Transceivers.[6146]

12.2.4.4-6 Radio Coverage
Surveys should be conducted to identify areas in which radio communication is not possible, e.g., "dead spots" or areas near sensitive equipment.
Additional Information: Other means of communication should be readily available in areas where radio use is prohibited.[6146]

12.2.4.4-7 Radio Repeaters
Radio repeaters should be installed to eliminate "dead spots" if radio communication is relied upon.[6146]

12.2.4.4-8 Use with Special Garments
Communication capability should be provided for personnel wearing protective clothing.
Additional Information: Voice communication with masks is considered in Section 10.2.7, Emergency Communications.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.4 Communication
12.2.4.5 Administrative Considerations

12.2.4.5-1 Training in Communications Practices
Communications training should be provided as a cost effective method of improving efficiency and reliability of communications.[6146]

12.2.4.5-2 Periodic Surveillance Programs
Administrative programs should provide for periodic system surveillance.[6146]

12.2.4.5-3 Intelligibility Tests
Determinations of speech intelligibility should be conducted for activities involving critical communications.[6146]

12.2.4.5-4 Page System Capacity Upgrading
Multiplexing should be added where needed to expand the number of page-party channels.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.5 Environment
12.2.5.1 Heat

12.2.5.1-1 Heat Stress
The level of physical activity and required protective clothing, as well as temperature and humidity, should be considered when assessing the danger of heat exposure.
Additional Information: Important considerations are the amount of metabolic heat being generated by the worker and the restriction of evaporative heat loss associated with protective clothing. Workers' abilities to withstand heat will also differ based on their physical conditioning and degree of acclimatization.[6146]

12.2.5.1-2 Engineering Controls
Engineering controls should be applied where heat may impair the effectiveness or threaten the well being of workers.
Additional Information: Examples of engineering controls include: shielding or insulating sources of radiant heat, eliminating steam leaks, increasing ventilation, and providing assists to reduce the strenuousness of the task. Temperature ranges intended to minimize performance decrements and potential harm to workers as a result of excessive heat are given in Table 12.6. The temperature ranges in the table are ceiling values; i.e., they assume that protective practices (such as acclimatization, training, and a cool place to rest) are in place.[6146]

12.2.5.1-3 Work Practices
Work practices should be adopted to minimize risk due to heat exposure that cannot be eliminated by engineering controls.
Additional Information: Recommended work practices recommended include training in the recognition and treatment of heat illnesses, water and salt replacement, acclimation, and work/rest cycles (stay times). Illustrations of how temperature (wet-bulb globe temperature, WBGT), metabolism, and clothing relate to stay times are found in Table 12.7. The times in the table are ceiling values; i.e., they assume that protective practices (such as acclimatization, training, and a cool place to rest) are in place.[6146]

12.2.5.1-4 Water Replacement
Water should be readily available in areas where the potential for heat stress exists.
Additional Information: Unusual measures may be necessary to provide drink to workers in restricted areas.[6146]

Table 12.6 Ranges of WBGT for different ranges of stay times

Stay Time	Work Clothes			Cotton Coveralls			Double Cottons			Cottons plus Plastics		
	Metabolism			Metabolism			Metabolism			Metabolism		
	Low	Mod	High	Low	Mod	High	Low	Mod	High	Low	Mod	High
0-15	50-52	42-50	38-42	48-50	41-49	37-41	46-48	38-46	34-38	44-46	36-44	32-36
	(122-126)	(108-122)	(100-108)	(118-122)	(106-120)	(99-106)	(115-118)	(100-115)	(93-100)	(111-115)	(97-111)	(90-97)
15-30	44-50	36-42	32-38	42-48	35-41	31-37	40-46	32-38	28-34	38-44	30-36	26-32
	(111-122)	(97-108)	(90-100)	(108-118)	(95-106)	(89-99)	(104-115)	(90-100)	(82-93)	(100-111)	(86-97)	(79-90)
20-45	42-48	34-38	31-34	40-46	33-37	30-33	38-44	30-34	27-30	36-42	28-32	25-28
	(108-118)	(93-100)	(89-93)	(104-115)	(91-99)	(86-91)	(100-111)	(86-93)	(81-86)	(97-108)	(82-90)	(77-82)
30-60	40-44	33-36	30-32	38-42	32-35	29-31	36-40	29-32	26-28	34-38	27-30	24-26
	(104-111)	(91-97)	(86-90)	(100-108)	(90-95)	(84-89)	(97-104)	(84-90)	(79-82)	(93-100)	(81-86)	(75-79)
45-90	38-42	32-34	29-31	36-40	31-33	28-30	34-38	28-30	25-27	32-36	26-28	23-25
	(100-108)	(90-93)	(84-89)	(97-104)	(89-91)	(82-86)	(93-100)	(82-86)	(77-81)	(90-97)	(79-82)	(73-77)
60-120	36-40	30-33	28-30	34-38	29-32	27-29	32-36	26-29	24-26	30-34	24-27	22-24
	(97-104)	(86-91)	(82-86)	(93-100)	(84-90)	(81-84)	(90-97)	(79-84)	(75-79)	(86-93)	(75-81)	(72-75)
90-3h	34-38	29-32	27-31	32-36	28-31	26-30	30--34	25-28	23-27	28-32	23-26	21-25
	(93-100)	(84-90)	(81-89)	(90-97)	(82-89)	(79-86)	(86-93)	(77-82)	(73-81)	(82-90)	(73-79)	(70-77)
2h-4h	32-36	28-30	26-28	30-34	27-29	25-27	28-32	24-26	22-24	26-30	22-24	20-22
	(90-97)	(82-86)	(79-82)	(86-93)	(81-84)	(77-81)	(82-90)	(75-79)	(72-75)	(79-86)	(72-75)	(68-72)

Table 12.7 Stay times for different WBGTs

Wet-Bulb Globe Temp		Work Clothes			Cotton Coveralls			Double Cottons			Cottons plus Plastics		
		Metabolism			Metabolism			Metabolism			Metabolism		
C	F	Low	Mod	High	Low	Mod	High	Low	Mod	High	Low	Mod	High
50	122	15-30	0-10		5-15	0-5		5-15					
48	118	20-45	5-15		15-30	5-10		10-20			5-15		
46	115	20-45	5-20		20-45	5-15		15-30	0-10		15-20		
44	111	30-60	10-25		20-45	5-20		20-45	5-15		15-30	0-10	
42	108	45-90	15-30	5-10	30-60	10-25		20-45	5-20		20-45	5-15	
40	104	60-90	15-45	10-20	45-90	15-40	5-10	30-60	10-25		20-45	5-20	
38	100	90-120	20-45	15-30	60-90	15-45	10-25	45-90	15-30	5-10	30-60	10-25	
36	97	2h-4h	30-60	15-40	90-120	25-45	15-30	60-90	15-45	10-20	45-90	15-30	5-10
34	93	3h-8h	45-90	20-45	2h-4h	30-60	15-45	90-120	20-45	15-30	60-90	15-45	10-20
32	90	NL	90-120	30-60	3h-8h	60-100	25-50	2h-4h	30-60	15-40	90-120	20-45	15-30
30	86	NL	2h-4h	60-120	NL	1h-2h	30-90	3h-8h	45-90	20-45	2h-4h	30-60	15-40
28	82	NL	NL	2h-4h	NL	1h-4h	lh-3h	NL	90-120	30-60	3h-8h	45-90	20-45
26	79	NL	NL	4h-8h	NL	NL	3h-8h	NL	2h-4h	60-120	NL	90-120	30-60
24	75	NL	NL	NL	NL	NL	NL	NL	NL	2h-4h	NL	2h-4h	60-120
22	72	NL	NL	NL	NL	NL	NL	NL	NL	4h-8h	NL	NL	2h-4h
20	68	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	4h-8h
<20	<68	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.5 Environment
12.2.5.2 Cold

12.2.5.2-1 Outdoor Equipment

Equipment located outdoors should be sheltered from the elements as much as possible.[6146]

12.2.5.2-2 Wind Chill

When considering the effects of cold on performance, the effect of air velocity should be taken into account.

Additional Information: Table 12.8 illustrates the wind chill effect; effective temperatures are shown for different combinations of air temperature and wind speed.[5680]

Table 12.8 Wind chill

Wind Speed (mph)	Actual Air Temperature (°F)									
	50	40	30	20	10	0	-10	-20	-30	-40
Calm	50	40	30	20	10	0	-10	-20	-30	-40
5	48	36	27	17	-5	-5	-15	-25	-35	-46
10	40	29	18	5	-8	-20	-30	43	-55	-68
15	35	23	10	-5	-18	-29	-42	-55	-70	-83
20	32	18	4	-10	-23	-34	-50	-64	-79	-94
25	30	15	-1	-15	-28	-38	-55	-72	-88	-105
30	28	13	-5	-18	-33	-44	-60	-76	-92	-109
35	27	11	-6	-20	-35	-48	-65	-80	-96	-113
40	26	10	-7	-21	-37	-52	-68	-83	-100	-117
45	25	9	-8	-22	-39	-54	-70	-86	-103	-120
50	25	8	-9	-23	-40	-55	-72	-88	-105	-123

12.2.5.2-3 Effects of Cold on Performance

The potential for exposure to cold to affect task performance should be evaluated.

Additional Information: Table 12.9 shows, for various tasks, the no-effect levels for the various impacts of cold on performance (i.e., temperatures below which performance decrements may occur).[5680]

Table 12.9 Temperatures above which no cold effects occur

	Air Temperature	Hand Skin Temperature
General Discomfort	69 °F	75 °F
Effects of Cold on the Hands		
Skin Sensitivity		75 °F
Numbness	54 °F	68 °F
Pain		61 °F
Finger Discrimination		37 °F
Grip Strength	14 °F	
Task Performance		
Fine Manual Tasks	64 °F	55 °F
Tracking	55 °F	
Gross Manual Tasks	54 °F	59 °F

12.2.5.2-4 Engineering Controls
Engineering controls should be applied where cold may impair the effectiveness or threaten the well being of workers.
Additional Information: Engineering controls increase the amount of heat received by the worker or insulate the worker from the cold; examples include providing space heaters or wind breaks, and insulating tool handles or valve handwheels. In addition, equipment handles and latches and panel switches and pushbuttons should be operable with gloved hands if located in areas where workers may be exposed to cold.[5680]

12.2.5.2-5 Work Practices
Work practices should be adopted to minimize risk due to cold exposure that cannot be eliminated by engineering controls.
Additional Information: Examples of administrative controls include scheduling outdoor maintenance for warmer seasons or times of day, assigning more worker to a job to reduce the duration of the exposure to cold, and allowing workers to take a break in warm areas when needed.[5680]

12.2.5.2-6 Protective Clothing
Insulated clothing, hats and gloves should be provided to workers who are exposed to cold.
Additional Information: The need to remove gloves to perform certain tasks should be taken into account, and engineering and administrative controls should be applied accordingly.[5680]

12.2.5.3-1 Quieting the Work Process
Steps should be taken to reduce noise at its source.
Additional Information: The preferred approach for mitigating the effects of noise is to reduce the vibration that is causing the noise by isolating or dampening the vibration with machine mountings. The speed of the operating machinery can be altered, thereby changing the frequency of the noise. The resonance of the vibrating objects can be reduced.[5680]

12.2.5.3-2 Limiting Noise Transmission
Steps should be taken to limit the transmission of noise.
Additional Information: Noise can be reduced by increasing the distance of the noise source from the worker. This technique is less effective for low frequencies. Sound-attenuating barriers or enclosures should be used when workers are required to work near equipment that, despite quieting measures, produces high levels of noise. Sound-absorbing materials can absorb 70% of the noise that strikes them. These materials are effective for both low and high frequencies.[5680]

12.2.5.3-3 Limiting Noise Exposure
Steps should be taken to protect workers from noise.
Additional Information: Administrative controls should limit the amount of time that workers spend in noisy locations.[5680]

12.2.5.3-4 Hearing Protection
Ear protection devices should be available and required to be worn in areas where noise levels are 85 dB or more.[6146]

12.2.5.3-5 Sound Attenuating Enclosures
When workers may be required to remain in high noise areas for extended periods of time, appropriate sound attenuating enclosures should be provided.[6146]

12.2.5.3-6 Auditory Capabilities of Users
The hearing sensitivity of the work force should be monitored.
Additional Information: The needs of those workers with hearing degradation should be taken into account.[6146]

12.2.5.3-7 Communications and Hearing Protection
Communication equipment in high noise areas should be compatible with ear protection devices.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.5 Environment
12.2.5.4 Lighting

12.2.5.4-1 Illumination Levels
The illumination levels should conform to those listed in Table 12.10.
Additional Information: The values in the table are based on conservative assumptions about the reflectance of the task background, the age of the worker, and the criticality of the task being performed. Lower illuminances may be justified for more favorable visual conditions or where the need to perform critical tasks can be ruled out. For tasks similar to those performed in the control room (e.g., reading instruments, calibration, reading procedures), the lighting recommendations in Section 12.1.2.3, Illumination, should be consulted.[0700, 5680]

Table 12.10 Range of recommended illuminances for inspection/assembly activities

Area/activity	Footcandles
Inspection/assembly	
Simple	50
Difficult	200
Rough Bench or Machine Work	50
In-plant areas	
Turbine Building	50
Auxiliary Building	20
Laboratory	100
Storage Room	20
ESF Equipment	50
Diesel Generator Building	50
Fuel Handling Building	50
Reactor Building	50
Stairways and Corridors	10

12.2.5.4-2 Portable Lighting
Easily used, portable lighting devices should be readily available nearby when permanent lighting (normal or emergency) may be inadequate.
Additional Information: A supply of fresh batteries should be stored near portable lighting devices. [6146]

12.2.5.5-1 Permanent Means of Access
Permanent means of access to equipment requiring recurrent or emergency operation should be provided when it is beyond the normal standing reach of workers.
Additional Information: Examples of access provisions include work platforms and ladders.[6146]

12.2.5.5-2 Temporary Means of Access
Temporary or movable access platforms to equipment should be available when the equipment is located beyond the normal standing reach of workers and permanent access provision is not feasible.[6146]

12.2.5.5-3 Appropriate Means of Access
Catwalks, ladders, and other suitable means should be provided for workers to reach equipment.
Additional Information: Workers should not be required to walk along pipes or to use components as "stepping stones" in order to reach equipment.[6146]

12.2.5.5-4 Sufficient Clearance
Sufficient clearance should be provided in the vicinity of equipment in contaminated or high temperature areas to allow workers easy access despite the use of protective garments and associated gear.[6146]

12.2.5.5-5 Impediments to Access
Access to equipment to be operated should not be impeded by structural elements.
Additional Information: Structural elements added to the plant (e.g., seismic reinforcements) should not restrict access to equipment.[6146]

12 WORKPLACE DESIGN
12.2 Local Control Stations
12.2.5 Environment
12.2.5.6 Vibration

12.2.5.6-1 Vibration Levels
The effects of vibration on visual and manual performance should be evaluated using Figure 12.4.
Additional Information: Engineering controls should be applied to reduce vibration; see Guidelines 12.2.5.6-2 and 12.2.5.6-3. If vibration levels still exceed those in the unshaded areas of Figure 12.4, a study should be performed to demonstrate that human performance is within acceptable limits. In the top graph, the shaded area represents conditions that will cause an error of 5% or more in number reading. In the bottom graph, the shaded area represents conditions that will cause a tracking error of 10% or more.[5680]

12.2.5.6-2 Reducing Vibration
Steps should be taken to reduce vibration at its source.
Additional Information: The preferred approach for reducing the vibration is to isolate or dampen the vibration with machine mountings.[5680]

12.2.5.6-3 Limiting Transmission of Vibration
Steps should be taken to limit the transmission of vibrations to workers.
Additional Information: Workers can be isolated from vibration in shock-mounted, energy-absorbing platforms.[5680]

12.2.5.6-4 Reducing the Effects of Vibration
User interfaces should be designed to reduce the disruptive effects of vibration.
Additional Information: Modifications that minimize the effects of vibration on task performance include installing larger dials that can be read despite vibration or providing a means for workers to stabilize their limbs.[5680]

12.2.5.6-5 Limiting Exposure to Vibration
Steps should be taken to protect workers from excessive vibration.
Additional Information: Administrative controls should limit the amount of time that workers are exposed to high levels of vibration. These controls would primarily address effects on comfort and worker safety.[5680]

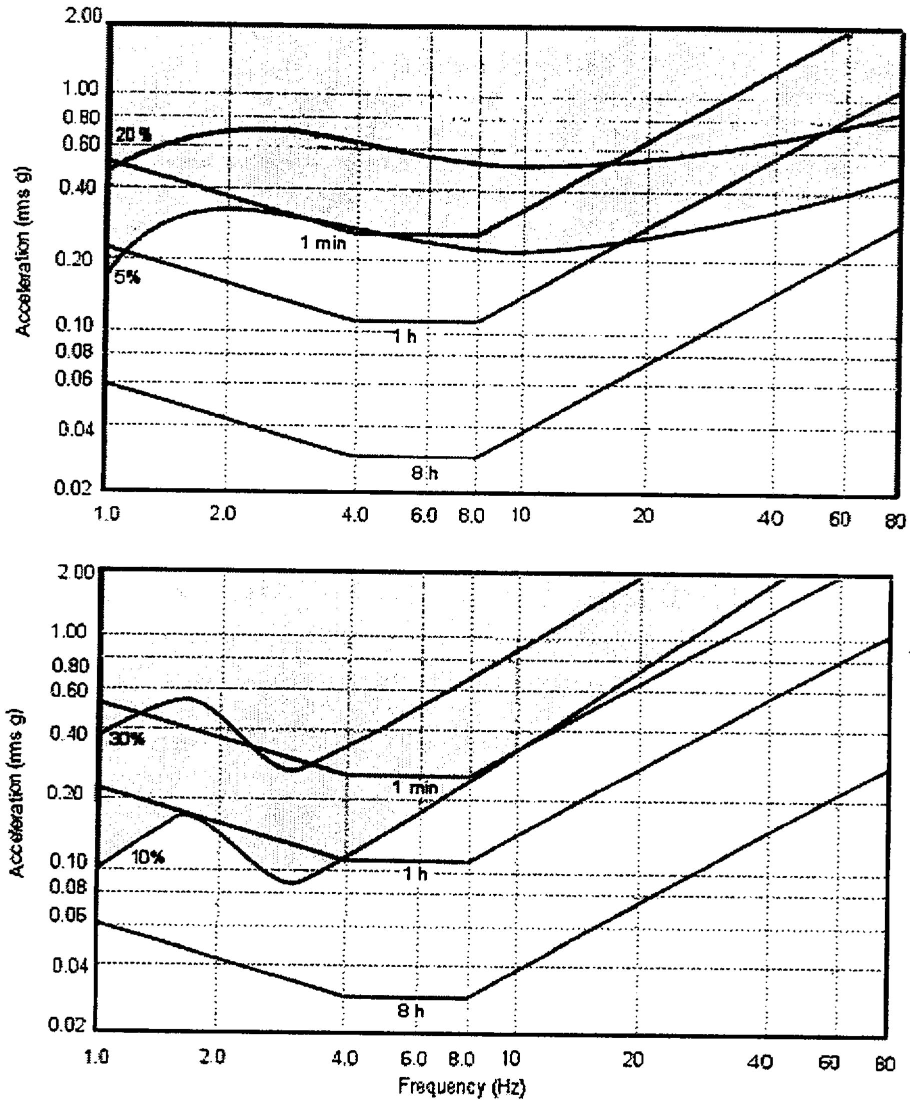


Figure 12.4 Acceleration/frequency combinations and the accuracy of number reading and manual tracking

Part IV
HSI Support

SECTION 13: MAINTAINABILITY OF DIGITAL SYSTEMS

13 MAINTAINABILITY OF DIGITAL SYSTEMS

The installation of digital equipment in NPP systems may range from replacing individual subsystems and components, to completely replacing entire systems, e.g., a system based entirely on digital technology may supercede an analog monitoring system. Rather than replacing the entire system, a control system consisting of sensors, processors, controls, displays, and equipment actuators, may have its analog processors upgraded with digital processors. When installing a digital processor, it may be necessary to install additional signal converters to translate the analog signals into digital format for the new processor, and then translate the digital output of the processor back into analog format for the rest of the system. Thus, much of the plant system may retain its original analog design, resulting in a hybrid of digital and analog components.

