Nuclear
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Action
Committee

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Human Engineering Principles for Control Room Design Review

September 1983

INPO 83-036 (NUTAC)

HUMAN ENGINEERING PRINCIPLES

FOR

CONTROL ROOM DESIGN REVIEW

Developed By

Nuclear Utility Task Action Committee

For

Control Room Design Review

September 1983

Publications produced by a Nuclear Utility Task Action Committee (NUTAC) represent a consensus of the utilities represented in the NUTAC. These publications are not intended to be interpreted as industry standards. Instead, the publications are offered as suggested guidance with the understanding that individual utilities are not obligated to use the suggested guidance.

This publication has been produced by the NUTAC on control room design review (CRDR) with the support of the Institute of Nuclear Power Operations (INPO). The officers of this NUTAC were Chairman Hamilton Fish (New York Power Authority) and Vice Chairman Bill Gainey (Carolina Power & Light Company.) The following utilities and service organizations have actively participated in the development of this document:

Alabama Power Company
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FOREWORD

Human Engineering Principles for Control Room Design Review (CRDR) was developed by the Nuclear Utility Task Action Committee (NUTAC) on CRDR to assist individual utilities in assessing potential problems identified during their control room reviews.

The INPO Analysis and Engineering Division Industry Review Group identified the need for a utility committee to deal with the CRDR item of the TMI Task Action Plan. The charter for such a group was approved by INPO management. The CRDR NUTAC, formed after this approval, identified several areas in which utilities could use assistance in the implementation of CRDRs. In addition to this document, the following documents have been published or are in advanced stages of development:

- Control Room Design Review Implementation Guideline INPO 83-026 (NUTAC)
- Control Room Design Review Survey Development Guideline (draft)
- Control Room Design Review Task Analysis Guideline (draft)

CHARTER

NUCLEAR UTILITY TASK ACTION COMMITTEE

ON

CONTROL ROOM DESIGN REVIEW

The Nuclear Utility Task Action Committee (NUTAC) on CRDR has been established by a group of representative utilities in recognition of the need for guidance on performing a CRDR. The principal objectives are (a) to determine the boundaries of the CRDR, (b) to develop a methodology, (c) to define terms, (d) to integrate other initiatives with the CRDR (e.g., SPDS development, EOP development, staffing, and training), and (e) to provide practical implementation guidelines that include but are not limited to the following:

- a CRDR methodology and implementation guideline
- a guideline on the development of CRDR survey checklists
- a CRDR task analysis guideline
- a set of human engineering review principles

The NUTAC will consider the need for other activities of generic benefit to the industry after the CRDR requirements are issued.

The NUTAC will establish liaison and solicit support from industry groups, such as NSSS owners groups, AIF, INPO, and EPRI. Communication on this industry initiative will be maintained with the NRC. Providing the NUTAC consensus to the NRC will help shape both the regulator and industry perspective on CRDR integration issues.

SUMMARY

This document was written in response to a utility industry request for assistance in the area of human factors, in general, and the CRDR, in particular. This document is offered as reference only. There is no obligation for any nuclear utility to follow any guidance contained in the document.

During any systematic design process, certain principles are used to define the specific characteristics of the item being designed. Due to the trade-offs made during the design process, the finished product may not comply with some desirable design criteria. During the survey phase of the CRDR, the existing control room is reviewed for compliance with commonly accepted human engineering design criteria. Aspects of the control room that do not conform to design guidelines are classified as human engineering discrepancies (HEDs).

During the assessment phase of the CRDR, each HED must be examined to determine the potential seriousness of errors that might result from such discrepancies. It can be useful during the assessment phase of the CRDR to keep in mind the principles on which detailed survey criteria are based. This document is basically a summary of the human engineering principles on which many of the detailed criteria are based.

The intended use for this document is to help assess whether particular aspects of a nuclear control room that have been identified as HEDs can still fulfill the design principle for that particular item. This document contains basic human engineering principles grouped into sections related to nuclear power plant control rooms. Each principle is followed by a short explanation, a list of references that can be consulted for detailed criteria related to that reference, and examples of methods that might be used to support that principle. A cross-reference guide to NUREG-0700, Section 6, is provided as an appendix to this document.