Digital systems may be described in terms of progressively smaller units, i.e., a unit of equipment may be defined an assemblage of items that includes modules, components, and parts that are packaged together into a single hardware package. A module is defined as an assemblage of two or more interconnected parts or components that comprise a single physical entity with a specific function. A module may be a printed circuit board or a smaller unit containing individual components that plugs into a printed circuit board. A component is defined as a subdivision of a unit of equipment that the maintainer can treat as an object, but which can be further separated into parts. A mounting board, together with its mounted parts, is an example of a component. A part is an object that cannot normally be broken down further without destroying its designated use; fuses, transistors, resistors, capacitors, and integrated circuit "chips" are examples of parts.

When maintaining a digital system, maintenance personnel inspect, test, and service these units of equipment, modules, components, and parts. Important characteristics for maintenance personnel include instrument cabinets and racks, equipment packaging, fuses and circuit breakers, labeling and marking, adjustment controls, test points, and service points. They are described below along with the test equipment used during maintenance.

INSTRUMENT CABINETS AND RACKS

Instrument cabinets and racks are enclosures that hold modules, components, and parts. They typically have access doors or removable panels that allow access to their contents. The layout of these enclosures affects visual and physical access. Visibility is also affected by the presence of lighting as either permanent or temporary (e.g., handheld) fixtures. Other considerations include the amount of electrical wiring and protective features at the enclosure. Review guidelines are provided in Section 13.2.

EQUIPMENT PACKAGING

This refers to the way that modules, components, and parts are arranged within the enclosure. Review guidelines are provided in Section 13.3. Three packaging considerations are modularization, layout, and mounting:

Modularization

This is a design strategy for enhancing maintainability by dividing a unit of equipment into individual modules. Four methods for organizing modules are logical flow packaging, circuit packaging, component packaging, and printed circuit boards. In logical flow packaging, circuits, parts, and components are arranged in correspondence with their functional relationships. In circuit packaging, all parts of a single circuit or logically related group of parts, and only that circuit or group, are placed in a separate module. In component packaging, similar parts or components are located together; for example, all the fuses or all the relays might be grouped together. With printed circuit boards, parts are mounted on a single integrated circuit board. Review guidelines are provided in Section 13.3.2.

Layout

This refers to the arrangement of modules relative to each other. Important considerations include their accessibility (e.g., consistency of orientation, spacing, and avoidance of stacking) and their grouping (e.g., by maintenance task). Review guidelines are provided in Section 13.3.3.

Mounting

This refers to the ways in which modules, components, and parts are attached. Considerations include the use of hinged mountings, rests, stands, and connectors, and their effects on mounting errors, equipment damage, and accessibility. Review guidelines are provided in Section 13.3.4.

FUSES AND CIRCUIT BREAKERS

These devices protect equipment from changes in electrical current. Considerations include their locations within equipment, indications of open circuits, protection of workers and circuits, and indication of rating. Review guidelines are provided in Section 13.4.

LABELING AND MARKING

This refers to the use of labels and demarcations to identify units of equipment, modules, components, and parts. Considerations include their placement, legibility, and durability. Review guidelines are provided in Section 13.5.

ADJUSTMENT CONTROLS

Personnel use adjustment controls to affect the operation of equipment, such as by setting the value at which the equipment will operate. These controls may be external (e.g., mounted on maintenance panels) or internal (e.g., test and relay switches located on printed circuit boards). Review guidelines are provided in Section 13.6.

TEST POINTS

Test points are locations on equipment where test equipment can be connected. Some are specially designed to receive test equipment, such as ports for voltmeters and multi-pin connectors for automatic test equipment. Others include electrical connectors and terminals where test probes may be used to measure voltages or current. Considerations include location, arrangement, marking, and accessibility. Review guidelines are provided in Section 13.7.

SERVICE POINTS

Service points are locations on equipment where personnel perform routine maintenance tasks such as cleaning and changing components. For example, a digital system may contain a ventilation fan with an air filter that must be periodically replaced. Considerations include location, arrangement, marking, and accessibility of service points. Review guidelines are provided in Section 13.7, with the guidelines on test points.

TEST EQUIPMENT

Test equipment includes the diagnostic tools maintenance personnel use to assess the status of equipment and locate any faults. This equipment is used in periodic surveillance tests, periodic maintenance, and unscheduled maintenance due to failures. Review guidelines on the general characteristics of test equipment are provided in Section 13.8.1. Specific topics for test equipment are described below.

Automatic Test Equipment

Automatic test equipment (ATE) can check two or more signals in sequence without the intervention of a maintainer. They are usually programmable devices designed to exercise a set of functions of a particular portion of a digital system to detect faults. ATE is intended to relieve some of the burdens associated with manually testing digital systems. The tests may be focused at a high level, such as the operation of a subsystem, or at a low level such as the operation of an individual component. Thousands of tests may be rapidly administered with minimal human intervention. For example, many integrated circuits, such as microprocessors, may require several hundred unique test patterns to verify that they are operating properly. ATE tests usually stop after the first out-of-tolerance signal is detected. General review guidelines are provided in Section 13.8.2.1.

Important specific considerations include

Testing intervals

This refers to the way that the automatic test sequences are initiated (e.g., continuous, automatically, or manually). Review guidelines are provided in Section 13.8.2.2.

Bypasses for plant and test equipment

Automatic capabilities must sometimes be disabled (bypassed) to allow tests to be performed and then reinstated. Review guidelines are provided in Section 13.8.2.3.

Failure indications

These are indications used to determine the presence of a possible equipment failure, and include the status of equipment redundancy, tolerance ranges, power, and circuit integrity. Review guidelines are provided in Section 13.8.2.4.

Display of test results

This refers to the way that test outcomes are presented. The go / no-go format provides results as one of two possible outcomes, the former indicating an acceptable condition and the latter indicating an unacceptable condition. This format may be used to indicate whether a given signal is in or out of tolerance. Collating test format presents the results of two or more checks as a single display. For example, a "test passed" indication would occur only if all of the relevant signals are in tolerance. Thus, it reduces the number of indications a maintainer must read, thereby reducing testing time. Other considerations for displaying test results include using high- and low-value fault messages, ease of interpretation, identification of fault location, and identification of out-of-tolerance signals for collating test equipment. Review guidelines are provided in Section 13.8.2.5.

Test equipment may exist as integral parts of plant equipment, such as built-in test capabilities, or as separate pieces of portable equipment. Portable test equipment may be as small as a handheld voltmeter or as large as an engineering workstation. For example, some portable ATE systems are essentially personal computers on wheels. It may be connected internally or externally to the plant equipment. For example, some test equipment has probes that are manually positioned on internal components of equipment to conduct tests. Other portable test equipment is connected to built-in test panels or ports located on the outside of the plant equipment. A built-in test panel may have multiple test ports, which may be annotated with block diagrams or overlays to identify the ports and their relationships to the equipment's components. General review guidelines are provided in Section 13.8.3.1, and guidelines specific to portable test equipment and built-in test panels are provided in Sections 13.8.3.2 and 13.8.3.3, respectively.

13 MAINTAINABILITY OF DIGITAL SYSTEMS

13.1 General

13.1.1 Minimizing Maintenance Demands

13.1.1-1 Minimizing Testing and Servicing
Requirements for periodic or repetitive testing and servicing of components should be avoided where the possibility of human errors may affect safety.
Additional Information: One way to reduce the need for testing and servicing is to use highly reliable components.[6636]

13.1.1-2 Equipment Independence for Maintenance
Units of equipment should be as independent as is practical, such that maintenance of one unit has minimal effects on the other equipment.
Additional Information: Functional, mechanical, electrical, and electronic independence can allow one unit to be maintained with minimal effects on other units. Units of equipment should correspond to the functional design of the equipment. The functional independence of each unit should be maximized while minimizing the interaction between them.[6636]

13.1.1-3 Minimize Maintenance Time
Equipment should be designed to minimize the time required for maintenance if having the equipment out of service can affect safety.
Additional Information: Minimizing the time required for maintenance can increase the equipment's availability. One factor that can increase maintenance time is high cognitive demands associated with such activities as finding components and test or service points, tracing flows between components, and detecting and interpreting symptoms. A second factor is high physical demands, such as dexterity for disassembling and reassembling equipment, accessing internal components, and using connectors, test points, and service points. Maintenance time may also be lengthened by factors that increase the likelihood of errors, such as inadequate feedback from plant or test equipment. In addition, factors that introduce delays or special logistic requirements, such as the need for special tools and test equipment may prolong maintenance.[6636]

13.1.1-4 Ease of Fault Detection
The design of equipment should facilitate rapid, positive fault detection and isolation of defective items.[6636]

13.1.1-5 Equipment Verification
When feasible, equipment should permit verification of operational status before its installation and without the need for disassembly.
Additional Information: For example, maintenance personnel should be able to verify that a module is in operating condition through inspections or tests, such as by attaching the equipment to a test device. These inspections and tests should not require the maintainer to disassemble the module.[6636]

13.1.1-6 Fault Detection Without Disassembly
Equipment should permit fault detection and isolation without removing components, through the use of BIT, integrated diagnostics, or standard test equipment.
Additional Information: Fault detection and isolation should unambiguously identify which component has failed.[6636]

13.1.1-7 Design for Repair by Module Replacement
To reduce the likelihood of personnel errors in normal repairs conducted in difficult field environments, the design should support simple modular replacement in the field, and their repair in the shop.

13 MAINTAINABILITY OF DIGITAL SYSTEMS

13.1 General

13.1.1 Minimizing Maintenance Demands

Additional Information: Repair activities, such as rewiring and replacing individual small components, may be more prone to errors when carried out in the field. Restricting field maintenance to replacing modules may reduce the likelihood of these errors.[6636]

13.1.1-8 Overall Accessibility
Equipment that is to be maintained should be visually and physically accessible to the maintainer.
Additional Information: Modules, components, parts, adjustment points, test points, cables, and connectors for all required maintenance tasks should be visually and physically accessible. Labels should be easily seen.[6636]

13.1.1-9 Standardized Designs for Construction
Equipment used in assembling equipment, such as connectors, should be standardized as much as possible.
Additional Information: Standardization reduces the need for maintainers to learn different skills for different designs, and may reduce the likelihood of errors from using the wrong technique when disassembling and reassembling equipment.[6636]

13.1.1-10 Design Flexibility
Equipment design should provide flexibility to allow future design modifications to be made without imposing high demands on personnel for installation and maintenance.
Additional Information: Equipment should be designed to accommodate future modifications or replacement of equipment. Design flexibility includes functional and physical modularity to accommodate replacements and upgrades, and spare physical capacity, such as in cabinets, panels, terminal strips, and wire ways, to provide room for larger or more components. Extra electrical and processing capacity may also support the maintainability of future modifications.[6636]

13.1.1-11 Minimize Maintenance Equipment and Tools
Units of equipment should be designed to minimize the numbers and types of auxiliary equipment and tools required to service them.
Additional Information: Tool requirements should be coordinated across the modules to minimize the number of different tools needed. For example, designers may design modules for the same type of screwdriver rather than requiring a slightly different one for each. The development of tool requirements requires an understanding of the maintenance tasks and the equipment's characteristics. The goal of minimizing the number and types of tools should be addressed early in the equipment design process, and then throughout design and development.[6636]

13.1.1-12 Use Common Test Equipment and Tools
Whenever possible, systems and units of equipment should be designed so they can be maintained with common test equipment and tools.
Additional Information: The need for specialty test equipment and tools should be avoided. Ideally, the tools required should be limited to those normally found in a maintainer's tool kit. Modules should be designed so that they are replaceable by hand or with common tools.[6636]

13.1.1-13 Need for Special Skills
Equipment should be designed to minimize the need for special skills on the part of the maintainers.[6636]

13.1.1-14 Need for Special Training
Equipment should be designed to minimize the need to specially train the maintainers.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.1 General
13.1.2 Continuous Operation and On-Line Maintenance

13.1.2-1 Local Indication of Redundant Equipment Status
If equipment can automatically transfer operation between redundant units, local personnel who maintain that equipment should be informed of the transfer and the status of the redundant units.
Additional Information: Some digital systems automatically transfer control between redundant processors when there is a failure. These redundant processors support on-line maintenance by allowing one processor to control the system while the others are being serviced. When maintenance is performed, local maintenance personnel should be alerted when an automatic transfer occurs, and should be able to readily determine the status of the redundant processors and identify the one controlling the system. Local indications are preferable to control room indications so local personnel need not rely on workers for status information.[6636]

13.1.2-2 Degraded Operation
Status and fault information should be provided to maintenance personnel and operators for equipment awaiting maintenance while operating in a degraded mode.
Additional Information: Because of their importance in a system, some units of equipment may be designed to operate in a degraded mode after a partial failure while awaiting maintenance. Degraded operation and faults should be sensed and appropriate information identified, displayed, or transmitted to maintenance personnel and operators.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS

13.1 General

13.1.3 Supporting the Operator Role in Maintenance

13.1.3-1 Monitoring and Trending Equipment Degradation
To support personnel awareness of impending equipment failures, monitoring and trending capabilities should be provided where possible to identify the degradation of equipment.[6636]

13.1.3-2 Operator Assistance in Testing and Repair
Where practical, equipment should be designed to facilitate testing and repairs without requiring the assistance of the on-shift operator.
Additional Information: Maintenance activities should be designed so that they do not interrupt the operator at staffed control stations.[6636]

13.1.3-3 Operator Indication of Testing or Repair Activities
The operators should be provided with an indication that testing or repairs are underway.
Additional Information: Some testing and repairs may affect equipment or system operability or make it more susceptible to unusual events, such as spurious trips.[6636]

13.1.3-4 Indications for Equipment that is Out of Service
Means for indicating the status of equipment that is out of service should be provided.
Additional Information: Administrative controls for managing these indications (i.e., for tagging-in and tagging-out equipment) also should be in effect.[6636]

13.1.4-1 Designing for Safety of Maintainers

Equipment should not present hazards to maintainers as they follow maintenance procedures.
Additional Information: A positive means (for example, disconnects or lockouts) should be designed into equipment to control hazardous conditions and increase safety. A hazardous condition is the presence of energy or a substance which is likely to cause death or injury by physical force, shock, radiation, explosion, flames, poison, corrosion, oxidation, irritation or other debilitating features.[6636]

13.1.4-2 Covering Exposed Parts

Protrusions and corners on equipment that maintainers might come into contact with should be covered with rubber or other appropriate materials.
Additional Information: Protrusions and corners on equipment may injure the maintainers or cause them to make sudden motions that could damage plant equipment.[6636]

13.1.4-3 Energy Dissipation Before Maintenance

Parts that retain hazardous levels of electrical potential or heat should be equipped with means to dissipate energy before to maintenance.
Additional Information: Heat sinks and electrical grounds can be used to dissipate energy before maintenance. Removing these hazards can reduce the risk of personnel injury. It may also reduce the risk of damage to plant equipment that could result from sudden personnel movements after touching hot or electrically charged surfaces.[6636]

13.1.4-4 Protecting Maintainers from Heat and Electrical Shock

Equipment or parts that retain hazardous levels of heat or electrical potential during maintenance should be located where maintainers will not touch them during their work, or they should be shielded.
Additional Information: For example, high-current switching devices should be shielded to prevent maintainers from coming into contact with them. Internal controls, such as switches and adjustment controls, should be located away from hazardous high-voltage sources with which the maintainers may make contact while operating the controls. Shocks and burns received from equipment may injure maintenance workers or cause them to make sudden motions resulting in damage to equipment. This concern is particularly important for parts that retain energy after external energy sources have been removed or turned off.[6636]

13.1.4-5 Avoidance of Hazards for Adjustment Controls, Test Points, and Service Points

Adjustment controls and test and service points should be located away from hazards.
Additional Information: Adjustment controls and test and service points should not be located close to dangerous voltages, moving machinery, or other hazards, since contact with these hazards may injure maintenance workers or cause them to damage plant equipment by their sudden motion. They should be separated by more than a hand's width, 4.5 in (114 mm), from the nearest hazard. If a hazardous location cannot be avoided, the control, test point, or service point should be appropriately labeled, shielded, and guarded.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.1 General
13.1.5 Protecting Equipment and Components from Hazards

13.1.5-1 Protecting Equipment from Hazards
Equipment should be protected from potential exterior hazards resulting from personnel actions.
Additional Information: Protection may be provided by the design and location of equipment, or by protective barriers or enclosures. Hazards resulting from personnel actions include physical forces, contact with contaminants (such as oil), other fluids, dirt, and contact with static electricity.[6636]

13.1.5-2 Avoiding Damage to Protruding Parts
Irregular protrusions on a unit of equipment should be easily removed to prevent damage by personnel during installation and maintenance.
Additional Information: An electrical cable is an example of an irregular protrusion.[6636]

13.1.5-3 Avoiding Damage When Opening and Closing Equipment
The parts and wiring of a module should be located and arranged so that personnel do not damage them when the module or the unit of equipment of which they are part is opened and closed.[6636]

13.1.5-4 Avoiding Damage When Maintaining Internal Components
Parts that are susceptible to damage by personnel should be located or shielded so that they will not be damaged during maintenance.[6636]

13.2-1 Instrument Racks

Instrument racks should support maintenance and testing by providing adequate physical and visual access to their contents.
Additional Information: Instrument racks provide a location for mounting instruments and wiring.[6636]

13.2-2 Cabinet Lighting

Cabinets requiring maintenance inside the enclosure should have permanent lighting.
Additional Information: Permanently installed lighting should be an aid to personnel in diagnostics, repairs, and troubleshooting. Using hand-held lights may pose hazards for personnel or cause damage to equipment.[6636]

13.2-3 Minimizing Field-Run Wiring

The amount of field-run wiring should be minimized to avoid errors in identifying and connecting wires.
Additional Information: The amount of wiring carried out in the field may be reduced by using multi-connector connections and pre-assembled wiring harnesses. Connectors may have features preventing problems such as improper indexing, electrical shorts, and inadvertent contacts.[6636]

13.2-4 Protective Electrical Grounds for Cabinets

A protective ground should be provided.
Additional Information: All cabinets where the operating voltage is greater than 50 volts should have a protective ground. Protective power grounds should be routed separately from signal grounds. Inadequate electrical grounding may cause electrical shocks to plant personnel resulting in injury or sudden motion that may damage plant equipment.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.3 Equipment Packaging
13.3.1 General

13.3.1-1 Organized by Maintenance Specialty
Parts and modules should be packaged, laid out, and mounted so that maintenance performed by one maintenance specialist does not require removing or handling of equipment or components maintained by another specialist.
Additional Information: Reducing the number of maintenance specialties involved with each part or module can simplify the process, reduce the likelihood of errors and delays due to communication difficulties between specialists, and reduce the time that equipment is out of service.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.3 Equipment Packaging
13.3.2 Modularization
13.3.2.1 General

13.3.2.1-1 Modularization
Units of equipment should be divided into as many modules as are practical and feasible to support personnel performance during maintenance.
Additional Information: Dividing a unit of equipment into a number of separate modules has several advantages, including making it easier to (1) locate and isolate malfunctions, (2) reach, remove, and maintain components, (3) handle the equipment for installation and repair, and (4) allocate maintenance functions and responsibilities between personnel with different skills.[6636]

13.3.2.1-2 Physical and Functional Interchangeability
If modules are physically interchangeable, they should also be functionally interchangeable to avoid errors in installing the wrong module.
Additional Information: Functionally interchangeable units of equipment perform the same function. Physically interchangeable units of equipment can fit into the same mounting position or fixture. If two units of equipment are interchangeable functionally, they should also be interchangeable physically. However, if they are not interchangeable functionally, they should not be interchangeable physically. Units of equipment having the same form and function should be interchangeable throughout a system and related systems.[6636]