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

Guidelines, or criteria, used during the CRDR are derived from more general principles related to human performance. Control room characteristics that do not conform to the specific criteria used during the CRDR are categorized as Human Engineering Discrepancies (HEDs). An HED, then, is some characteristic of the existing control room that deviates from human engineering design guidance and, therefore, may adversely affect operator performance. Once a control room characteristic has been categorized as an HED, each one then must be assessed to determine whether that feature normally does, or probably will, affect an operator's performance.

The human engineering design criteria that exist in reference documents have been selected to ensure that equipment designed using the criteria will be usable by human operators of that equipment. While this assumption of operability is usually true, the converse is not always true. That is, a control room characteristic that deviates from a given design criterion is not necessarily unusable for its intended function. To ascertain whether that feature is usable or not, it must be evaluated with respect to the underlying human performance principle upon which the specific design guideline was based.

An example might help to illustrate the evaluation described above. Suppose that a particular design criteria specifies that all characters engraved on labels must be a certain minimum height. Any label having engraved characters shorter than the minimum height must be categorized as an HED. During the assessment of these HEDs, the reason behind the minimum height guidelines must be understood. The underlying principle is not that all characters must be a certain minimum height but that all labels must be readable from the appropriate operating location.

How, then, can the HEDs concerning lettering height be assessed? Knowing the principle involved, the question concerning character height can be reworked to be more operationally oriented. First, choose an acceptable minimum visual angle that must be subtended to ensure readability. This number can be chosen from several sources. Next, given the height of the existing characters, calculate the maximum viewing distance at which that minimum visual angle is maintained. If an operator has to read that label from a location that is beyond the calculated distance, then there is a real potential for misreading the label. If it is not necessary to read the label from a distance beyond that calculated above, then the principle of readability is not compromised, and the HED can be dismissed.

The purpose of this document is to list and describe many of the general principles upon which specific CRDR human engineering criteria are based. The principles presented here do not exhaust the list of human performance principles upon which human engineering design criteria are based. An attempt has been made to identify the principles most generally applicable to the CRDR process. The principles are quite general and describe the most desirable design characteristics. In practice, no existing control room will be able to achieve the level of operator usability implied by these principles. In some cases, certain principles may dictate designs that violate regulatory design criteria or even other principles. In these instances, the final design decision must be based on other criteria in addition to the performance principles.

1.2 DOCUMENT ORGANIZATION

This document, Human Engineering Principles for Control Room Design Review, is presented in three sections and one appendix.

1.2.1 Section 1 - Introduction

The introduction explains the purpose, scope, organization, and use of this document.

1.2.2 Section 2 - Definitions

This section provides definitions of the terms associated with human engineering principles as those terms are used in this document.

1.2.3 Section 3 - Principles

This section presents the human engineering principles that can be used during the assessment phase of the CRDR. The format for presenting the principles is described briefly at the beginning of this section.

Appendix A is a cross-reference between NUREG-0700 and this document. It is included to facilitate locating the human engineering principle(s) upon which specific NUREG-0700 criteria are based.

1.3 RECOMMENDED USE OF THIS DOCUMENT

The principles presented in this document can be used to assess the potential impact of HEDs on operator performance. The principles must be understood to develop meaningful survey criteria but should not be used in lieu of more detailed criteria during the review phase of the CRDR. They should be used during the assessment phase as one basis for determining the impact, if any, of each HED generated during the review phase. The reference documents, cited as guidance for each principle, can be consulted for more detailed and illustrative information, if necessary.

2 DEFINITIONS

2.1 GENERAL CRDR TERMS

Abnormal Transient Operating Guidelines (ATOG) - Same as Emergency Procedure Guidelines (EPGs). The guidelines developed by the B&W Owners Group are called ATOGs.

Control Room Design Review (CRDR) - A post-TMI task listed in NUREG-0660, "Task Action Plan Developed as a Result of the TMI-2 Accident," and NUREG-0737, "The Staff Supplement to NUREG-0660," as Task I.D.1.

Control Room Survey - One of the activities that constitutes a CRDR. The control room survey is a static verification of the control room performed by comparing the existing control room instrumentation and layout with selected human engineering design criteria, i.e., checking the control room match to the physical capabilities and limitations of the human operator.

Elements of a Utility CRDR Implementation Process - Necessary parts of a cohesive CRDR implementation process that a utility should consider in developing and reviewing their implementation plan and schedule.

Emergency Operating Procedures (EOPs) - Plant procedures directing the operator actions necessary to mitigate the consequences of transients and accidents that cause plant parameters to exceed reactor protection setpoints, engineered safety feature setpoints, or other appropriate technical limits.

Emergency Procedure Guidelines (EPGs) - Guidelines, developed from system analysis of transients and accidents, that provide sound technical bases for plant-specific EOPs.

Emergency Response Guidelines (ERGs) - Same as EPGs. The guidelines developed by the Westinghouse Owners Group (WOG) are called ERGs.

Human Engineering Discrepancy (HED) - A characteristic of the existing control room that does not comply with the human engineering criteria used in the control room design review.

Nuclear Utility Task Action Committee (NUTAC) for CRDR - Representatives from various nuclear utilities and INPO who are organized to define areas of CRDR implementation for which an overall industry effort can provide assistance to individual utilities in completing Task I.D.1, NUREG-0737.

Operational Experience Review - One of the activities that constitutes a CRDR. The operating experience review screens plant operating documents and operator experience to discover human engineering shortcomings that have caused actual operating problems in the past.

Review Team - A group of individuals responsible for directing the CRDR of a specific control room. (See Survey Team.)

Safety Parameter Display Systems (SPDS) - An aid to the control room operating crew for use in monitoring the status of critical safety functions (CSFs) that constitute the basis for plant-specific, symptom-oriented EOPs.

Survey Team - A group of individuals responsible for conducting the control room survey. The survey team may or may not include individuals from the review team. (See Review Team.)

System Function Analysis - The determination of system functions required to meet system goals.

Task Analysis - The systematic process of identifying and examining operator tasks to identify conditions, instrumentation, skills, and knowledge associated with the performance of a task. In the CRDR context, task analysis is used to determine the individual tasks that must be completed to allow successful emergency system operation. In addition, this activity can verify and validate the match of information available in the control room to the information requirements of the emergency operating tasks.

Validation - The process of determining whether the control room operating crew can perform their functions effectively given the control room instrumentation and controls, procedures, and training. In the CRDR context, "validation" implies a dynamic performance evaluation.

Verification - The process of determining whether instrumentation, controls, and other equipment exist to meet the specific requirements of the emergency tasks performed by operators. In the CRDR context, "verification" implies a static check of instrumentation against human engineering criteria.

2.2 HUMAN ENGINEERING TERMS

Access - Available to an operator's vision or manipulation.

Accessible - Within the possible physical grasp of fifth to ninety-fifth percentile humans; not placed behind physical barriers.

Ambiguous - Having more than one meaning or interpretation.

Anthropometry - The study of human body measurement. Here used to denote dimensions of the fifth percentile female to the ninety-fifth percentile male, thus including all but the smallest 5 percent and largest 5 percent humans in a specified population.

Arrangement - The physical layout or ordering of objects in space.

Consistent - A regular, repetitious duplication of format or pattern that is invariant in essential character.

Controls - Any device found on a control board that transmits information to the plant or other control board devices. Controls include devices that are on/off, discrete setting, quantitative setting, continuous, and data entry such as keyboards.

Determine - To decide by choice of alternatives.

Discriminable - Able to be discriminated or identified. Able to observe a difference between.

Displays - Any device found on a control board that transmits information to the operator. Displays include devices that are dynamic and static. Information from a display may be quantitative, qualitative, setting, check, status, tracking, pictorial/graphic, identifying, alphanumeric, or symbolic.

Documents - All written materials used to support operation, including procedures, tech. specs., etc.

Emergency - For the purposes of the CRDR, any plant condition that requires the use of EOPs or the actions set out in them.

Equipment - Hardware, fittings, or installations that are not part of the control board but are found in the control room.

Functional Groups - Items related by operational outcome.

Global - Referring to the entire system, control board, or control room. Universal or overall.

Hierarchical Labeling - A method of providing information with labels by dividing information into categories from general to specific and placing this information on major, intermediate, and minor labels with corresponding sizes.

Indication - Approximate, qualitative amount of a specified measurement.

Information - A signal or character representing data.

Instruments - Controls and displays whether active, interactive, or passive.

Item - Used here to refer to anything found on a control board or in a control room.