13.3.2.1-3 Distinguishing Noninterchangeable Modules
The appearance of noninterchangeable modules should be distinguishable, and the difference should be apparent when the module is in its installed position.
Additional Information: Interchangeable units of equipment should be clearly identifiable and easily distinguishable from units that are similar, but not interchangeable. Identification methods might be physical (such as size, shape, and mounting provisions) or visual (such as color coding and labeling).[6636]

13.3.2.1-4 Replacement of Failed Components
Equipment should be designed so that components that fail frequently can be easily replaced.
Additional Information: Lamps and fuses are examples of parts that fail more frequently. If a module has parts that are significantly less reliable than the remaining ones, the unreliable parts should be accessible without removing the module.[6636]

13.3.2.1-5 Maintenance in Installed Location
When possible, modules should be designed so that they can be maintained in their installed position, without requiring disconnection, disassembly, or removal of other modules.[6636]

13.3.2.1-6 Removal and Testing
Modules should be designed to permit testing when they are removed from their installed position.
Additional Information: Personnel should not be required to re-install a module into the system to determine whether it has failed, because errors may occur during installation. Other system characteristics also may mask faults in the module. These problems may be avoided by testing the module directly.[6636]

13.3.2.1-7 Installation and Testing
Each module should allow separate installation and functional testing before the complete system is integrated.
Additional Information: The design should allow maintenance personnel to test and confirm that the installed module is functioning properly before the complete system is installed.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.3 Equipment Packaging
13.3.2 Modularization
13.3.2.1 General

13.3.2.1-8 Installation and Calibration
Modules should require little or no calibration immediately after installation.[6636]

13.3.2.1-9 Interconnectivity
The number of inputs and outputs associated with a module should be minimized, where possible, to reduce the likelihood of errors in installing connections or testing multiple inputs and outputs.[6636]

13.3.2.1-10 Modularization Method
The modularization of digital equipment should be based on a systematic method that can be readily understood by maintenance personnel.
Additional Information: Modularization, dividing a unit of equipment into individual modules, is a design strategy for enhancing maintainability. The following lists modularization methods that were recommended for the commercial aviation industry, in order of preference: (1) logical flow packaging, (2) circuit packaging, and (3) component packaging. In logical flow packaging, circuits, parts, and components are packaged and arranged in correspondence with their functional relationships. In circuit packaging, all parts of a single circuit or logically related group of parts, and only that circuit or group, are placed in a separate module. In component packaging, similar parts or components are located together, for example, all the fuses or all the relays might be grouped together.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.3 Equipment Packaging
13.3.2 Modularization
13.3.2.2 Logical Flow Packaging

13.3.2.2-1 Isolating Module Faults via Single Input-Output Checks

When logical flow packaging is used to modularize digital equipment, a module should be designed so that only single input and output checks are necessary to isolate a fault in it.[6636]

13.3.2.2-2 Indication of Unidirectional Signal Flow

When logical flow packaging is used to modularize digital equipment, the unidirectional signal flow within a module should be clearly indicated.[6636]

13.3.2.3-1 Locating Parts in a Single Module

When circuit packaging is used to modularize digital equipment, all parts of a given circuit or group of logically related parts should be located in a single module to help personnel find and test them. *Additional Information:* Testing and diagnosis may be difficult if related parts are distributed in different locations.[6636]

13.3.2.3-2 Only One Circuit or Group of Related Parts Per Module

When circuit packaging is used to modularize digital equipment, a module should contain only one circuit or group of related parts to support testing and diagnosis.
Additional Information: If a module contains multiple circuits or groups, then testing and diagnosis may be difficult (e.g., personnel may access the wrong parts when testing a circuit.)[6636]

13.3.2.3-3 Packaging a Circuit as a Single Terminal-Board or Plug-In Module

When circuit packaging is used to modularize digital equipment, the circuit should be packaged as a single terminal board or plug-in module, when possible, to support its testing and installation.
Additional Information: Providing a single board or module reduces the number of parts that must be handled and reduces the likelihood of errors during handling, testing, and installation.[6636]

13.3.2.3-4 Grouping Circuits to Minimize the Crossing of Signals

When circuit packaging is used to modularize digital equipment, circuits should be grouped to minimize criss-crossing of signals among modules.
Additional Information: When circuits are improperly grouped, crossed signals may result from handling errors. Furthermore, crossed signals can complicate fault detection and diagnosis.[6636]

13.3.2.4-1 Grouping Components with Similar Replacement Schedule

When using component packaging to modularize digital equipment, similar parts that are likely to require replacement at approximately the same time should be grouped together.[6636]

13.3.2.4-2 Grouping Components with Similar Servicing Requirements

When component packaging is used to modularize digital equipment, components requiring the same maintenance work should be grouped together, e.g., test points or components requiring a particular cleaning method.[6636]

13.3.2.5-1 Design for Removal and Replacement
Printed circuit boards should be designed and mounted for ease of removal and the elimination of errors during replacement.
Additional Information: The physical design should make it impossible to install a printed circuit board upside down or backwards.[6636]

13.3.2.5-2 Plug-In Printed Circuit Boards
Plug-in printed circuit boards should be structurally rigid and easy to remove and replace, providing finger access and gripping aids if necessary.[6636]

13.3.2.5-3 Feedback When Installing Plug-In Printed Circuit Boards
Feedback should be provided to the maintainer when plug-in printed circuit boards are securely connected.
Additional Information: For example, a tactile or audible "click" may indicate that the printed circuit board has been properly inserted.[6636]

13.3.2.5-4 Identification of Printed Circuit Boards and Parts
Printed circuit boards should be marked to identify the board and the parts mounted on it.
Additional Information: MIL-STD-130J (U.S. Department of Defense, 1997) has guidance for identifying printed circuit boards. MIL-STD-454 (U.S. Department of Defense, 1985) Requirement 67, gives guidance on providing references for parts mounted on a printed circuit board.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS

13.3 Equipment Packaging

13.3.3 Layout

13.3.3.1 Module Accessibility

13.3.3.1-1 No Interference from Other Parts
Modules should be laid out so that all parts can be removed and replaced without interference from or removal of other parts.
Additional Information: Units that may have to be removed for maintenance should be situated so they can be moved without interference in straight horizontal or vertical paths.[6636]

13.3.3.1-2 No Stacking of Parts
To support accessibility, parts that make up a module should be mounted in an orderly, flat, two-dimensional array and should not be stacked one on top of another.
Additional Information: An orderly, two-dimensional array allows parts to be accessed individually. Stacking is not recommended because some parts must be removed to provide access to the parts located below or behind them.[6636]

13.3.3.1-3 Consistent Orientation
If a module has more than one part of the same type that must be inserted in a particular orientation, all such parts should be oriented in the same direction.
Additional Information: For example, a set of connectors should be installed with the same orientation.[6636]

13.3.3.1-4 Spacing of Parts
The parts that make up a module should be spaced and oriented so that required tools can be used without difficulty.
Additional Information: For example, the spaces between parts should accommodate the use of test probes or soldering irons. Parts should be oriented so they can be reached with the required tools.[6636]

13.3.3.1-5 Separation of Parts and Wiring on Printed Circuit Boards
To support accessibility for testing parts on printed circuit boards, all parts should be mounted on one side of the board and all wiring, including printed circuits, should be located on the other side.
Additional Information: Damage to circuit boards during testing can be avoided by making parts accessible.[6636]

13.3.3.1-6 Spacing of Terminals
Terminals to which wires are to be soldered should be far enough apart so that work on one terminal does not damage neighboring terminals or nearby parts.[6636]

13.3.3.1-7 Indicator Lights
If a module has indicator lights, it should be possible to change them from the front panel, without opening or removing the module.[6636]

13.3.3.1-8 Shutoff Switches
If the module contains emergency shutoff switches, they should be positioned within easy reach, and they should be located or guarded to prevent inadvertent operation.[6636]

13.3.3.1-9 Test, Adjustment, and Connection Points
Test points, adjustment points, and cable and line connectors should be located where the maintainer can see them easily and operate on them without interference.[6636]

13.3.3.2-1 Grouping Maintenance Display Devices
All maintenance display devices relevant to a particular task should be grouped together and located where they can easily be seen.[6636]

13.3.3.2-2 Separate Maintenance and Operational Display Devices
If a unit of equipment contains both maintenance and operational display devices, the two types of devices should be separated.[6636]

13.3.3.2-3 Separate Maintenance and Operational Displays in a Display Network
If a display device contains displays for both maintenance and operations personnel, then the maintenance displays should have a separate location in the display network.
Additional Information: Maintenance displays should not be located within the same part of the display network as operational displays because their presence may interfere with the ability of operators to promptly access operational displays. Displays used by maintenance personnel generally should not be accessible by operational personnel, unless operators need them to perform their tasks. Access to maintenance displays should be protected by passwords, key locks, or similar measures.[6636]

13.3.4-1 Support for Hinged Mounting
If a module is mounted on hinges, supports should hold the module in the "out" or "open" position.
Additional Information: Parts and wiring should be positioned so that they are not damaged during opening and closing; see Guideline 13.1.5-3.[6636]

13.3.4-2 Rests and Stands
If a module contains parts that might be damaged when it is moved into position for maintenance, it should include rests or stands that are integral with the construction of the module to protect those parts.[6636]

13.3.4-3 Preventing Mounting Errors by Physical Design
Modules should be designed so that it is physically impossible to mount them incorrectly.
Additional Information: Incorrect mounting includes reversal, mismating, and misaligning. Measures to prevent incorrect mounting include (1) incorporating keys or other aligning devices, (2) using asymmetrical mounting brackets, and (3) having asymmetrical mounting holes.[6636]

13.3.4-4 Controls
Modules should be mounted so that it is unnecessary to disconnect controls that may be needed for maintenance.[6636]

13.3.4-5 Front Access
Replaceable modules should be accessible through the front of the equipment, rather than the back, if the panel or console is not used by operators.
Additional Information: Convenient access can reduce the likelihood of damage during installation, replacement, and testing. However, if maintenance is to be performed on-line, then access to the module access should not interfere with plant operations.[6636]

13.3.4-6 Orientation of Modules within Cases
If a module has a case, the proper orientation of the module within its case should be obvious, preferably through the physical design of the case, rather than through labeling.[6636]

13.3.4-7 Connectors
Electrical connections between modules should be simple and minimize the demands for manual dexterity.
Additional Information: A plug-in connector requires minimal dexterity. Connectors requiring greater dexterity may be used when there are special requirements, such as holding power or sealing.[6636]

13.3.4-8 Standard Connectors
Connectors should be standardized as much as possible.
Additional Information: Standardization reduces the need for different techniques for using each connector and may reduce the likelihood of errors from using the wrong technique.[6636]

13.4-1 Location of Fuses and Circuit Breakers
Fuses and circuit breakers should be grouped in a minimum number of centralized, readily accessible locations for removal, replacement, and resetting.
Additional Information: Fuses should be located so they can be replaced without removing any other components.[6636]

13.4-2 Verification of an Open Circuit
An indication should be given when a fuse or circuit breaker has opened a circuit.[6636]

13.4-3 Individual Fused Units
Fuses or circuit breakers should be provided so that each unit of a system is separately fused and adequately protected from harmful variations in voltages that personnel may cause.[6636]

13.4-4 Worker Safety
Fuse installations should be designed so that only the neutral ("cold") terminal of the fuse can be touched.
Additional Information: Shocks received from equipment may injure maintenance workers or cause them to make sudden movements, which can damage equipment.[6636]

13.4-5 Safeguarding the Circuit
Fuses should be provided that safeguard the circuit if the wrong switch or jack position is used.[6636]

13.4-6 Easily Removed Fuse Holders
Fuse holder cups or caps should be easily removed by hand.
Additional Information: Fuse holder cups or caps should be of the quick-disconnect type rather than the screw-in type; they should be knurled and large enough to be handled easily. Replacing fuses should not require special tools, unless they are needed for safety.[6636]

13.4-7 Identifying Fuses and Circuit Breakers
Fuses and circuit breakers should be permanently labeled or marked.
Additional Information: The labeling or marking should be legible in the anticipated ambient work conditions. Both fuses and fuse holders should be labeled.[6636]

13.4-8 Indicating Fuse Ratings
A fuse's rating should be indicated on the fuse and adjacent to the fuse holder.
Additional Information: The rating should be in whole numbers, common fractions, such as ½, or whole numbers and common fractions, such as 2½ .[6636]

13.4-9 Identifying Affected Circuits
The area of equipment served by a fuse or circuit breaker should be identified.[6636]

13.5-1 Standard Labels
Equipment labels should be standardized as much as possible.[6636]

13.5-2 Information Content of Labels and Markings for Modules
Modules should be labeled or marked to supply information needed by maintainers.
Additional Information: Labels or markings used for modules should
- outline and identify functional groups of parts
- identify each part by name or symbol
- indicate direction of current or signal flow to aid troubleshooting
- identify the value and tolerance level of parts or test points, if applicable
- identify each part by a unique serial identification number [6636]

13.5-3 Visibility of Labels and Markings
Labels and markings on parts or in cabinets should be placed so that the maintainer can see them without having to move or remove anything.
Additional Information: The maintainer should not be required to remove parts or move wires to read labels and markings.[6636]

13.5-4 Consistent Placement of Labels and Markings
Labels and markings should be consistently placed in relation to the parts to which they refer.
Additional Information: This placement may be on, or immediately adjacent to, the part.[6636]

13.5-5 Luminescent Labels
If labels must be read under very low ambient light, they may be marked in phosphorescent colors.[6636]

13.5-6 Electrical Parts
Small electrical parts that are attached to mounting boards, such as resistors and capacitors, should be labeled or marked on the mounting boards.
Additional Information: Labeling and marking should appear on the mounting boards if the parts are too small to accommodate legible, salient labels and markings.[6636]

13.5-7 Identification of Parts
Parts should be identified with labels or markings.
Additional Information: Labels or markings should be placed either on the parts themselves or on the chassis or adjacent board. The following types of parts that should be labeled or marked:
- All parts identified by designations in drawings, schematics, and parts descriptions of the module
- All wires, sockets, plugs, receptacles, and similar parts designated in wiring diagrams of the module
- All replaceable mechanical parts
- All semi-fixed electrical items, such as fuses and ferrule-clipped resistors
- Items having critical polarity or impedance ratings [6636]

13.5-8 Identification of Terminals on Terminal Strips or Blocks
The terminals of terminal strips or blocks should be labeled on the strip or block, or on the chassis, adjacent to the terminals.[6636]

13.5-9 Identification of Terminals on Parts

When parts have terminals (e.g., transformers, relays, and capacitors), each terminal should be identified by an adjacent label.[6636]

13.5-10 Identification of Parts Accessible from Both Sides

Receptacles that are accessible from both sides of a board or panel should be identified on both sides.
Additional Information: Some boards and panels contain receptacles that allow parts to be accessed from either side.[6636]

13.5-11 Durability of Markings

Markings should be durable enough to last the life of the equipment.[6636]

13.5-12 Marking Stacked Parts

If parts or modules are stacked, marking should permit identification of the individual parts or modules.
Additional Information: Stacking of parts or modules is not recommended (see Guideline 13.3.3.1-2).[6636]

13.5-13 Marking Enclosed or Shielded Parts, Modules, Test Points, and Service Points

Enclosed or shielded parts, modules, test points, and service points should be marked both outside the enclosure or shield, and inside it.[6636]

13.5-14 Hazard Warnings

If there is any hazard from a part or module, a warning or caution label should be provided on it, on the case or cover, or both.[6636]

13.5-15 Labeling Symmetrical Parts

Parts that are symmetrical should be labeled or marked to indicate their proper orientation for mounting.[6636]

13.5-16 Insertion Holes

If a module has holes through which parts must be aligned and then inserted, labels showing the proper orientation of the part should be placed adjacent to the holes.
Additional Information: Tubes and connectors are examples of parts that may be inserted through holes in modules.[6636]

13.5-17 Auxiliary Information for Parts

Parts to which auxiliary information applies should be labeled with that information.
Additional Information: Examples of auxiliary information include values and tolerances of resistors and capacitors. This information should be in an easily readable form.[6636]

13.6-1 Misalignment
Controls and displays should be designed to prevent misalignment that might be caused by vibration, service use, or accidental contact.[6636]

13.6-2 Controls and Feedback
Each adjustment control should provide feedback.
Additional Information: This feedback might be visual, audible, or tactile.[6636]

13.6-3 Simultaneous Access to Controls and Displays
Maintainers should have simultaneous access to an adjustment control and its associated display or other source of feedback.
Additional Information: Maintainers should be able to observe the effects of adjustments as they are made.[6636]

13.6-4 Differentiating Maintenance Controls from Operational Controls
Maintenance and operational controls should be clearly differentiated.[6636]

13.6-5 Location of Maintenance and Operational Controls
The maintenance and operational controls should not appear on the same panel if maintenance and operation of a unit of equipment are performed by different sets of people.
Additional Information: If maintenance and operational controls must appear on the same panel, the maintenance controls should be grouped and separated from the operational controls. If appropriate, the maintenance controls might also be guarded with removable covers so as not to interfere with the operator's performance.[6636]

13.6-6 Independence of Adjustment Controls
Where possible and practical, the adjustment of one control should be independent of the adjustments of others.[6636]

13.6-7 Sequential Adjustments
If the adjustment of one control affects the adjustment of another, the controls should be arranged in sequential order, and labeled or marked to indicate the order of adjustment.[6636]

13.6-8 Functionally Related Adjustments
If a single control is used to affect multiple variables, then the user interface should be designed to prevent mode errors.

Additional Information: Mode errors occur when the user performs an action that is appropriate for one mode when a different mode is in effect. Four design strategies for preventing mode errors are eliminating modes, making modes distinct, providing different inputs for different modes, and coordinating inputs across modes. Eliminating modes prevents mode errors by eliminating the conditions under which they occur (i.e., if there are no modes there can be no mode errors). Making modes distinct deals with the problem through feedback. By saliently indicating the currently active mode, operators are more likely to be aware of it and less likely to provide an incompatible input. Providing different inputs for different modes addresses the problem by ensuring that the same input is not valid in more than one mode. Thus, if the operator provides an input while in the wrong mode, the system will not accept it. Coordinating inputs across modes ensures that a command producing a benign effect in one mode does not produce a severely negative effect in another mode.[6636]

13.6-9 Degree of Adjustment
Controls should accommodate the degree of adjustment required; that is, gross adjustment, fine adjustment, or both.[6636]

13.6-10 Mechanical Stops
Adjustment controls intended to have a limited range of motion should have mechanical stops.
Additional Information: These stops should be able to withstand a force or torque 100 times greater than the resistance to movement within the range of adjustment.[6636]

13.6-11 Previous Settings
If a task requires that a maintainer be able to quickly return a control to its previous setting, the control should have a scale and pointer, or equivalent.[6636]

13.6-12 Preventing Inadvertent Adjustment
Adjustment controls should be located and mounted so that they cannot be adjusted inadvertently.[6636]

13.6-13 Critical or Sensitive Adjustments
Critical or sensitive adjustments should incorporate features, such as locking devices, to prevent inadvertent or accidental adjustment.
Additional Information: If a locking device is used, its operation should not change the adjustment setting.[6636]

13.6-14 Hand or Arm Support
If an adjustment control or the maintainer will be subject to vibration during adjustment, a suitable hand or arm support should be provided.
Additional Information: Vibrations can cause the maintainer to overshoot or undershoot the desired adjustment value.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.7 Test Points and Service Points
13.7.1 General

13.7.1-1 Ease of Servicing
Equipment should be designed so that it can be serviced in its installed position to prevent errors associated with disassembling and reassembling it.[6636]

13.7.1-2 Appropriate Use of Test Points
Test points should be provided on units of equipment as required to support personnel in checking, adjusting, and troubleshooting it.
Additional Information: Strategically placed test points make signals available to maintenance personnel. Test points may not be required if the equipment has self-checking capabilities.[6636]

13.7.1-3 Single Adjustment Control Per Test Point
A test point should not have more than one associated adjustment control.[6636]

13.7.1-4 Ground Points
Special grounding points should be provided, as needed, in locations in which surfaces have poor electrical grounding characteristics.
Additional Information: Maintainers may have difficulty if only painted surfaces are available for ground connections.[6636]

13.7.2-1 Test Points for Units of Equipment
Where possible, each input to and output from a unit of equipment should have test points to support testing and diagnosis of faults.[6636]

13.7.2-2 Tracing Signals
Test points should be provided to permit the systematic tracing of signals and voltages through a unit of equipment to support fault detection and diagnosis.
Additional Information: These test points allow a maintainer to determine the point at which signals or voltages in a malfunctioning unit are out of tolerance.[6636]

13.7.2-3 Test and Service Point Accessibility
All test and service points should be visible and physically accessible to the maintainer for checking and troubleshooting.
Additional Information: Recommended minimum clearances are 19 mm (0.75 in) when only finger control is required, and 75 mm (3 in) when using gloves.[6636]

13.7.2-4 Proximity of Controls, Displays, and Test Points
Test points should be located in physical and visual proximity to the controls and displays used to make the adjustments.
Additional Information: The adjustment control should provide a signal detectable at the test point that clearly indicates when the correct adjustment has been made.[6636]

13.7.2-5 Proximity of Controls, Displays, and Service Points
Service points should be located in physical and visual proximity to the controls and displays used when adjusting them.[6636]

13.7.2-6 Test and Service Point Location
Test and service points should be provided, designed, and located in accordance with their frequency of use and any time-limits on maintenance.
Additional Information: Isolated test or service points should be avoided because they are likely to be overlooked or neglected.[6636]

13.7.2-7 Compatibility of Test and Service Points
Test and service points should be designed for compatibility with checking, troubleshooting, and servicing procedures, and with test and service equipment.[6636]

13.7.2-8 Distinctive Connections
Each type of test or service equipment should have distinctively different connectors or fittings to minimize the likelihood of error.
Additional Information: Providing visually distinct connectors or fittings for different types of test and service equipment may reduce the likelihood that a maintainer will mistake one type for another. Physical differences between different types of connectors and fittings may prevent a maintainer from connecting the wrong piece of test or service equipment, if it is physically incompatible with the test or service connector or fitting.[6636]

13.7.2-9 Distinguishable Marking

Test and service points should be designed and marked so that they are easily distinguishable from each other.

Additional Information: If color coding is used, the color of test points should clearly differ from that of service points.[6636]

13.7.3-1 Access Openings for Test Equipment
Access openings necessary to connect test equipment should accommodate maintainers, equipment, and required tools.[6636]

13.7.3-2 Test Probe Guides
Suitable guides for test probes should be provided when test points are located internally to an enclosure. *Additional Information:* When a maintainer inserts a test probe through an opening in an enclosure, a guide can help the test probe make contact with the internal test point.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.8 Test Equipment
13.8.1 General

13.8.1-1 Built-In Test Capabilities
All test capabilities for a unit of equipment should be built in, to the extent feasible, to reduce the likelihood of testing errors.
Additional Information: Built-in test capabilities can avoid errors associated with disassembling plant equipment or connecting test equipment. The handling involved with removing and transporting a component to a test site may introduce new faults in sensitive equipment. Built-in diagnostics and testing features allow equipment to be tested in place. If it is not practical or possible to incorporate all test equipment, then test jacks may be provided to allow internal components to be tested by external test devices without disassembling the plant equipment.[6636]

13.8.1-2 Appropriate Use of Alarms
If critical equipment is not regularly monitored, an alarm should be provided to indicate malfunctions or conditions that would cause personnel injury or equipment damage.
Additional Information: The alarm may be auditory, visual, or both. If an auditory alarm would be overly intrusive or disruptive, the alarm should be visual. A combination of auditory and visual alarms should be provided when the ambient illumination may impair the maintainer's ability to see the latter. A high degree of ambient illumination may cause visual glare, affecting the detection of light-emitting alarms. A low degree of ambient illumination may interfere with their ability to detect and read alarms on light-reflecting displays.[6636]

13.8.1-3 Accuracy of Test Equipment
The accuracy of test equipment should be consistent with testing requirements.
Additional Information: In general, the accuracy of test equipment should exceed that of the equipment being tested.[6636]

13.8.1-4 Instructions
Clearly written and easily understandable operating instructions for the test equipment should be available to the maintainer.[6636]

13.8.1-5 Labels
Equipment labels should identify all items the maintainer must be able to recognize, read, or use.
Additional Information: The test equipment should be labeled to identify the equipment, its purpose, and any precautions that should be observed in its use. There should be adequate warnings wherever potential hazards exist.[6636]

13.8.1-6 Minimizing Errors
The test equipment should be designed to minimize the occurrence of errors by the maintainer.
Additional Information: If possible, it should provide messages to support the detection of errors.[6636]

13.8.1-7 Minimizing Hazards
When possible, fail-safe features should be incorporated in test equipment to minimize dangers to maintainers or equipment.
Additional Information: For example, test equipment should have fuses or other protective features to prevent damage or injury if a wrong switch or jack position is used.[6636]

13.8.2.1 General

13.8.2.1-1 Automated Aids

Fault isolation, inspection, and checkout tasks should be automated to the extent practical to support personnel performance.

Additional Information: These tasks are prone to human error. At a minimum, self-check diagnostic tests should operate automatically on power up of plant equipment and at the operator's request.[6636]

13.8.2.1-2 On-Line Diagnostics

Computer systems should have on-line diagnostic capabilities, if the detection and diagnosis of computer faults is required.

Additional Information: The detection and diagnosis of computer faults can be complicated and difficult. On-line diagnostic capabilities, which allow computer systems to be tested while they are running, can be effective for finding faults because they test the computer under operating conditions. On-line diagnostic capabilities should be able to check both hardware and software when the symptoms may appear similar to maintenance personnel. Checks may be used to detect software malfunctions and unauthorized changes in software.[6636]

13.8.2.2-1 Continuous On-Line Self-Testing
The capability for continuous on-line self-testing should be provided when practicable to support prompt detection of faults.
Additional Information: Continuous on-line self-testing allows tests to be performed with minimal involvement by personnel, and can reduce the amount of time between the occurrence and the detection of a fault. Tests may include, but should not be limited to, random access memory and read-only memory failure checks, arithmetic processing unit failure checks, data link buffer checks, and central processing unit reset of watchdog timers. For safety-related systems, testing features should be designed to reduce the complexity of safety-related software logic and data structures.[6636]

13.8.2.2-2 Periodic Testing
The capability for periodic functional testing that is manually initiated but executed automatically should be provided when personnel require control of the test intervals.
Additional Information: Automatic execution of tests is preferred when human errors may cause transients.[6636]

13 MAINTAINABILITY OF DIGITAL SYSTEMS
13.8 Test Equipment
13.8.2 Automatic Test Equipment
13.8.2.3 Bypasses for Plant and Test Equipment

13.8.2.3-1 Automatic Bypass
When a test is initiated manually, the correct bypasses required for testing should be established automatically, and the operators should be aware of all of them.
Additional Information: When a component is tested, it may be necessary to bypass other systems or functions associated with the component to prevent them from being affected. The operators should be made aware of these bypasses.[6636]

13.8.2.3-2 Indicators for Test and Bypass Status
Local indication of pass or fail for test and bypass status should be provided for periodic functional tests.
Additional Information: Indicators should be provided at the local cabinet to quickly show the pass or fail status for the test, and the status of bypasses.[6636]

13.8.2.3-3 Removal of Automatic Bypass
When a periodic functional test sequence is completed, all bypasses established to allow the test to be performed should be automatically removed, to relieve the operator of this task.
Additional Information: Indications should be given to allow operators to verify the status of the bypasses and that the system has been properly reconfigured for normal operation. Removal of automatic bypasses may reduce the potential for errors that could unintentionally activate equipment.[6636]

13.8.2.3-4 Bypassed Diagnosis Routines
To support the diagnosis of faults, diagnosis routines that are bypassed during maintenance should be run again before equipment is put back in service.
Additional Information: When a component is serviced, it may be necessary to disable some automatic diagnosis routines. Running the routines before the equipment is put back into service ensures that they are available. It also supports the detection of any faults that may have occurred during testing. Failure to restore the diagnostic routines may increase the time required to detect future faults.[6636]

13.8.2.4-1 Loss of Redundancy
If part of a redundant system, unit of equipment, module, or component becomes inoperable, an alarm signaling the loss of redundancy should be provided to the user immediately.
Additional Information: Users should be able to acknowledge such an alarm, but the lack of available redundancy should be continuously displayed until the redundant system, equipment, module, or component becomes operable again.[6636]

13.8.2.4-2 Overload Indications
Overload indications should be provided for equipment subject to this condition.
Additional Information: This indication should be provided even if the equipment continues to operate when overloaded.[6636]

13.8.2.4-3 Identification of Acceptable Ranges
When practical, the ranges for which test values are within acceptable limits should be indicated on built-in test equipment.
Additional Information: For example, an acceptable reading for a meter or an acceptable wave shape for an oscilloscope should be coded for each position of the rotary switch of the built-in test equipment.[6636]

13.8.2.4-4 Out-of-Range Indicators
If equipment has failed or is not operating within acceptable limits, an indication should be provided.[6636]

13.8.2.4-5 Power Failure Indicators
If a power failure occurs, an indication should be given.
Additional Information: A power-on indicator that extinguishes with loss of power should be provided. If a fuse or circuit breaker has opened a circuit, there should be an indication.[6636]

13.8.2.5-1 Inclusion of Fault Messages
Fault messages should only be shown if they add value to the maintenance process.
Additional Information: The presence of unnecessary fault messages can reduce the effectiveness of maintenance personnel by increasing the workload associated with locating and using messages that support diagnosis and repair. The flexibility of computer-based technologies and the needs of secondary users of the maintenance system can result in the inclusion of variables and capabilities that do not support the performance of primary users. Limiting messages to those that are valuable to the maintenance process can help personnel use the automated test equipment effectively. The status of some variables can be determined by direct observation without using automated test equipment. The appropriateness of including these variables in a test device should be based on consideration of their effects on maintenance performance. Thus, the burdens associated with viewing additional variables should be weighed against the potential benefits of having fault indications consolidated in a test device.[6636]

13.8.2.5-2 Direct Interpretation of Test Results
Messages provided by test equipment should require a minimum amount of interpretation.
Additional Information: Messages provided by test equipment should not use abbreviations, contractions, or numeric codes. Conversion tables should not be needed to determine whether the equipment is within tolerances. Test equipment that requires maintenance personnel to read codes and then look up the code on a table to obtain an explanation are susceptible to errors in reading, recording, and looking up the codes.[6636]

13.8.2.5-3 Identification of Failure Location
Test features should identify the location of the detected failure to the lowest replaceable module.
Additional Information: Test equipment should also inform maintenance personnel of the types of actions required to return the equipment to service. For example, even though the failure exists in component A, the corrective action may require that components B, C, and D be replaced at the same time.[6636]

13.8.2.5-4 Identification of Out-of-Tolerance Signals on Collating Test Equipment
If equipment fails a test performed by collating test equipment, the test equipment should indicate which signal(s) are out of tolerance.
Additional Information: Collating test equipment presents the results of two or more checks as a single display; for example, a "test passed" light illuminates only if all of the relevant signals are within tolerance. Collating test equipment reduces the number of displays the maintainer must read, thereby reducing testing time. However, it should identify the out-of-tolerance signal(s) rather than merely indicating that the equipment failed the test.[6636]

13.8.3.1 General

13.8.3.1-1 Requirements for Test Equipment and Bench Mockups
Test equipment and bench mockups should be treated like any other equipment with respect to the HFE design requirements for units, covers, cases, cables, connectors, test points, displays, and controls.
Additional Information: Test equipment and bench mockups should be designed to be consistent with the capabilities of users and to prevent personal injury.[6636]

13.8.3.1-2 Selector Switches
Selector switches should be used rather than many, individual plug-in connections as long as the effects of switching do not degrade the desired information.
Additional Information: When connecting test equipment to particular circuits, selector switches can be used more quickly than many, individual plug-in connections, and can reduce the likelihood of incorrect or faulty connections.[6636]

13.8.3.1-3 Minimizing Test Equipment Accessories
The number and types of test equipment accessories, such as connectors and test cables, should be minimized.[6636]

13.8.3.1-4 Minimizing Test Equipment Controls, Displays, and Modes
Test equipment should be simple to operate and have a minimum number of controls, displays, and modes.
Additional Information: Controls and displayed information should be organized to reduce the amount of mental effort required to find, access, and use them. Test equipment should not have many individual control and display devices that the maintainer must coordinate to operate it. However, their number should not be reduced to such a degree that many control and display modes are introduced, which can create opportunities for mode errors.[6636]

13.8.3.1-5 Reducing the Number and Complexity of Steps
The number and complexity of steps required to operate the test equipment should be minimized.
Additional Information: The number and complexity of steps may be reduced by grouping controls, such as by sequence or criticality, or by automating certain operations.[6636]

13.8.3.1-6 Individual Operation
Test equipment should be designed for operation by one person, if practical.[6636]

13.8.3.1-7 Calibration Check
Test equipment should be easily calibrated or equipped with a simple check to indicate whether or not it is out-of-calibration or malfunctioning.
Additional Information: A go/no-go indicator may provide a simple check of the status of the test equipment.[6636]

13.8.3.1-8 Avoid Temporary Equipment Configurations for Testing
The use of temporary equipment configurations for periodic, functional testing of equipment should be avoided.
Additional Information: Temporary equipment configurations include added jumpers, lifting leads, and swapping cables. Built-in test features may alleviate problems experienced in NPPs that result from designs with poor testability.[6636]

13.8.3.2-1 Portable Diagnostic Tools
Portable diagnostic equipment should be provided to aid in fault isolation when built-in equipment is not practical.
Additional Information: Built-in equipment is generally preferable to portable equipment when it eliminates activities prone to error, such as disassembling plant equipment or connecting portable test equipment.[6636]

13.8.3.2-2 Ease of Connection
Portable test equipment should allow rapid and error-free connection to the equipment being tested.
Additional Information: The use of a single, multi-prong connector can avoid errors that could occur if multiple wires were connected individually.[6636]

13.8.3.2-3 Calibration Information
If maintenance personnel are required to verify that test equipment has been calibrated, then this information should be available to them.
Additional Information: A calibration record may be attached to the equipment with this information.[6636]

13.8.3.3-1 Test Point Connections
Test points should permit the connection of the appropriate test equipment, such as voltage meters.
Additional Information: The purpose of a built-in test panel is to allow external test devices to assess internal components without disassembling the plant equipment.[6636]

13.8.3.3-2 Test Point Indication Labeling and Demarcation
Test points should be clearly indicated on the test panel.
Additional Information: For example, test points might be arranged within a miniature block diagram of the system with each block representing components or units of equipment. As another example, an overlay may be provided to indicate the test points that should be checked, the order in which they should be checked, and the tolerance limits for signals.[6636]

APPENDIX A

High-Level Human-System Interface Design Review Principles

Appendix A
High-Level Human-System Interface Design Review Principles

The design of human-system interfaces (HSIs) should support the operating personnel's primary task of monitoring and controlling the plant, without imposing an excessive workload associated with using the HSI (window manipulation, display selection, and navigation, for example). The HSI also should support the recognition, tolerance, and recovery from any human errors. HFE guidelines for design review help to ensure that these goals are achieved. The "high-level" design-review principles contained in this appendix represent the generic HSI characteristics necessary to support personnel performance. While these principles are not detailed review *guidelines*, they serve several purposes. First, they were used to develop many of the detailed review guidelines in this volume. Second, as general principles, they can be used to support the evaluation of aspects of the HSI not well defined by the detailed guidelines. Thus, for example, they can be used in reviewing novel HSI designs, such as display formats not identified in the guidelines. Third, they can support the evaluation of the significance of individual discrepancies in the guideline.

The 18 principles are divided into four categories: general principles, primary task design, secondary task control, and task support (summarized in Table A.1). The categories and the principles that comprise them are described below.

Table A.1 Design review principles

Category	Principle
General	Personnel Safety Cognitive Compatibility Physiological Compatibility Simplicity of Design Consistency
Primary Task Design	Situation Awareness Task Compatibility User Model Compatibility Organization of HSI Elements Logical/Explicit Structure Timeliness Controls/Displays Compatibility Feedback
Secondary Task Control	Cognitive Workload Response Workload
Task Support	Flexibility User Guidance and Support Error Tolerance and Control

A.1 General Principles

These principles ensure that the HSI design supports personnel safety, and is compatible with their general cognitive and physiological capabilities.

- *Personnel Safety* – The design should minimize the potential for injury and exposure to harmful materials.
- *Cognitive Compatibility* – The operator's role should consist of purposeful and meaningful tasks that enable personnel to maintain familiarity with the plant and maintain a level of workload that is not so high as to negatively affect performance, but sufficient to maintain vigilance.
- *Physiological Compatibility* – The design of the interface should reflect consideration of human physiological characteristics including visual/auditory perception, biomechanics (reach and motion), characteristics of motor control, and anthropometry.
- *Simplicity of Design* – The HSI should represent the simplest design consistent with functional and task requirements.
- *Consistency* – There should be a high degree of consistency between the HSI, the procedures, and the training systems. At the HSI, the way the system functions and appears to the operating crew always should be consistent, reflect a high degree of standardization, and be fully consistent with procedures and training.

A.2 Primary Task Design

These principles support the operator's primary task of process monitoring, decision-making, and control to maintain safe operation.

- *Situation Awareness* – The information presented to the users by the HSI should be correct, rapidly recognized, and easily understood (e.g., "direct perception" or "status at a glance" displays) and support the higher-level goal of user awareness of the status of the system.
- *Task Compatibility* – The system should meet the requirements of users to perform their tasks (including operation, safe shutdown, inspection, maintenance, and repair). Data should be presented in forms and formats appropriate to the task (including the need to access confirmatory data or raw data in the case of higher-level displays), and control options should encompass the range of potential actions. There should be no unnecessary information or control options.
- *User Model Compatibility* – All aspects of the system should be consistent with the users' mental models (understanding and expectations about how the system behaves as developed through training, use of procedures, and experience). All aspects of the system also should be consistent with established conventions (i.e., expressed in customary, commonplace, useful and functional terms, rather than abstract, unusual or arbitrary forms, or in forms requiring interpretation).
- *Organization of HSI Elements* – The organization of all aspects of the HSI (from the elements in individual displays, to individual workstations, to the entire control room) should be based on user requirements and should reflect the general principles of organization by importance, frequency, and order of use. Critical safety-function information should be available to the entire operating crew in dedicated locations to ensure its recognition and to minimize data search and response.
- *Logical/Explicit Structure* – All aspects of the system (formats, terminology, sequencing, grouping, and operator's decision-support aids) should reflect an obvious logic based on task requirements or some other non-arbitrary rationale. The relationship of each display, control, and data-processing aid to the overall task/function should be clear. The structure of the interface and its associated navigation aids should make it easy for users to recognize where they are in the data space and should enable them to get rapid access to data not currently visible (e.g., on other display pages). The way the system works and is structured should be clear to the user.

- *Timeliness* – The system design should take into account users' cognitive processing capabilities as well as process-related time constraints to ensure that tasks can be performed within the time required. Information flow rates and control performance requirements that are too fast or too slow could diminish performance.
- *Controls/Displays Compatibility* – Displays should be compatible with the data entry and control requirements.
- *Feedback* – The system should provide useful information on system status, permissible operations, errors and error recovery, dangerous operations, and validity of data.

A.3 Secondary Task Control

These principles minimize secondary tasks, i.e., tasks that personnel perform when interacting with the human-system interface that are not directed to the primary task. Examples of secondary tasks include activities associated with managing the interface, such as navigation through displays, manipulating windows, and accessing data. Performing secondary tasks detracts from the crew's primary tasks, so the demands of secondary tasks must be controlled.