Label - A placard, legend, sign, or marking that allows personnel to identify, interpret, or understand the function of an item.

Legibility - Attribute of alphanumeric characters that makes each one distinctive from others.

Obscure - To block from view, to decrease visual access.

Off-Normal - Any nonpreferred plant condition. An unexpected plant condition.

Operating Location - The location of an operator who is using controls or displays.

Orient - To arrange in a predetermined direction or position.

Panel - A surface on which controls and displays are mounted.

Procedures - Written instructions for performing an operation or series of operations.

Reachable - Within the unextended grasp of fifth to ninety-fifth percentile humans. This does not include awkward positions or mechanical assistance.

Readability - A quality that makes possible the recognition of information whether presented in meaningful alphanumeric groups, e.g., words and sentences, or as indications of plant parameters via control board displays.

Refresh (rate) - The rate at which CRT displays are redrawn on the screen so they appear constant and do not flicker perceptibly.

Resolution - The quality of a visual image measured in information per unit area. CRT displays measure vertical resolutions in raster scan lines per unit distance and horizontal resolution in terms of the number of resolvable elements per unit length along the lines.

Scanning - A rapid visual survey, without stopping to read, of specific displays, values, or control positions.

Set Point - A particular value or position of a multivalue or multiposition control.

Spurious - Erroneous. Refers to a false signal being displayed or causing equipment actuation.

Status - The existing state, condition, or mode.

Stereotypes - Standardized behavior patterns based on cultural, personal, or system consistencies--operator expectations.

Stress - A state of physical or mental tension caused by internal or external factors.

Tags - Temporary labels or markings that indicate equipment is not available or that identify operating restrictions.

Traffic - The flow of personnel through the control room, including visitors, auxiliary operators, construction workers, and other operations and nonoperations personnel.

Train - In nuclear plants, a complete chain of instruments and equipment that can be used to perform a function; e.g., a high pressure injection (HPI) train.

Unambiguous - Having only one meaning or interpretation; clear.

Unit - A determinate quantity adopted as a standard of measurement.

Values - Numeric, quantitative, or amount of a specified measurement.

Visibility - The quality of a symbol that makes it distinctive from its surroundings.

3 HUMAN ENGINEERING PRINCIPLES

The following sections describe the human engineering principles to be used in assessing HEDS. Each section contains principles associated with a particular aspect of the control room, such as displays, controls, etc. The format for each principle is identical. That is, each principle is listed on a separate page containing the following four categories:

Principle - The principle is expressed as a complete sentence.

Explanation - An explanation of the principle is provided, along with some descriptive guidance. One or more references are provided from which design criteria based on the principle can be obtained.

Guidance - References are provided for further explanation of the principle and detailed methods for accomplishing the principle.

Examples - One or more specific examples that illustrate the principle are cited. These examples, while generally acceptable, are neither recommendations nor preferred practices but are presented for illustrative purposes.

3.1 GENERAL CONTROL ROOM LAYOUT

The following principles address the general layout of the nuclear power plant control room. They involve control boards and the instrument arrangement on the control boards. They also involve control room environment and operator work station arrangement. The contents of this section are listed below.

3.1.1 Physical Characteristics

- o Functional Grouping
- o Consistent and Orderly Arrangement
- o Distinguishing Critical Instruments
- o Consistent Location System
- o Control Board Section Labels
- o Consistent Control/Display Relationship
- o Arrangement of Recurrent Functional Groups
- o Location of Critical and Frequently Used Instruments

3.1.2 Equipment Status

- o Method of Displaying Status
- o Failed Instruments
- o Off-Normal Indication
- o Testing of Emergency Equipment

3.1.3 Physical Arrangement

- o View of Control Boards
- o Access to Control Boards
- o Reducing Clutter
- o References
- o Multi-Unit Control Rooms
- o Adequate Working Area
- o Inventory of Spare Parts

3.1.4 Environment

- o Temperature and Humidity
- o Ventilation
- o Lighting

- Glare
- Noise
- Restrooms and Eating Areas

3.1.5 Hazards

3.1.6 Manning

3.1.7 Protective Equipment

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.1: Controls and displays should be placed in functional groups, such as systems or subsystems.

Explanation: Functional grouping aids identification of system components. It also aids system status monitoring because system parameters are all located in the same vicinity. Functional grouping facilitates operation and reduces errors.