- *Cognitive Workload* – The information presented by the system should be rapidly recognized and understood; therefore, the system should minimize requirements for making mental calculations or transformations and use of recall memory (recalling lengthy lists of codes, complex command strings, information from one display to another, or lengthy action sequences). Raw data should be processed and presented in directly usable form (although raw data should be accessible for confirmation).
- *Response Workload* – The system should require a minimum number of actions to accomplish an action; e.g., single versus command keying, menu selection versus multiple command entry, single input mode (keyboard, mouse) versus mixed mode. In addition, the system should not require the entry of redundant data, nor the re-entry of information already in the system, or information the system can generate from already resident data.

A.4 Task Support

These principles address the characteristics of the HSI that support its use by personnel, such as providing (1) HSI flexibility so tasks can be accomplished in more than one way, (2) guidance for users, and (3) mitigation of errors.

- *Flexibility* – The system should give the user multiple means to carry out actions (and verify automatic actions) and permit displays and controls to be formatted in a configuration most convenient for the task. However, flexibility should be limited to situations where it offers advantages in task performance (such as to accommodate different levels of experience of the users); it should not be provided for its own sake because there is a tradeoff with consistency and the imposition of interface management workload (which detracts from monitoring and operations tasks).
- User Guidance and Support – The system should provide an effective "help" function. Informative, easy-to-use, and relevant guidance should be provided on-line and off-line to help the user understand and operate the system.
- Error Tolerance and Control – A fail-safe design should be provided wherever failure can damage equipment, injure personnel, or inadvertently operate critical equipment. Therefore, the system should generally be designed such that a user error will not have serious consequences. The negative effects of errors should be controlled and minimized. The system should offer simple, comprehensible notification of the error, and simple, effective methods for recovery.

APPENDIX B

Design Process Guidelines

Appendix B
Design Process Guidelines

Guidelines for reviewing important considerations in the design process aspects of information displays, user interface interaction and management, and computer-based procedure systems are provided in Sections B.1, B.2, and B.3, respectively. (See the Preface for additional information on the purpose of these guidelines).
The review guidelines were formatted to correspond to the NRC's general design process guidelines in NUREG-0711.

B.1 Review Guidelines for the Information Display Design Process

B.1.1 Operating Experience Review (OER)

(1) Available operating experience with advanced information systems should be reviewed to take advantage of lessons learned in the operational use of the systems, as well as to ensure that problematic aspects of their design implementation are addressed.

B.1.2 Function and Task Analysis

(1) The function analysis and task analysis criteria by which information requirements are defined should be clearly documented.

(2) The information requirements established in advanced graphical displays should be based on the operators' cognitive tasks (i.e., situation assessment, monitoring and detection, response planning and response implementation).

(3) The analysis of information requirements should consider the different needs of individual staff in the control room.

B.1.3 Human-System Interface Design

(1) Explicit guidance should be available defining the relationship between the physical form of the display and its meaning with respect to the plant's status.

(2) The information presented and its organization into display pages should be based on considering operators' tasks when using the displays. Display pages should include as much information as can be efficiently represented and interpreted to minimize the need for operators to retrieve additional pages.

(3) When more than one display format is used on a display page, an evaluation should determine whether the user's perception of one format is negatively impacted by the presence of the other one(s).

(4) The density of information on a display page should be evaluated to ensure that important information is readily perceived, and needed information is rapidly identified.

(5) The organization scheme of display pages within the network should be readily apparent to operators.

(6) The effects of instrumentation failures on graphic displays should be analyzed. Potential failure problems should be evaluated with respect to the following:

- Can operators detect a failure of instrumentation?
- Can instrument failures result in representations that are interpreted by operators as real process failures; perhaps more importantly, can real process failures be misinterpreted as instrument failures?
- If operators detect a failure, should use of the display be suspended?
- Since the display integrates many parameters into a single display, what effect does its loss have on operations and how effectively can operators transition to backup displays?

(7) Access to displays within a network should be evaluated to ensure rapid, efficient retrieval of information needed to support operators' tasks.

(8) Unwanted effects of integrating a new, novel graphic representation into a conventional HSI (other displays, other control room HSIs, and environmental considerations such as lighting levels) should be evaluated and minimized.

(9) The following aspects of information system design should be carefully analyzed and evaluated:

- Number of VDUs – to ensure that the display area is sufficient to show the important information needed by operators without them having to perform extensive interface management
- Interface management functions – to ensure that the HSI features are easy to use and provide explicit interface management support
- Flexibility of HSI and display features and functions – to ensure that the flexibility of the system does not unduly burden operators, nor increase the chance of misunderstandings and errors.

(10) Methods should be specified for assuring that plant modifications (such as changes in instrumentation or systems) are incorporated into the display and do not introduce inconsistencies in how they correspond to plant situations, or lead to technical inaccuracies and, possibly, invalid displays.

(11) If display formats are developed for a generic plant design or as an "off-the-shelf" product, any plant-specific inputs to display characteristics need to be analyzed to ensure that the display correctly reflects the relationship between changes in the display format and the changes in the specific plant it is intended to represent.

B.1.4 Training Program Development

(1) The knowledge, skills, and abilities that the operators need to use and understand the information system should be specified.

(2) Operators should be trained on the relationship between the display form and the plant states it is intended to represent, including failure modes and their effect on graphical representation.

(3) Users should be trained in using the interface management features of the information system, including navigation within and between displays, manipulation of on-screen features such as windows, and use of user-definable characteristics and features.

(4) Users should be trained to an acceptable level of proficiency with unfamiliar graphic displays before using them in the control room to ensure that operators are sufficiently familiar with them to correctly assess their meaning.

B.2 Review Guidelines for the User Interface Interaction and Management Design Process

B.2.1 Function and Task Analysis

(1) Analyses of function allocation should be performed for new or modified interface management functions that are associated with important personnel actions. These analyses should consider the effects of new or changed interface management functions on crew situation awareness and workload. Opportunities to automate aspects of interface management to reduce its demands on personnel should be identified.

(2) Task analyses should identify requirements for managing multiple, concurrent tasks, especially during high workload conditions, including factors that affect the pace of tasks, requirements for alternating concurrent tasks, demands for detecting changes and shifting attention, and resulting workload. Operator activities addressed by these analyses should include concurrent access to information and controls, keeping track of in-progress and suspended tasks, anticipating future demands, and coordinating and communicating with other personnel. These analyses should provide a basis for HSI characteristics, including: (1) the types of information and controls that should be presented together on display pages, (2) types of display pages that should be presented together in display networks, (3) the number and placement of display devices (VDUs) in the HSI. These analyses should also provide a basis for the types of interactions between the users and the HSI that are to be supported by the HSI design.

(3) Task analyses should identify specific interface management skills that users will need for managing multiple, concurrent tasks, especially during high workload conditions. These analyses should assess the current skills and skill levels and determine any increment that will be required from formal and on-the-job training.

(4) If a HSI is modified, then the task analyses should address strategies and skills used by personnel in the existing HSI configuration to access and use information and controls. Strategies that users employ for modifying the HSI or adjusting it for particular tasks should be noted for possible inclusion in the HSI design goals. When user modifications and adjustments of the HSI are identified that represent weaknesses of the current design, these weaknesses should be corrected through the design goals for the upgrade. When they represent desirable dimensions of HSI flexibility that should be retained by the HSI upgrade, these desirable dimensions should be identified in the HSI design goals.

(5) Task analyses should identify requirements for multiple individuals to interact with shared displays and controls. These analyses should provide a basis for HSI features that support crew interaction, including group-view displays and methods of human-system interaction that support the sharing of controls and displays. These analyses should also provide a basis for determining training requirements for the use of shared displays and controls.

(6) Task analyses should be conducted to assess the potential effects of interface management tasks on the performance of primary (supervisory control) tasks. These analyses should address demands

associated with use of the interface management features. These analyses should also address tasks associated with malfunctions of the HSI.

B.2.2 Human Reliability Analysis

(1) Human reliability analyses (HRA) should be performed when the introduction of HSI technologies are likely to change interface management demands associated with risk-important tasks to determine the potential impact on reliability. The scope of these human reliability analyses should address personnel actions resulting from the HSI technologies and their interactions with the rest of the plant. Consideration should be given to the effects that changes in the HSI may have on the existing plant HRA, including:

- Whether the original HRA assumptions are valid for the upgraded design
- Whether the human errors analyzed in the existing HRA are still relevant to the upgrade
- Whether the probability of errors by plant personnel may change
- Whether new errors not modeled by the existing HRA and PRA may be introduced
- Whether the consequences of errors established in the existing HRA may change.

B.2.3 Human-System Interface Design

B.2.3.1 HSI Design Process Inputs

(1) Design goals and requirements for interface management features should be derived from analyses of user tasks. These analyses should address: information and control capabilities required by users, requirements for managing multiple concurrent tasks, requirements for multiple individuals to interact with shared displays and controls, and backup information and control capabilities for coping with malfunctions of the HSI. If the HSI component or system will be installed as an upgrade to an existing HSI, then the design goals and requirements should also be derived from analyses of strategies and skills used by personnel in the existing HSI configuration to access and use information and controls.

B.2.3.2 HSI Design Guidance Development

(1) HFE guidelines should be developed and used that specifically address the design of interface management features.

B.2.3.3 HSI Detailed Design and Integration

(1) *General Considerations* – Design requirements should define the types of human-system interactions to be provided to support interface management. The HSI should be designed to reduce cognitive demands associated with interface management tasks so that interference is reduced (1) between interface management tasks and primary tasks, and (2) between multiple interface management tasks that are performed concurrently. By facilitating concurrent task performance, the overall level of operator performance can be increased. The following are specific considerations:

- Simplicity and Ease of Use – Reducing the overall level of cognitive demands required for individual interface management tasks can make cognitive resources available for other concurrent tasks.

- Clear Designation of Tasks – Ambiguity in the presentation of display formats and elements can lead to errors in which the wrong operator response is produced (e.g., as in capture and description errors). These errors may result in the operator performing a plant control action when an interface management action was intended or performing one interface management task when another was intended. Conscious efforts by operators to avoid these errors can increase the overall level of mental workload and divert cognitive resources from other tasks.

- Consistency of Operation – A lack of consistency in the rules of operation for user interfaces can increase mental workload demands because the operator must first recognize the user interface and then retrieve the proper rule from memory. This increased mental workload can interfere with concurrent task performance.

(2) *Display Area* – Analyses should be conducted to determine the number and placement of display devices based on the task requirements of personnel. Design requirements for the number of display devices should reflect the maximum number of tasks that each operator will be performing at one time and the maximum number of display pages that must be viewed concurrently to support those tasks. Design requirements for the placement of display devices should reflect the needs of personnel to use these displays in a coordinated manner, such as integrating information across multiple displays or monitoring multiple displays simultaneously. These determinations should ideally be made after the requirements for the individual display pages and display network have been established.

(3) *Display Density* – Analyses should be conducted to determine the density of information that can be provided in a display.

(4) *Information Organization* – Design requirements for the new HSI component or system should include: (1) information and controls that should be presented together on display pages, and (2) display pages that should be located near each other in the display network. Design decisions regarding the layout of display pages and the display network should be based on analyses that consider the operator's need to view and use related items (i.e., information and controls) together. Both the display pages and the display network should be designed to increase the proximity of related items and minimize information access cost (i.e., the time and attention required for accessing them). Items that must be used together should be located on the same display page. Display pages that are used together or in sequence should have minimal navigation distance between them in the display network.

(5) *HSI Flexibility* – Design decisions regarding the type and degree of flexibility provided in the HSI for interface management should be based on considerations of human performance costs to individual operators. These include: (1) interface management demands, such as the degree to which workload associated with using the HSI flexibility feature diverts cognitive resources from the primary tasks, and (2) the effects that the flexibility have on the primary task (i.e., the degree to which the changes to the HSI brought about by the flexibility feature impair the operator's ability to perform the primary tasks). Features should be provided as a result of careful analyses of task requirements, the level of expertise of the user population regarding interface management, and the performance benefits and costs associated with the use of the HSI flexibility feature. The design of HSI flexibility features should address the need to optimize operator performance under specific conditions and should be consistent with the skills and knowledge of the user population. Flexible features should not be provided as a way of avoiding analyses of user requirements. That is, the work of analyzing operator requirements should not be avoided by providing a design that can be used in many different ways. These analyses should consider the effects that HSI flexibility may have on HSI consistency (i.e., whether it will cause part of the HSI to look or operate inconsistently with the rest of the HSI). These

analyses should also consider human performance benefits associated with the HSI flexibility feature in light of any increases in user workload associated with setting up or operating the feature and of the consequences of any errors associated with its use. In analyzing HSI flexibility, consideration should be given to the effects on other crew members who must view or use HSI components that have been modified by others. Flexible HSI features should not be provided if their use by one individual may have significant negative effects on the performance of other personnel who must also use the HSI component, such as when an HSI component is shared or when one person must monitor the performance of another (e.g. over-the-shoulder observation).

(6) *Separation of Interface Management Features and Plant Control Features* – Consideration should be given to designing interface management feature that utilize different cognitive resources than plant control features.

(7) *Compatibility with Existing Features* – If an HSI is being modified or a new HSI is being integrated into an existing control room, compatibility of interface management methods between the new and existing HSIs should be addressed.

B.2.4 Procedure Development

(1) To minimize demands on memory and search time, plant procedures should identify the proper displays or controls to use for particular tasks if the HSI provides multiple displays and controls that are similar and if confusion may exist regarding the proper one to use.

B.2.5 Training Program Development

(1) Necessary interface management skill should be identified and should be addressed in personnel training. It should also address failure modes of the computer-based system and personnel tasks that result from these failures.

(2) Since operators are required to concurrently perform multiple monitoring and control tasks, they should receive training in strategies for managing concurrent tasks, especially in high-workload situations. This training should explicitly address interface management aspects of performance, such as optimum strategies for allocating and switching viewports in multi-function displays.

(3) The development of training programs to teach interface management skills and strategies should take into account differences in levels of experience and individual differences with respect to the kind of task management strategies employed and their effectiveness.

B.2.6 Human Factors Validation

(1) Validation trials should be conducted to assess the effects of interface management tasks on the performance of primary (supervisory control) tasks to ensure that the both can be performed by operators.

(2) The number and placement of display devices in the HSI should be validated through performance-based trials to assess adequacy and effectiveness under operational considerations. These performance-based trials should take into account operator strategies for dedicating particular display devices to particular displays. These trials should also address the placement of display devices for tasks that require operators to integrate information across display devices and for tasks that require multiple personnel to share controls and displays. For example, the total number of display devices

needed by crew members may be reduced if some are shared among multiple operators. Alternatively, the total number of display devices may be increased if it is determined that additional display devices may be needed to support coordination of activities among personnel, as with the implementation of plant overview displays.

(3) Performance measures developed for validation trials should be sensitive to changes in work methods and performance objectives adopted by operators as the task load increases. Performance measures that are focused entirely on plant performance or operator outputs may not accurately assess the effects that interface management tasks have on personnel performance. As task load increases, there is a natural tendency for operators to adopt less effortful work methods, such as modifying the HSI to require less demanding interactions. There is also a tendency for operators to focus effort on the highest priority task objectives, such as safety, and disregard lower level objectives. Performance measures that do not attempt to capture and describe these changes may provide inaccurate assessments of operator workload. Test scenarios should be developed in conjunction with performance measures to ensure that the measures are appropriate for each scenario.

B.3 Review Guidelines for the Computer-Based Procedure System Design Process

B.3.1 HFE Program Management

(1) CBP design and evaluation should be performed with a multidisciplinary team.

(2) An implementation plan should be developed to deal with CBP design, maintenance, training, and evaluation.

(3) The CBP's design constraints or assumptions should be documented and their implications for safety should be evaluated to ensure they do not compromise the CBP system's goals.

(4) The CBP development program should be fully documented, including design goals and assumptions, use of operating experience, design analyses, establishment of system requirements, tests and evaluations, detailed description of the design, and verification and validation.

B.3.2 Operating Experience Review

(1) The CBP design should eliminate or minimize PBP problems where practical. Experience with paper procedures should be reviewed to take advantage of lessons learned in their operational use, maintenance, and configuration control as well as to help ensure that problems in implementing PBPs are resolved. Table B.3.1 is a partial list of identified PBP problems.

(2) Operating experience with CBP systems should be reviewed to take advantage of lessons learned in using the systems, as well as to ensure that any problems in implementing CBPs are dealt with.

(3) Human performance issues, such as visual fatigue, arising from the computerization of documents and manuals should be addressed.

Table B.1 Examples of deficiencies in paper-based procedures

Issue	Deficiency
Design Process	• Inadequate participation of operations and training personnel in developing procedures • Technically incorrect EOPs • Suitable under standard situations, but less support in unusual situations • Incomplete procedures • Inadequate consideration of the time required to complete procedural actions • Insufficient verification and validation (V&V) of procedures
Implementation	• Nonspecific entry and exit conditions for support procedures • Procedures are fixed and inflexible • Incorrect sequencing of action steps • Inadequate consistency across procedures • Inconsistencies in formatting and use of terminology • Incorrect identification of plant equipment • Inadequate provision for varying level of detail • Non-sequential presentation of information • Difficulties in navigating to related information • Inadequate management of multiple procedures • Unsatisfactory integration of procedure tasks and other tasks • Problems in labeling and headings • Notes and cautions in improper places • Lack of context-dependent highlighting and navigation • Requirements to use multiple procedures simultaneously and move between sections • Lack of flowcharts to guide procedure use • Inadequate support and reference material • Bulkiness • Physical handling of procedures near control panels • Separation from other information sources, such as SPDS • Inconsistency with other HSIs in terms of references to plant equipment
Training	• Operators poorly trained in using procedures
Maintenance	• Maintaining technical accuracy of procedures lacking

B.3.3 Functional Analysis

An overall concept should be developed of the operators' role in managing and supervising plant procedures.

B.3.4 Task Analysis

(1) The effect of the CBP on the tasks of individual members of the crew should be analyzed, considering any potential changes that may result from the combined use of CBPs and PBPs, and also the effect on communications.

(2) CBP tasks should be analyzed and used as an input to its design.

(3) Tasks associated with CBP failure and back-up should be identified to define the requirement for indicating malfunctions. The task of smoothly transitioning from CBPs to a back-up method (such as PBPs) also should be addressed.

B.3.5 Staffing

(1) The demands of operating and maintaining the CBP should be assessed for their implications for personnel skills and qualifications.

B.3.6 Human Reliability Analysis

(1) Any effects on performance caused by computerization of procedures should be analyzed for their implications for those human actions modeled in a PRA.

(2) The analysis should consider the effects on human reliability of loss of CBPs and transfer to PBPs.

B.3.7 Human-System Interface Design

(1) The HSI design should consider methods by which procedure elements are represented in the CBP and the extent to which usability principles for PBPs generalize to CBP systems.

(2) The procedure functions to be provided by the CBP system should be carefully analyzed to ensure that the system is consistent with the utilities' general approach to procedure-based operations, and that the operator's inputs and judgments are included, where appropriate.

(3) The following aspects of CBP design should be carefully evaluated to ensure that the use of procedures is not jeopardized and that task requirements are adequately supported:

- Number of VDUs
- Interface management and navigation functions
- Flexibility of CBP display and operations

(4) The potential interactive effects between procedure use and the hardware and software used to implement them should be evaluated.

(5) The means by which CBPs can support crew cooperation, communication, and decision making should be evaluated.

(6) Operators should be involved in developing and evaluating prototypes to ensure that their final design is usable.

B.3.8 Procedure Development

B.3.8.1 Scope of Procedures

(1) The purpose and scope of the CBP system should be clearly defined.

B.3.8.2 Bases of Procedures

Procedure bases refer to the background information used to develop the CBPs. Procedures are critical management tools because they are among the more important means of guiding human interactions with the plant systems. The procedures must not only prescribe technically correct actions, but must also implement licensee's and the NRC's expectations for the conduct of operations. Consequently, their content should be consistent with the technical, regulatory, and management bases of plant operations, no matter what medium is used to present them.

(1) The technical bases for procedures should be documented. Where the documented bases for paper procedures are unchanged by computerization, the existing document may be used. This should include the sources of technical information, as well as the process by which the information was used to define the desired operator actions and supplemental information, such as cautions and warnings, figures, and tables.

(2) The regulatory bases for procedures should be specified, and the manner in which they were applied in developing the CBPs should be documented.

(3) The management bases for procedures should be documented.

(4) If the CBPs are to be implemented in an operating plant using PBPs, their impact on existing management bases should be evaluated.

(5) If the CBPs are developed for a generic plant design or for new designs, plans and methods should be specified for incorporating the licensee-specific management bases. Since the specific characteristics of the intended users and their work environments may not be known, the methods by which the CBPs can be tailored for them should be identified.

B.3.8.3 Technical Information

(1) The selection of parameters and indicators of plant state to be monitored at each procedure step should be reviewed.

(2) The means by which the CBPs make the following types of assessments should be completely documented and reviewed by a multidisciplinary team, including plant operators:

- Conditions for entering procedures
- Analysis of step logic

- Assessment of cautions and notes
- Performance of calculations
- Assessment of exit conditions from procedures
- Assessment of high-level procedural goals

(3) Procedures should be specifically tailored to the intended users, their physical work environment, and the organization in which the tasks are performed.

B.3.8.4 Maintenance of Procedures

(1) Methods should be specified for assuring that procedure revisions do not introduce technical inaccuracies, or inconsistencies in how the CBPs are presented.

(2) Provisions should be made for temporarily changing procedures. Administrative procedures for introducing and handling procedure changes should identify how to properly implement the changes in the CBP system. These changes should be clearly identified in the CBP's interface.

B.3.9 Training Program Development

(1) The training program should address the role of the operators to assure that they remain in control of the CBP system and independently supervise it.

(2) The knowledge, skills, and abilities that users will require to interact successfully with the CBP should be specified by the designers.

(3) The training requirements for using CBPs should be specified and incorporated into a training program that should cover both initial and ongoing training. Training should consider the design features, functions, and limitations of CBPs (such as the potential for incorrect assessments).

(4) The training program should inform operators about limited and complete failures of the CBP. Operators should be trained to determine when to override CBP evaluations and advice. They should be able to manage the transition to PBPs when CBPs are lost and move back to them when system function is restored.

(5) The training program should address the importance of teamwork and communication when the CBP is being used.

(6) For CBP systems used for EOPs only, the compatibility with day-to-day operations needs to be evaluated to ensure that the system can be easily understood and used.

(7) The means by which the CBP will be introduced and implemented in an operating plant should be specified.

B.3.10 Human Factors Verification and Validation

(1) A verification and validation (V&V) plan should be established.

(2) V&V of procedures should ensure that the CBPs are technically correct and usable. Three types of

design considerations must be addressed when evaluating their usability: (1) HFE design standards and guidelines for human-computer interaction, (2) HFE design guidelines for the format of text instructions and graphics used in presenting procedural information, and (3) the unique influence of site-specific characteristics and users. The acceptability of a CBP system cannot be determined without documentation that all three types of considerations were acceptably addressed.

(3) An independent review team should conduct V&V.

(4) CBP evaluations should use several crews and scenarios. They also should use operator-in-the-loop evaluations to ensure that the system's objectives are achieved and that any transitions between CBP and PBP are accomplished.

(5) Each CBP EOP procedure should be evaluated in the plant's simulator.

(6) Operators should be able to detect CBP errors and failures.

(7) The V&V should establish that crew performance is not degraded as compared with that reached using PBPs.

(8) The criteria for accepting the CBP should be specified.

GLOSSARY

GLOSSARY

Abbreviation – A shortened form of a word or phrase used for brevity.

Acknowledged alarm – An alarm is considered to be acknowledged when the operator has made some type of input to the alarm system (such as pressing a button) to indicate receipt of the alert or message provided by the alarm system. The act of acknowledging an alarm typically causes the attention-getting characteristics of its display to cease or decrease (e.g., the sound stops and the flashing display changes to a steady illumination).

Acknowledgment – Providing feedback to the sender that a message has been received.

Acronym – A word formed from the initial letter(s) of each of the successive or major parts of a compound term.

Action sequence – A set of operations that must be performed sequentially to carry out a control action.

Activated alarm – The condition in which a monitored parameter exceeds a specified limit (setpoint), the deviation is evaluated by the processing portion of the alarm system, and a message is conveyed to the operator via the display portion of the alarm system (e.g., annunciators).

Active window – The window in which user is currently interacting with the system. Typically, this means that an active window (a) is currently receiving input from the user, (b) has last received input from the user, or (c) has been readied for input through the user's explicit action. The user is generally said to be "working in" the active window (such as processing a document, controlling a system, entering data). (See also inactive and closed windows).

Additive color process – Presentation of color images by the simultaneous selective projection of red, green, and blue light on a screen.

Addressing messages – Preparing header information to specify the destination for transmitting data.

Advanced alarm system – A primarily digital alarm system employing alarm processing logic and advanced control (e.g., on-screen controls) and display (e.g., VDU) technology. (This is in contrast to conventional alarm systems, which are largely based on analog instrument and control technologies.)

Advanced control room (ACR) – A control room that is primarily based on digital technology. ACRs typically allow the operator to interact with the plant via computer-based interfaces, such as video display units. This is in contrast to "conventional" control rooms, which provide interaction via analog interfaces, such as gauges.

Adjustment controls – Controls used by personnel to correct or adjust the operation of equipment, such as to set an operating value. These controls may be external, such as controls mounted on maintenance panels, or internal, such as test and relay switches located on printed circuit boards.

Alarm – The term alarm is used in the broad sense, i.e., a plant parameter, component, system, or function that is currently in a state requiring the attention of plant personnel. For example, a monitored parameter exceeds a specified limit (setpoint), the deviation is evaluated by the processing portion of the alarm system, and a message is conveyed to the operator via the display portion of the alarm system.

Alarm availability – The display processing method by which the results of alarm processing are made available to the operating crew. This relates to which alarms are made available to the operator rather than how they are presented (which is referred to as alarm display). Three techniques are identified: filtering, suppression, and prioritization.

Alarm display – The method(s) by which alarm coding and messages are presented to plant personnel.

Alarm generation processing – A class of alarm processing which includes techniques that analyze the existing alarms and, then based upon this, generate alarm messages which (1) give the operator higher level or combined information, (2) notify the operator when "unexpected" alarms occur, or (3) notify the operator when "expected" alarms do not occur.

Alarm message – Information presented to the operator by the auditory, visual, and other display devices of the alarm system in response to an alarm condition.

Alarm processing techniques – The rules or algorithms that are used to analyze plant sensor data to determine their importance, validity, and relevance, and determine whether an alarm message should be presented to the operator.

Alarm signal processing – The process by which signals from plant sensors are automatically evaluated. This process, which includes signal validation and other techniques, determines whether an alarm condition exists.

Alarm system – An automated system consisting of processing and display hardware and software, which processes or analyzes signals from plant sensors and alerts the operator via visual and/or auditory displays when monitored parameters deviate from specified limits (setpoints) or predefined conditions.

Alphabetic – Pertaining to a character set that contains letters and other symbols, excluding numbers.

Alphanumeric – Pertaining to a character set that contains letters, digits, and usually other symbols, such as punctuation marks.

Alphanumeric code – A set of letters and/or numbers used to identify a group of data (e.g., in a table).

Alphanumeric keyboard – A keyboard used for typing letters or numbers into the computer.

Analytical redundancy – The calculation of expected parameter values using a model of system performance.

Annunciator – An indicator of the status of a plant parameter, component, system, or function that does not necessarily require the attention of plant personnel. When such attention is required, an alarm condition exists. The term annunciator is sometimes used to refer to the spatially dedicated display portion of an alarm system.

Applicant – An organization, such as a nuclear plant vendor or utility, that is applying to the U.S. Nuclear Regulatory Commission for design certification or plant licensing.

Arrow buttons – A pair of buttons used to change a value by increments each time they are pressed. Often, the button that produces an increase is marked with an upward arrow and the button that produces a decrease is marked with a downward arrow.

Audio – Pertaining to acoustic, mechanical, or electrical frequencies corresponding to normally audible sound waves.

Auditory – Pertaining to the sense of hearing.

Automatic mode – A mode in which processing proceeds without human intervention (as contrasted with interactive and manual modes).

Automatic, self-correcting features – Features that detect and automatically correct errors that users make when providing inputs. For example, a "Delete" command that is incorrectly entered as "DLE" may be automatically changed to its correct form, "DEL," and then executed.

Automatic test equipment – Test equipment that checks two of more signals in sequence without the intervention of a maintainer. The test usually stops when the first out-of-tolerance signal is detected.

Backlash – Failure of the output signal to track a control input as the movement of the control is started or stopped; in mechanical systems this is also referred to as 'play'.

Bar chart – A graphic figure in which numeric quantities are represented by the linear extent of parallel lines (or bars). The length of the line (or bar) is proportional to the numbers represented. Bar charts are useful for comparing separate entities or showing a variable sampled at intervals.

Bench mockup – An actual unit of equipment or replica used in training for checking or locating faults.

Binary – (1) Pertaining to a characteristic or property involving a selection, choice, or condition in which there are two possibilities. (2) Pertaining to the number representation system with two values.

Blank – Containing no data; a non-printing graphic character used to separate data; a space for the entry of data.

Buffer – A file or device that temporarily stores data.

Built-in test – An integral part of a unit of equipment that performs diagnostic tests. Built-in features may be as simple as a voltmeter, or as complex as an automatic checker.

Built-in test panel – A panel containing connections for external test devices so that internal components can be assessed.

Button – A type of hardware control device or a defined control region on the display screen which, when selected, causes some action.

Cancel – A capability that regenerates (or re-initializes) the current display without processing or retaining any changes made by the user.

Capture error – An error of execution (slip) that occurs when an infrequently performed action requires a sequence of operations, some of which are the same as or similar to those of a frequently performed action. In attempting the infrequent action, the more frequent action is performed instead. For example, an operator intends to perform task 1, composed of operations A, B, C, and D, but instead executes the more frequently performed task 2, composed of operations A, B, C, and E.

Category – A grouping of data values along a dimension defined for operational purposes.

Cathode ray tube – An electronic vacuum tube, such as a television picture tube, that can be used to display textual information and/or graphics. Typically abbreviated "CRT."

Caution signal – A signal that alerts the operator to an impending condition requiring attention, but not necessarily immediate action (See warning signal).

Character set – A set of unique representations called characters; e.g., the 26 letters of the English alphabet, and the 128 characters of the ASCII alphabet.

Character width – The horizontal distance between a character's origin (a point on the base line used as a reference location) and the next character's origin.

Character – A letter, digit, or other symbol that is used as part of the organization, control, or representation of data.

CIE distance – Difference between colors expressed as a distance in the Uniform Color Space established by the Commission Internationale de l'Eclairage (International Commission on Illumination); the three-dimensional color space is based on the response of the human eye to light of different wavelengths.

Circuit breakers – Devices that protect equipment from excessive electrical current.

Circuit packaging – A method for organizing equipment into modules in which all parts of a single circuit or logically related group of parts, and only that circuit or group, are placed in a separate module.

Clear – A system function that removes the current selection but does not put it into the temporary buffer. A copy is retained, accessible immediately by the Undo command.

Cleared alarm – An alarmed parameter that has returned from an alarmed state to its normal range. Some alarm systems generate alarm messages when the parameter enters the normal range. The operator may be required to reset the alarm in order to "clear" it.

Click – An input device "button-down" action (e.g., depressing and releasing the button on a mouse or trackball) for the actual entry (enabling, activation) at a designated position. This action is distinct from cursor positioning. Also, the auditory feedback from keyboard entry.

Closed window – A window which is not visible and which requires some action by the user to gain perceptual and functional access. For example, a user may select and open an icon that represents a window or, in contrast, might input a command to open a specific window. (See also active and inactive windows).

Coding – Use of a system of symbols, shapes, colors or other variable sensory stimuli to represent specific information. Coding may be used (a) for highlighting (i.e., to attract a user's attention to part of a display), (b) as a perceptual indicator of a data group, or (c) to symbolize a state or attribute of an object (e.g., to show a temperature level or for warning purposes).

Coherence mapping – A map between the features in the representation and the physical and cognitive characteristics of the operator (how comprehensible the representation is to the operator).

Collating test equipment – Test equipment that presents the combined results of two or more checks. For example, a light might come on only if a number of different signals are all within tolerance.

Color – The aspect of objects or light sources that may be described in terms of hue, lightness (or brightness), and saturation.

Column – A vertical arrangement of items.

Command – (1) The act of instructing the computer or system to perform an action. (2) An entry provided by a user, which instructs the computer system to perform an action.

Command language – A type of dialogue in which a user composes entries, possibly with minimal prompting by the computer.

Communication systems – Systems that support communications, such as between personnel in the main control room, between the main control room and local sites within the plant, and across sites within the plant. The broad variety of communication media may be generally categorized as speech-based and computer-based systems.

Component – The meaning of the word component depends on its context. In context of the entire plant, it is an individual piece of equipment such as a pump, valve, or vessel; usually part of a plant system. In a human-system interface context, a component is one part of a larger unit, such as one meter in a control board. In a maintenance context, a component is a subdivision of a unit of equipment that can be treated as an object by the maintainer, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component.

Component packaging – A method for organizing equipment into modules in which similar parts or components are located together; for example, all the fuses or all the relays might be grouped together.

Computer-based procedure systems – Systems that present plant procedures in computer-based rather than paper-based formats.

Computerized operator support systems – Systems that use computer technology to support operators or maintenance personnel in situation assessment and response planning. They can monitor status and provide recommendations or warnings.

Concatenation – (1) The process of linking data together. (2) A set of logically related items which are treated as a whole.

Configural display – A display in which information dimensions are uniquely represented, but where new emergent properties are created from interactions between the dimensions. Configural display representations often use simple graphic forms, such as a polygon.

Confirmation step – A step in a transaction sequence that requires the user to respond to a warning or advisory message. For example, the user may respond to the question, "Are you sure you want to do this?" by pressing "Yes" or "No."

Context definition – Displaying an indication of previous user actions or computer processing that will affect the results of current actions, to help a user predict how the system will respond.

Continuous – Marked by uninterrupted extension in space, time, or sequence; see also discrete.

Continuous-adjustment interfaces – Computer-based formats that have continuous ranges usually accessed with some type of slewing motion requiring a gross movement followed by a fine adjustment. Their operation is similar to that of physical control devices that provide continuous adjustment, such as rotary dials or slider switches.

Continuous on-line self-test – A testing capability that continuously monitors overall system availability by rapidly identifying hardware failures.

Contrast – Diversity of adjacent parts in color and intensity.

Contrast ratio – The measured luminance at one point divided by the measured luminance at another, equal to Lt/Lb, (Ls-Lb)/Lb, or (1+Ls)/Lb, where

Lt = total luminance, or luminance of the image in the presence of background;

Ls = luminance of the symbol without background (luminance emitted by CRT in the case of CRT displays);

Lb = luminance of background.

Contrast ratio, rather than contrast, is often specified by display manufacturers because it is numerically larger (by one) than contrast.

Control – A mechanism used to regulate, and/or guide the operation of a component, equipment, subsystem, or system.

Control entry – User input for sequence control, such as function key activation, menu selection, command entry.

Controlling transmission – The process of ensuring that transmitted data are saved until they can be delivered or returned to the sender.

Conventional alarm system – A primarily analog-based alarm system employing little or no alarm display processing logic and using conventional control (e.g., pushbutton) and display (e.g., annunciator tiles) technology. (This is in contrast to advanced alarm systems).

Copy – A system function that puts a duplicate of the selection into the temporary editing buffer without disrupting the original data.

Correspondence mapping – A map between the properties and characteristics of the system to be represented and the features in the representation (how well the display communicates meaningful information about the plant to operators).

Cross-coupling – A defect of a multiple-axis positioning system whereby an adjustment of one axis causes an undesired change in another.

CRT – A cathode ray tube, i.e., an electronic vacuum tube, such as a television picture tube that can be used to display textual information and/or graphics.

Cursor – A display graphic that is used to indicate the position of the user's operation on the display (such as an arrow or flashing bar).

Cut – A system function that removes the current selection from the screen and puts it into the temporary editing buffer, replacing the buffer's previous contents. Cut may be used to either delete or to move a selection.

Darkboard – An alarm display in which the medium is dark (not illuminated) if all monitored plant parameters are in the normal range. Thus, an illuminated alarm-display device indicates a deviation from normal plant conditions. This is in contrast to many conventional alarm systems, which employ display devices to indicate both normal and abnormal changes in the plant's condition.

Data – The raw materials from which a user extracts information. (A user can be a human or another component of the system, such as an expert system.) Data may include numbers, words, and/or pictures.

Data display – Output of data from a computer to its users. Generally, this phrase denotes visual output, but it may be qualified to indicate a different modality, such as an "auditory display".

Data entry – User input of data for storage in, and/or processing by, the system.

Data item – A set of characters of fixed or variable length that forms a single unit of data. Sometimes a data item might contain only a single character. Data items may be entered by a user or may be displayed by the system.

Data protection – Functional capabilities that guard against unauthorized access to and tampering with data, and data loss due to user errors or computer failure.

Data transmission – Computer-mediated communication among system users, and also with other systems.

Data validation – A process by which data are checked for accuracy by comparing values from redundant sources (e.g., automated comparison of data from redundant sensors).

Database – A structured set of data, manipulated using a data management system.

De-emphasis – The inverse of pre-emphasis, employed for the purposes of restoring original vowel-consonant amplitude relationships in pre-emphasis speech; primarily useful in maintaining the "natural" sound quality.

Decibel (dBA) – Sound level in decibels, measured using A-weighting. The use of A-weighting causes the frequency response of the sound level meter to mimic that of the human ear, i.e., response is maximum at about 2kHz, less at very low or very high frequencies. A-weighted measurements correlate well with measures of speech interference and judgments of loudness.

Default – A 'typical' or 'safe' value or setting that is used if no alternative is specified; the value assumed unless specifically overridden. Defaults represent predetermined, frequently used, values for data or control entries intended to reduce entry actions required from the user.

Demarcation – The technique of enclosing functional or selected groups of controls and displays with a contrasting line to emphasize their relatedness.

Density – (Screen Density) The amount of the display screen that contains information; often expressed as a percentage of the total area.

Description error – An error of execution (slip) that involves performing the wrong set of well-practiced actions for the situation. Description errors occur when the information that activates or triggers the action is either ambiguous or undetected.

Diagram – A special form of a picture in which details are only shown if they are necessary to perform a task. For example, an electrical wiring diagram for a facility would show wiring but not necessarily furniture or plumbing.

Dialogue – A structured series of interchanges between a user and a computer. A dialogue can be initiated by a computer (e.g., question and answer) or by a user (e.g., command language).

Digitizing tablet – (Graphics Tablet) Device used to convert an image into digital code drawing or tracing with a pen-like or puck-like instrument. The instrument is moved across the tablet and a series of X-Y coordinates is generated.

Dimension – A scale or categorization along which data may vary, taking different values at different times.

Direct manipulation – The user manipulates symbols in the display by directly interacting with the symbol. The direct manipulation is generally performed by using a display structure, such as a pointer, and a cursor control device, such as a mouse.

Discrete – Consisting of distinct or unconnected elements; see also continuous.

Discrete-adjustment interfaces – Computer-based formats with individual settings that usually can be accessed using fairly gross movements. Their operation is similar to discrete-adjustment controls, such as push buttons.

Display – A specific integrated, organized set of information. A display can be an integration of several display formats (such as a system mimic which includes bar charts, trend graphs, and data fields).

Display control – Procedures by which a user can specify what and/or how data are shown.

Display device – The hardware used to present the display to users. Examples include video display units and speakers for system messages.

Display element – A basic component used to make up display formats, such as abbreviations, labels, icons, symbols, coding, and highlighting.

Display format – The general class of information presentation. Examples of general classes are continuous text (such as a procedure display), mimics and piping and instrumentation diagram (P&ID) displays, trend graphs, and flowcharts.

Display network – A group of display pages within an information system and their organizational structure.

Display page – A defined set of information that is intended to be displayed as a single unit. Typical nuclear power plant display pages may combine several different formats on a single VDU screen, such as putting bar charts and digital displays in a graphic P&ID format. Display pages typically have a label and designation within the computer system so they can be assessed by operators as a single "display."

Display selection – Refers to the specification of data outputs, either by a user or automatically.

Display structure – Functional or information-presenting aspects of a display that are consistent in appearance and use across applications, e.g., providing reference to the user's location in an information system and display of control options available.

Display tailoring – Designing displays to meet the specific task needs of a user, rather than providing a general display that can be used for many purposes.

Dot matrix – A rectangular array of dots or lights from which characters are built.

Drag – The act of moving a follower (such as a cursor) or selected icon through parts of a display (typically using a direct manipulation device such as a mouse).

Dynamic – Marked by continuous activity or change.

Dynamic display – Contains screen structures that change one or more feature(s), e.g., numerical value, color, shape, or spatial location, in real time or near real-time.

Emergent feature – A high-level, global perceptual feature produced by the interactions among individual parts or graphical elements of a display (e.g., lines, contours, and shapes).

Enter – An explicit user action that affects computer processing of user entries. For example, after typing a series of numbers, a user might press an ENTER key that will add them to a database, subject to data validation.

Enter key – Key used to indicate completion of data entry for current field or record.

Entry – (1) The act of inputting information to the system. (2) Something that has been entered, such as data or a command.

Equipment packaging – The way that modules, components, and parts are arranged within an enclosure.

Excerpt file – A file which allows the user to move data from one location to another; it differs from a temporary editing buffer in that the excerpt file can be saved. Data can be appended to or interleaved into the existing contents of the excerpt file.

Existing alarm – An acknowledged alarm that has not yet cleared.

Extinguished alarm (also called reset alarm) – An alarm that has returned to an inactive state (e.g., the plant parameter has returned to the normal range and all associated alarm messages have been acknowledged by the operator).

Fault-tolerant digital control systems – Digital systems with redundant processors that use fault-diagnostic routines that can detect single faults and isolate the failed equipment. This ensures that the equipment that is still operational takes over the control function.

Feedback – System or component response (e.g., visual or aural) that indicates the extent to which the user's desired effect was accomplished. Feedback can be either intrinsic or extrinsic. Intrinsic feedback is that which the individual senses directly from the operation of the control devices (e.g., clicks, resistance, control displacement). Extrinsic feedback is that which is sensed from an external source that indicates the consequences of the control action (e.g., indicator lights, display changes, aural tones).

Field – An area of the display screen reserved for the display of data or for user entry of a data item. In a database, a specified area used for a particular category of data, for example, equipment operational status.

Field label – A displayed word or phrase that identifies the data display or entry field.

File – A collection of data which is treated as a single unit, e.g., such as that stored in the computer.

Filtering – An alarm display processing technique which may eliminate alarm messages that are irrelevant, less important, or otherwise unnecessary. These alarm messages are not available to the operators. (This is in contrast to suppression, which does not make the alarm messages immediately available but does allow the operator to retrieve them.)

First-out alarm – An alarm message that indicates the initial change in parameter responsible for reactor and/or turbine trips.

Fixed form – Pertaining to a mode of input in which the user is presented with a set of blanks to be filled in.

Fixed format – An unchanging description of specification of information content in a particular area.

Fixed function key – A key having a function that cannot be changed by the user or system and that remains constant between applications.

Flowchart – A diagram that illustrates sequential relations among elements or events. Flowcharts are often shown as boxes connected by arrows.

Follower – The on-screen symbol (such as a cursor and arrow pointer) that responds to the movement of computer input devices (such as a cursor key, mouse, trackball, and light pen).

Form – A dialogue technique that presents category labels and requires the user to fill in the blanks. A formatted output to the user with blank spaces for inserting required or requested information.

Format – The arrangement of data.

Formatting – The process or act of arranging data.

Frequency modulation – Sinusoidal variation of the frequency of a tone around a center frequency.

Frequency – Rate of signal oscillation in cycles per second (Hz or Hertz).

Function – (1) A software supported capability provided to a user to aid in performing a task. (2) A process or activity that is required to achieve a desired goal; see, e.g., safety function.

Function allocation – The process of assigning responsibility for function accomplishment to human or machine resources, or to a combination of human and machine resources.

Function analysis – The examination of system goals to determine what functions are needed to achieve them.

Function areas – Specific screen or panel locations that are reserved for specific purposes.

Function key – A key whose activation will affect a control entry. Detection of the signal usually causes the system to perform some predefined function for the user.

Fuses – Devices that protect equipment from changes in electrical current.

Gloss – The extent to which light incident on a surface at angle x is reflected from that surface at angle -x (minus x) relative to a line perpendicular to the surface. A mirror has maximum gloss.

Gloss instrument – A device that measures reflected light as a function of illumination and angle of view. The angle for which gloss is measured is typically 60 degrees.

Go/no-go test equipment – Test equipment that provides one of two alternative answers to any question. For example, it may give a qualitative assessment of the condition of equipment by indicating whether a given signal is in (go) or out (no-go) of tolerance.

Graph – A display that represents the variation of a variable in comparison with that of one or more other variables.

Graphic element – A component part of a graphic display, such as a line, a circle, or a scale.

Graphic interaction – A dialogue in which the user selects displayed control elements by pointing or by other direct manipulation.

Graphical display – A display that provides a pictorial representation of an object or a set of data. Graphical displays include line, solid object, and perspective drawings; bar, pie, and line charts and graphs; scatterplots; displayed meters; flowcharts and schematic diagrams.

Graphics – Data specially formatted to show spatial, temporal, or other relations among data sets.

Graphics tablet – (Digitizing Tablet) Device used to convert an image into digital code by drawing or tracing with a pen-like or puck-like instrument. The instrument is moved across the tablet, generating a series of X-Y coordinates.

Grid – A network of uniformly spaced horizontal and vertical lines for locating points by means of coordinates.

Group – A set of items.

Grouping – (1) Locating alarm messages that are related to a common function or system in one area of a display. (2) The act or process of combining in groups.

Hardcopy – A printed copy of computer output in a readable form; for example, printed process displays an alarm listing.

Help – Information provided to guide the user in operating the system or displayed at the user's request for on-line guidance.

Hierarchical branching – A method of structuring menu items that are hierarchically related which allows selection among alternatives without requiring the opening and closing of a series of menus; the entire hierarchy is contained in one menu.

Hierarchy – The designated order or rank of items; a series of items that are classified by rank or order.

Highlight – A means of directing the user's attention to a feature of the display. Highlighting methods include image reversal (reverse video), brightness/boldness contrast, color, underlining, blinking, flashing arrows, and changes in font. Emphasizing displayed data or format features in some way, e.g., by using underlining, bold, or inverse video.

Histogram – A type of bar chart used to depict the frequency distribution for a continuous variable. The variable may be grouped into classes.

Human engineering discrepancy (HED) – A departure from some benchmark of system design suitability for the roles and capabilities of the human operator. This may include a deviation from a standard or convention of human engineering practice, an operator preference or need, or an instrument/equipment characteristic that is implicitly or explicitly required for an operator's task but is not provided to the operator.

Human factors – A body of scientific facts about human characteristics. The term covers all biomedical, psychological, and psychosocial considerations; it includes, but is not limited to, principles and applications in the areas of human factors engineering, personnel selection, training, job performance aids, and human performance evaluation (see human factors engineering).

Human factors engineering (HFE) – The application of knowledge about human capabilities and limitations to plant, system, and equipment design. HFE ensures that the plant, system, or equipment design, human tasks, and work environment are compatible with the sensory, perceptual, cognitive, and physical attributes of the personnel who operate, maintain, and support it (see human factors).

Human-system interface (HSI) – The human-system interface (HSI) is that part of the system through which personnel interact to perform their functions and tasks. In this document, "system" refers to a nuclear power plant. Major HSIs include alarms, information displays, controls, and procedures. Use of HSIs can be influenced directly by factors such as, (1) the organization of HSIs into workstations (e.g., consoles and panels); (2) the arrangement of workstations and supporting equipment into facilities such as a main control room, remote shutdown station, local control station, technical support center, and emergency operations facility; and (3) the environmental conditions in which the HSIs are used, including temperature, humidity, ventilation, illumination, and noise. HSI use can also be affected indirectly by other aspects of plant design and operation such as crew training, shift schedules, work practices, and management and organizational factors.

Icon – Pictorial, pictographic, or other nonverbal representation of objects or actions.

Identification – A code number or code name that uniquely identifies a record, block, tile, or other unit of information.

Identifier – A symbol whose purpose is to identify, indicate or name a body of data.

Inactive window – Windows perceptually and functionally available to the user (the user may be able to see and obtain information from them) but not immediately available in the sense that the user must activate an inactive window before working in it. (See also active and closed windows).

Index – To prepare an ordered reference list. An ordered reference list of the contents of a file or document, together with keys or reference notations to identify or locate those contents.

Information – Organized data that users need to successfully perform their tasks. Information can include (a) a representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or automatic means; and (b) any representations, such as characters or analog quantities, to which meaning is, or might be, assigned.

Information system – Those aspects of the human-system interface that provide information on the plant's processes and systems to the operator.

Initiating transmission – The process of actually sending a command, message, or data file. Transmission can either be initiated by the computer, or by a system user.

Input – (1) Information entered into a system for processing. (2) The process of entering information. (3) Pertaining to the devices that enter information.

Input/output – (1) Pertaining to either input or output, or both. (2) A general term for the equipment used to communicate with a computer, commonly called I/O. (3) The data involved in such communication. (4) The media carrying the data for input/output.

Insert mode – A data entry mode that allows the user to insert new information within existing information. If the cursor is placed within existing information, old characters are moved forward to allow insertion of the new characters.

Instrument cabinets and racks – Enclosures that hold modules, components, and parts. They typically have access doors or removable panels for access to their contents.

Integral display – A display that depicts the integration of information in such a way that the individual parameters used to generate the display are not explicitly represented in it.

Interactive graphics – A mode of input in which the user is graphically (e.g., by plot, histogram) presented data from which to choose. Once an input has been so selected, the user may interact with the system to correct or refine the data.

Interactive mode – A processing mode in which the user is assumed to be available to the system for inputs or decision making. The user submits one input at a time to the system and each input is processed by the system as soon as possible (as contrasted with manual and automatic modes).

Interface – (1) The point at which a user and the system interact. (2) A shared boundary, e.g., a hardware component to link two devices or a portion of storage or registers accessed by two or more computer programs.

Interrupt – Stopping an ongoing transaction to redirect the course of the processing. Examples of interrupt options are BACKUP, CANCEL, RESTART.

Input field – The area in a display that is used to enter input. For example, a soft control may have an area in which operators can enter numerical data to adjust control setpoints or commands to execute actions.

Interface management – Actions performed by the operator to control the human-system interface rather than the plant, including finding and retrieving displays and adjusting display windows. Operators typically navigate through displays and retrieve needed controls and displays.

Interlock – A feature that requires operator actions to proceed in a specific sequence. For example, action B must be performed after action A, and action C after action B.

Joystick – A stick-type control device that can provide continuous cursor control in any direction on a display screen.

Justification – The act of adjusting, arranging, or shifting digits to the left, right, or center to fit a prescribed pattern.

Keystroke – The act of striking a key.

Keystroke command – A single or limited number of keystrokes that define a command. The keystrokes are often initiated by simultaneously pressing a key that signals a keystroke command and the first letter of a one-word command. Another version of the keystroke command is the function key.

Keyword – A word exemplifying the meaning or value of the data: (a) one of the significant, informative words in a title or document that describes the content of that document; (b) a symbol that identifies a parameter; or (c) a part of a command operand that consists of a specific character string.

Label – Descriptor that is distinguishable from, and helps to identify, displayed screen structures or components.

Labeling and marking – The use of labels and demarcations to identify units of equipment, modules, components, and parts.

Large-screen display – A large display that can be viewed from multiple workstations and locations in a control room. It typically contains important information that should be commonly available to control room crew members.

Layered windows – Layered windows (in contrast to tiled windows) refer to the on-screen positioning of multiple windows so that windows can overlap and may obscure the contents of the covered windows

Layout – The physical arrangement of the parts and components that make up a module or a unit of equipment.

Left justified – (1) The left-hand digit or character (or its sign) occupies the left-hand position of the space allotted for displaying it. (2) Alignment of text along the left margin, leaving the ends of the lines 'ragged' on the right side.

Legend – (1) The textual content of a continuously present, spatially dedicated alarm display. (2) An explanatory list of symbols or highlighting used on a graph, chart, diagram, or map.

Legibility – The quality of a display that allows groups of characters and symbols to be easily discriminated and recognized.

Level of abstraction – A hierarchy consisting of levels increasing in abstraction

- Physical form – the appearance and spatial location of the components
- Physical function – the characteristics of the components and their interconnections
- Generalized function – the basic functions a system was designed to achieve
- Abstract function – the causal structure of the process in terms of mass, energy, information or value flows
- Functional purpose – the purpose for which the system was designed; the functional characteristics of the plant as opposed to physical characteristics.

Light pen – A pencil- or pen-like control device that interacts with the computer system through the display device screen either by emitting or sensing light.

Local control station (LCS) – An operator interface related to process control that is not located in the main control room. This includes multifunction panels, as well as single-function LCSs, such as controls (e.g., valves, switches, and breakers) and displays (e.g., meters) that are operated or consulted during normal, abnormal, or emergency operations.

Location – A position or site occupied or available for occupancy.

Lockin – A feature that keeps an ongoing operation active by preventing personnel actions from terminating it prematurely.

Lockout – A feature that prevents personnel from providing input that may have negative effects. Statically defined lockouts may restrict operators' inputs to a specific, predefined range or set of values. Context-sensitive lockouts may restrict input values based on the current situation.

Logical flow packaging – A method for organizing equipment into modules in which circuits, parts, and components are packaged and arranged in correspondence with their functional relationships.

Loss-of-activation error – An intended action is not carried out due to a failure of memory (i.e., the intention has partially or completely decayed from memory). A special case of loss-of-activation errors involves forgetting part of an intended act while remembering the rest (e.g., retrieving a display while not being able to remember why it is needed).

Macro-command – A group of a series of commands redefined as a single command.

Main menu – A top level menu displayed upon entry into the system.

Maintainability – The design of equipment to support effective, efficient maintenance activities.

Maintenance – A process with the objective of preserving the reliability and safety of plant structures, systems, and components or restoring that reliability when it is degraded.

Manual mode – A processing mode in which the user is assumed to provide all inputs (as contrasted with interactive and automatic modes).

Matte – A surface that scatters incident light nearly equally in all directions; a surface that lacks gloss.

May – The word 'may' is used to denote permission and applies to a characteristic that is acceptable but not necessarily recommended (e.g., an equally acceptable alternative may exist); see also 'should'.

Medium – The material, or configuration thereof, on which data are recorded, for example, paper tape, cards, magnetic tape.

Menu – A type of dialogue in which a user selects one item out of a list of displayed alternatives. Selection may be made by actions such as pointing and clicking and by depressing an adjacent function key.

Menu bar – A specialized function area that displays categories of alternatives of user responses.

Menu selection – A type of dialogue in which a user selects one item out of a list of displayed alternatives, whether the selection is by pointing, by entry of an associated option code, or by activating an adjacent function key.

Message – (1) Alarm information displayed in text. (2) Data that are transmitted from another user or from the system.

Message area – A specialized function area for communication from another user or from the system.

Mimic – A display format combining graphics and alphanumerics used to integrate system components into functionally oriented diagrams that reflect the components' relationships.

Mirror-imaging – Symmetrical arrangement of sets of items about a axis such that relationships among thing within one set are reversed relative to those in the other set.

Misordered components of an action sequence – A human error involving skipped, reversed, or repeated steps.

Mistake – An error in intention formation, such as forming one that is not appropriate to the situation. Mistakes are related to incorrectly assessing the situation or inadequately planning a response.

Mockup – A static representation of a human-system interface (See simulator and prototype).

Mode – A state of operation in which the system operates in specific, unique ways or has specific, unique characteristics.

Mode editor – A text editing system in which the interpretation of the same user input varies depending whether the system is in entry mode or edit mode. Specifically, in a mode text editor the user must enter special commands to cause subsequent inputs to be entered either as text or as editing commands.

Mode error – Performing an operation that is appropriate for one mode when the device is in another mode. Mode errors occur when the user believes the device is in one mode when it is in another one.

Modeless editor – A text editing system in which the interpretation of the same user input does not vary; ordinary characters are entered as text, and commands are invoked using special keys.

Modularization – The separation of equipment into physically and functionally distinct units that can be easily removed and replaced.

Module – An assemblage of two or more interconnected parts or components that comprise a single physical entry, such as a printed circuit board, with a specific, singular function.

Monitor – The physical device housing the electronics, display, and display controls for an interactive computer system (See also video display unit).

Mounting – The positioning and attachment of parts, components, and modules.

Mouse – A control device whose movements across a flat surface are converted into analogous movements of the cursor across the screen.

Multitasking – The parallel performance of two or more tasks.

N-key rollover – A feature of a keyboard input system that stores keystrokes and generates the corresponding characters in the correct sequence despite more than one key being depressed at the same time (as in very rapid typing).

Natural language – A type of dialogue in which users compose control entries in a restricted subset of their natural language, e.g., English.

Non-disruptive – An action that does not interfere with the ongoing activities of the system or user.

Nuisance alarm processing – A class of alarm display processing which includes techniques that essentially eliminate alarm messages having no operational significance to current plant conditions. For example, mode dependent processing eliminates alarms that are irrelevant to the current mode of the plant, e.g., a low temperature or pressure signal that is an alarm condition in normal operation mode but is expected and normal during startup or cold shutdown.

Numeric – Pertaining to numerals or to representation by means of numerals.

Object display – A type of integral display that uses a geometric object to represent parameter values graphically, but where the individual information dimensions or data contributing to the object are not displayed.

Objects – Distinct information whose representation can be displayed and/or manipulated as a single entity. Objects are normally represented by graphic icons and/or names.

On-line maintenance – Maintenance performed while the plant is at power.

Open window – Windows that are both perceptually and functionally available to the user. Two types of open windows exist: active and inactive. (See also window)

Open/closed – When a window is opened it appears on the screen. Windows may be closed (removed from the screen) and reopened.

Operand – That which is operated upon. Information entered with a request to define the data in which the processor is to operate and control the execution of the processor.

Operating experience review – A review of relevant history from the plant's on-going collection, analysis, and documentation of operating experiences.

Operation – (1) A defined action, namely, the act of obtaining a result from one or more operands in accordance with a rule that completely specifies the result for any permissible combination of operands. (2) The set of such acts specified by such a rule, or the rule by itself.

Optical reader – A device that reads handwritten or machine printed symbols into a computing system.

Output – The data that are the product of an information handling operation or series of operations; the data emitted from a storage device; the data being transferred from primary storage (central processing unit) to secondary storage (tape, floppy disk); electrical pulses; reports produced by a printer or typewriter unit; a general term for output media, such as cards and tape. Contrasts with Input.

Packaging – The grouping of functions, components, and parts into units or modules.

Page – (1) The data appearing at one time on a single display screen. (2) A fixed-length block of data, especially that which fits into a printed record or screen. (3) To summon a particular page or the next logical page.

Paging – A method of viewing and moving through data in which a user conceives data as being grouped into display-sized pages and moves through it by discrete steps. Also, to summon by calling out by name.

Panel – The front face of an assembly, normally used for mounting controls and displays.

Parallax – The apparent change in the relative position of objects at different distances from the observer as the observer's position changes.

Parameter – (1) A power-conversion process variable or quantity that can assume any of a given set of physically feasible values. Plant parameters are typically measures of the performance of systems and processes of the plant, e.g., the parameter 'T-hot' is a measure of the temperature of reactor coolant that has passed through the reactor core. (2) A variable that is measured.

Part – An object that cannot normally be broken down further without destroying its designated use. Fuses, transistors, resistors, and capacitors are examples.

Paste – A system function that puts the contents of the temporary editing buffer (a selection previously cut or copied) at the insertion point of the current interactive window. The buffer contents are not altered by this operation.

Peak-clipping – A technique for controlling amplitude relationships in speech by limiting the instantaneous peak-amplitudes to improve its intelligibility, usually followed by amplification of the signal to increase the amplitude of the clipped peaks to their original level, with a proportional increase of the weaker speech sounds.

Performance-based test – Tests that involve the measurement of behavior of personnel, the human-system interface, or aspects of the plant to address design issues and design acceptability.

Personal safety – Relates to the prevention of individual accidents and injuries of the type regulated by the Occupational Safety and Health Administration.

Physically interchangeable units – Units of equipment that can fit into the same mounting position or fixture.

Pictographic – Pertaining to a picture-like representation of an object.

Pie charts – A circle divided into sections (as pieces of a pie) to represent graphically the relative proportions of different parts of a whole. A circular chart cut by radii into segments illustrating magnitudes or frequencies.

Plant – The operating unit of a nuclear power station including the nuclear steam-supply system, the turbine, electrical generator, and all associated systems and components. In the case of a multi-unit plant, the term plant refers to all systems and processes associated with the unit's ability to produce electrical power, even though some systems or portions of systems may be shared with the other units.

Plant variable – A variable that represents the status of a plant system or process. For example, the variable reactor coolant system pressure represents the pressure inside the piping of the reactor coolant system. (See variable.)

Pointing interface – A computer-based user interface operated via cursor or touch screen.

Pop-up menu – A menu whose items are normally "hidden" from the user's view until they are activated or brought into full view by a complete selection action. Pop-up menus remain visible until the user takes another action to hide the menu or make a selection.

Position – In a string, each location that may be occupied by a character or binary digit, and may be identified by a serial number.

Position designation – User selection and entry of a position on a display, or of a displayed item. (See also cursor).

Pre-emphasis – Systematic distortion of the speech spectrum to improve intelligibility of the sound by attenuating the low-frequency components of vowels (relatively unimportant for intelligibility) and proportionately increasing the amplitude of high-frequency vowel components and consonants (highly important for intelligible speech transmission).

Precision – The degree of discrimination with which a quantity is stated. For example, a three-digit numeral discriminates among 1000 possibilities.

Preparing messages – Includes specification of contents, format, and header information.

Primary tasks – Those tasks performed by the operator to supervise the plant; i.e., monitoring, detection, situation assessment, response planning, and response implementation.

Print queue – An area of computer memory that temporarily stores a file to be printed so that the user can continue interacting with the system while the file prints.

Printed circuit board – A module organization in which parts are mounted on an integrated circuit board.

Printer – A device that writes output data from a system on paper or other media.

Prioritization – A class of alarm-display processing that presents alarm messages to the operator according to an evaluation of importance, often using 2 to 4 categories of priority. The intent of this approach is to help the operators focus attention on the most important alarm conditions when there are multiple alarm conditions.

Processing – The execution of a systematic sequence of operations.

Programmable function keys – User programmable keys whose function may vary between applications or between users within an application.

Prompting – The process or act of assisting by suggestion.

Prototype – A dynamic representation of a human-system interface that is not linked to a process model or simulator. A model of an interface that includes the functions and capabilities expected in the final system, though not in a finished form. (See simulator and mockup.)

Pull-down menu – A menu whose items are normally hidden from the users view and accessed by the user holding the selection button down over the desired menu-bar label.

Query language – A type of dialogue in which users compose questions using a special-purpose language to retrieve information.

Question and answer – A type of dialogue in which a computer displays questions, one at a time, for a user to answer.

Queue – A waiting line or list formed by items in a system waiting for service; for example, tasks to be performed or messages to be transmitted in message switching system.

Record – A group of related data fields that are operated on as a single entity in a database.

Redundant alarm processing – A class of alarm-display processing which includes techniques that evaluate active alarm conditions to identify those that are true/valid but are redundant with other active alarm conditions. This processing filters, suppresses, or reduces the priority of alarm messages that have been determined to be of less importance because they provide information that is redundant with other existing alarm conditions and theoretically provide no new/unique information to the operator. For example, in causal-relationship processing, alarm messages associated with "causes" are displayed prominently, while alarm messages associated with "consequences" are eliminated or lowered in priority.

Reflash – A method of alarm presentation that can be implemented any time an alarm condition is based on input from more than one plant parameter. Reflash causes an alarm display to re-enter the new alarm state when an associated plant parameter reaches its setpoint. The alarm display cannot return to normal until all related parameters return to their normal ranges.

Reflectance – The ratio of reflected light to incident light.

Rejection level – The minimum level of certainty (represented by a number) required by a speech recognition system for a spoken command to be executed.

Remote – Acting on or controlling indirectly from a distance.

Request – A user input specifying the operation(s) to be performed.

Response time – The time between the submission of an item of work to a computing system and the return of results.

Retrace – A capability that returns a user to the last previous display in a defined transaction sequence (also called "backup").

Retrieval – The act, method, or procedure for recovering stored data.

Review – In the context of a human-system interface design, a capability that returns a user to the first display in a defined transaction sequence, while retaining any entries made by the user.

Right justified – To adjust the printing positions of characters on a page so that the right margin of the page is regular. To shift the contents of a register so that the least significant digit is at some specified position of the register.

Ringback – An alarm display feature that provides a distinct cue such as a slow flash or audible tone to indicate that an alarm condition has cleared, i.e., the monitored parameter(s) has returned to its normal range.

Row – A horizontal arrangement of characters or other expressions.

Rubberbanding – In computer graphics, the continuous stretching, shrinking, or reorientation of connecting lines as a point defining a line or shape is moved.

Safety function – Safety functions are those functions that serve to ensure higher-level objectives and are often defined in terms of a boundary or entity that is important to plant integrity and the prevention of the release of radioactive materials. A typical safety function is "reactivity control." A high-level objective, such as preventing the release of radioactive material to the environment, is one that designers strive to achieve through the design of the plant and that plant operators strive to achieve through proper operation of the plant. The function is often described without reference to specific plant systems and components or the level of human and machine intervention that is needed to carry out this action. Functions are often accomplished through some combination of lower-level functions, such as "reactor trip." The process of manipulating lower-level functions to satisfy a higher-level function is defined here as a control function. During function allocation the control function is assigned to human and machine elements.

Safety goal – A high-level objective such as, "Preventing the release of radioactive material to the environment" which designers strive to achieve through the design of the plant, and which plant operators strive to achieve through its safe operation.

Safety-related – A term applied to those plant structures, systems, and components (SSCs) that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public (see Appendix B to Part 50 of Title 10 of the U.S. Code of Federal Regulations). These are the SSCs on which the design-basis analyses of the safety analysis report are performed. They also must be part of a full quality assurance program in accordance with Appendix B of that document.

Scale – A graduated series or scheme of rank or order.

Scaling – The positioning of displayed data elements with respect to a defined measurement standard.

Scatterplot – A scaled graph that shows relations among individual data points in a two- dimensional array.

Screen – The software-controlled visual interface of a monitor, e.g., the display surface of a CRT.

Screen dump – An action, usually performed with a keystroke sequence, that causes the exact contents of the current screen display to be captured for printing or storage in a file.

Screen structure – A generic display element, such as a menu bar or title.

Scroll – To move data being viewed in a line-by-line manner; to roll upward or downward.

Scrolling – An orientation for display framing in which a user conceives of data as moving behind a fixed display frame. The opposite of panning.

Secondary tasks – Those tasks that operators perform when interacting with the human-system interface that are not directed to the primary task. Secondary tasks may include: navigating through and paging displays, searching for data, choosing between multiple ways of accomplishing the same task, and making decisions regarding how to configure the interface.

Selecting – A user's action of identifying display elements to the computer to ready them for use in some way (e.g., to open a valve by an input device click on a graphic representation of a valve).

Selection display – Any display from which the operator may make a selection, such as choosing a plant variable, plant component, or a command. Two formats commonly used for selecting plant components and variables are the menu and mimic.

Separable display – Each process parameter is presented individually and no relationships between the parameters are shown by the representation itself. The key aspect of separable displays is not the individual parameters are presented, but that no interaction or relationship between them is perceived.

Sequence – An arrangement of items according to a specified set of rules.

Sequence control – Logic and means by which user's actions and computer responses are linked to become coherent transactions.

Service points – Equipment locations used for performing routine maintenance tasks, such as adjusting, cleaning, or replacing components.

Setpoint – The value of a monitored parameter that defines the boundary between the parameter's normal range and an alarm condition. An alarm condition exists when the parameter exceeds the normal range that is defined by the upper and/or lower limit setpoints. Graded alarms may have multiple setpoints outside the normal range that produce alarms that indicate increasing levels of severity of the abnormal condition, such as Low Level, or Low-Low Level.

Shared alarm – An alarm condition that is defined by the activation of one or more of a set of different process deviations. An example of a shared alarm is a "reactor coolant system trouble" message, which may be displayed when any one of the reactor coolant pumps malfunctions. An individual alarm message associated with the particular malfunctioning reactor coolant pump may also be displayed in addition to the former message.

Should – The word 'should' is used to denote a recommendation; see also 'may'.

Signal validation – A set of alarm processing techniques by which signals from redundant or functionally related sensors are compared and analyzed to determine whether a true alarm condition exists. The purpose of these techniques is to prevent false alarms being presented to the operator due to malfunctioning plant instrumentation, such as a failed sensor.

Significance processing – A class of alarm display processing which includes techniques that evaluate active alarm conditions to identify those that are true/valid but are of less operational significance than other active alarm conditions. This processing filters, suppresses, or reduces the priority of alarm messages that have been determined to be of less importance. For example, in an anticipated transient without scram event, alarms associated with minor disturbances on the secondary side of the plant are eliminated or lowered in priority.

Simulator – A facility that physically represents the human-system interface configuration and that dynamically represents the operating characteristics and responses of the plant in real time (See prototype and mockup).

Situation awareness – The relationship between the operator's understanding of the plant's condition and its actual condition at any given time.

Slip – An error in carrying out an intention. Slips result from "automatic" human behavior, when schemas, in the form of subconscious actions that are intended to accomplish the intention, get waylaid en route to execution. Thus, while one action is intended, another is accomplished. An expert's highly practiced behavior leads to the lack of focused attention that increases the likelihood of some forms of slips.

Soft control – A control device that has connections with the control or display system mediated by software rather than direct physical connections. As a result, the functions of a soft control may be variable and context-dependent rather than statically defined. Also, the location of a soft control may be virtual (e.g., within the display system structure) rather than spatially dedicated. Soft controls include devices activated from display devices (e.g., buttons and sliders on touch screens), multi-function control devices (e.g., knobs, buttons, keyboard keys, and switches that perform different functions depending upon the current condition of the plant, the control system, or the human-system interface), and devices activated via voice input.

Soft slider – An input format used to directly manipulate a variable over a set range of values (also called a slider bar or a scroll bar). A soft slider resembles a bar chart with a pointer directed toward the current value. They are typically manipulated via pointing interfaces, such as a touch screen or mouse. Input is provided by sliding the pointer along the length of the bar chart scale to the desired value. It is used when the range of possible values and the ratio of a value to the range must be displayed.

Spacing – The distance between any two objects.

Spatially focused, variable location, serial display – A display where alarms are presented in no fixed location and according to some logic, such as time or priority. Usually, the same display device can be used to present many different alarms (in contrast with SDCV display where a given location presents only one alarm). A scrolling message list is an example of this type of display.

Spatially dedicated, continuously visible (SDCV) alarm display – An alarm display that is in a spatially dedicated position and is always visible whether in an alarmed or cleared state. Conventional alarm tiles are an example of an SDCV alarm display.

Specular reflectance – The light incident on a surface at angle x that is reflected at angle – x (minus x).

Speech display – Speech messages (either computer-generated or a recorded human voice) presented through audio devices, such as speakers and headsets.

Speech recognition – Permits a user to provide spoken input that a computer interprets as data or commands.

Status information – Information pertaining to the state of the system or components (e.g., on/off, open/closed, automatic/manual) that is displayed either automatically or by user's request.

Status setpoints – Criterion values used in display systems to indicate a change in status of a variable, such as to indicate the approach to an unsafe operating condition.

Storage – Any device on which data can be entered, held, and retrieved. The act of storing data on such a device.

String – A linear sequence of entities such as characters or physical elements.

Stroke width – The width of a line comprising a character.

Style guide – A document that contains guidelines that have been tailored so they describe the implementation of human factors engineering guidance to a specific design, such as for a specific plant control room.

Stylus – Pen-shaped instrument used to "draw" images or point to icons or menu selections.

Subsystem – A collection of modules that perform a particular function.

Subtractive color process – The presentation of color images by selective absorption of projected light.

Suppression – A class of alarm display processing by which alarms determined by processing techniques to be less important, irrelevant, or otherwise unnecessary are not presented to the operators, but can be accessed by operators upon request. This approach is intended to help the operators focus attention on the most important alarm conditions when multiple alarm conditions exist.

Symbol – A representation of something by reason of relationship, association, or convention.

Syntax – The way in which words are put together to form phrases, clauses, or sentences.

System – An integrated collection of plant components and control elements that operate together, and possibly in conjunction with other systems, to perform a function.

System response time – The elapsed time between the initiation of a command and the notification to the user that the command has been completed.

System response – The manner in which the computer system behaves after receiving inputs from the user.

System security – Features that restrict personnel access to aspects of the computer system to prevent accidental or deliberate damage.

Table – A rows and columns structure consisting of functional areas that contain data and that may or may not require input. Tables may be used to present a variety of types of information. A collection of data in a form suitable for ready reference.

Task analysis – A method of detailing the components of a task in terms of the demands placed upon the human operator, the information required by the operator, the extent to which the task requires reliance on or coordination with other personnel, and the relation of the task to other tasks.

Task – A series of transactions that comprises part of a user's defined job. A group of activities that have a common purpose, often occurring in temporal proximity, and that utilize the same displays and controls.

Terminal – An input/output device used to enter and display data. Data are usually entered via a keyboard, and are usually displayed via a video screen (soft copy) or a printer (hard copy). A device, usually equipped with a keyboard and some kind of display, which can send and receive information over a communication channel.

Terminology – The technical or special terms of expressions used; nomenclature.

Test equipment – Diagnostic tools used to assess the status of equipment and locate faults that may be present.

Test points – Equipment locations used for conducting tests to determine the operational status of equipment and for isolating malfunctions. Test equipment may be connected at these points.

Text – The primary display for word processing, consists of alphanumeric character strings in linear arrays, making up words, sentences, and paragraphs. The main body of printed or written matter on a page or in a message.

Text entry – Initial entry and subsequent editing of textual data.

Tile – A type of spatially dedicated, continuously visible alarm-display that changes state (i.e., brightness, color, and/or flash rate) to indicate the presence or absence of an alarm condition, and includes text to identify the nature of the alarm state.

Tiled windows – Tiled windows (in contrast to layered windows) refers to the on-screen positioning of multiple windows side-by-side so that no window overlays information on another.

Tiling – A means of manipulating windows by which multiple windows on the same display abut, but do not overlap. As the number of windows increases in the tiled window environment, the size of each window decreases.

Touch screen – A control device that allows the user to communicate with the computer by touching a screen.

Touch zone – An area of a display that a user can activate to perform a predefined operation (e.g., displaying a pop-up window).

Trackball – A control device with which the user can control cursor movement in any direction by rotating a ball.

Transaction – An action by a user followed by a response from the computer. Transaction is used here to represent the smallest functional unit of user-system interaction.

Transilluminated display – A display having light passed through, rather than reflected off, an element to be viewed, e.g., illumination used on traditional annunciator tile panels or indicators using edge or back lighting techniques on clear, translucent, fluorescent, or sandwich-type plastic materials (in contrast to video display units).

Turnaround time – (1) The elapsed time between submission of a job to a computing center and the return of results. (2) In communications, the actual time required to reverse the direction of transmission from send to receive when using a half-duplex circuit.

Unacknowledged alarm – An alarm that has not been acknowledged and displays attention-directing characteristics, such as rapid flashing.

Undo – A capability that reverses the effect of the previous operation.

Unit of equipment – An assemblage of items that may include modules, components, and parts that are packaged together into a single hardware package.

Unvalidated data – Data that have not been checked for accuracy. (Unvalidated data may be determined to be either valid or invalid if subjected to a data validation process.)

Update – Regeneration of changing data to show current status, by user request or automatically by the computer.

User response time – The speed with which a user can enter commands and control a system regardless of the computer's ability to quickly process the commands.

User-system interaction – The set of methods provided in a computer system through which personnel and the computer communicate with each other.

Value – Specified data for a particular parameter or variable.

Variable – A quantity that can assume any of the given set of values.

Variable function key – A dedicated key which invokes functions of the system; the specific function invoked varies depending, e.g., on the mode of operation selected by the user.

Verification – The process by which the human-system interface design is evaluated to determine whether it acceptably satisfies personnel task needs and human factors engineering design guidance.

Verification step – A step in a transaction sequence that requires the user to verify an intention to perform a particular action. For example, the user selects an option and then presses the Enter key to verify the selection.

VDU – A video display unit.

Video display unit – An electronic device for the display of visual information in the form of text and/or graphics. Typically abbreviated VDU.

Vigilance – The degree to which an operator is alert.

Visual angle – A measure, in degrees, of the size of the retinal image subtended by a viewed object. It represents the apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). An object of constant size will subtend a smaller visual angle as it is moved farther from the viewer. Visual angle is typically defined in terms of minutes of visual arc.

Warning signal – A signal that alerts the operator to a condition requiring immediate action (see caution signal).

Watchdog timer – An electronic self-testing feature that detects when an expected electrical signal is not received within an expected period, thus indicating a possible malfunction.

Window – A geometric area on a computer screen within which the system displays information or receives input from the user.

Window overlay – A portion of a display that is temporarily used to show added features such as requested data, menus, or user guidance, which may obscure previously displayed data.

Word – A character string or a bit string considered as an entity.

Word wrap – Occurs when words displaced from one line are moved to the next line so as to maintain the continuity of the text.

Workload – The physical and cognitive demands placed on plant personnel.

Workstation – The physical console at which a user works.

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11. ABSTRACT *(200 words or less)*

The U.S. Nuclear Regulatory Commission (NRC) staff reviews the human factors engineering (HFE) aspects of nuclear power plants in accordance with the *Standard Review Plan* (NUREG-0800). Detailed design review procedures are provided in the *HFE Program Review Model* (NUREG-0711). As part of the review process, the interfaces between plant personnel and plant systems and components are evaluated for conformance with HFE guidelines. This document, the *Human-System Interface Design Review Guidelines* (NUREG-0700, Revision 2), provides the guidelines necessary to perform this evaluation. In addition to the review of actual human-system interfaces (HSIs), the staff can use the NUREG-0700 guidelines to evaluate a design-specific HFE guidance document or style guide. The HFE guidelines are organized into four basic parts, which are divided into sections. Part I contains guidance for the basic HSI elements: displays, user-interface interaction and management, and controls. These elements are used as building blocks to develop HSI systems to serve specific functions. Part II contains the guidance for reviewing six such systems: alarm system, group-view display system, soft control system, computer-based procedure system, computerized operator support system, and communication system. Part III provides guidance for the review of workstations and workplaces. Part IV provides guidance for the review of HSI support, i.e., maintainability of digital systems.

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