Guidance: McCormick and Sanders, 1982, Chapter 12
Van Cott and Kinkade, 1972, pp. 400-404
MIL-STD-1472C, 5.4.1.3.4
NUREG-0700, 6.8.1.1, 6.8.1.2, 6.8.2.1

Examples of methods that might be used to support this principle include the following:

- o All high pressure injection instrumentation is located on one well-marked panel section.

- o Electrical distribution is controlled from one panel.

- o All nuclear instrumentation is grouped on a single panel section.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.2: Controls and displays should be arranged on control boards in a consistent and orderly pattern.

Explanation: Consistent relationships among instruments from system to system and board to board allow users to learn instrument placement easily. Controls and displays can be arranged in many ways. No particular arrangement necessarily is superior to another. However, the arrangement should be consistent.

Guidance: McCormick and Sanders, 1982, Chapter 8
Van Cott and Kinkade, 1972, p. 400
MIL-STD-1472C, 5.4.1.3
NUREG-0700, 6.8.2.2, 6.8.2.3, 6.8.2.4

Examples of methods that might be used to support this principle include the following:

- o Controls and indicators for a given system are on the same control board section.
- o The control activation sequence goes from top to bottom.
- o Controls are located directly below related displays.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.3: Critical controls and displays should be easily distinguishable from noncritical instruments.

Explanation: Timely operator response is aided when critical instruments are located easily. During some modes of operation, e.g., emergency operation, some controls and displays are critical. Such instruments should be distinguished easily from noncritical controls and displays.

Guidance: McCormick and Sanders, 1982, Chapter 9
Van Cott and Kinkade, 1972, p. 401
MIL-STD-1472C, 5.4.1.4
NUREG-0700, 6.8.1.3

Examples of methods that might be used to support this principle include the following:

- o Critical instruments are surrounded with a color patch.
- o Critical displays are larger than noncritical displays.
- o Critical controls are color-coded.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.4: A consistent method should be used to identify the location of systems within the control room and components within systems.

Explanation: Systems and components that are easy to locate can be accessed rapidly, especially during stressful modes of operation.

Guidance: McCormick and Sanders, 1982, Chapter 8
Van Cott and Kinkade, 1972, pp. 401-404
MIL-STD-1472C, 5.5.6
NUREG-0700, 6.6.1.1, 6.6.1.2, 6.6.2.1, 6.6.3.3, 6.6.6.1, 6.6.6.2, 6.6.6.3, 6.6.6.4, 6.8.2.3, 6.8.2.4

Examples of methods that might be used to support this principle include the following:

- o The control board is divided into rectangular grids.

- o Hierarchical labeling is used.

- o Systems are individually color-coded.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.5: Control board sections should be labeled. (See Section 3.6, LABELS.)

Explanation: Although not essential to the trained operator, control board section labels provide additional information under stress and aid in operator training. They also contribute to a systematic labeling program. Such labels may be of value to non-operator personnel during emergencies. Each section of the control board should contain instrumentation for one plant system or function (see Principle 5, Section 3.1.1). These functional groups should be labeled (e.g., FEEDWATER).

Guidance: Van Cott and Kinkade, 1972, p. 401
MIL-STD-1472C, 5.5.6.1
NUREG-0700, 6.6.1.2, 6.6.2.1

Examples of methods that might be used to support this principle include the following:

- The turbine control area of the control board is identified by a large label engraved "TURBINE."
- Hierarchical labeling is used on all control board sections.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.6: Control and display relationships should be consistent and unambiguous.

Explanation: When control movement is consistent with the controlled parameter's display movement, the probability of operator errors due to incorrect display interpretation is reduced. Likewise, any required control compensation by the operator is facilitated by such a consistent relationship.

Guidance: McCormick and Sanders, 1982, Chapter 12
Van Cott and Kinkade, 1972, pp. 401-404
MIL-STD-1472C, 5.4.1.3
NUREG-0700, 6.9.1.1, 6.9.1.2, 6.9.2.2, 6.9.2.3, 6.9.3.1

Examples of methods that might be used to support this principle include the following:

- o Rotary controls increase to the right, and their associated displays show increase by pointers that move to the right.

- o Controllers increase flow by moving a pointer up and the associated display is a meter with a pointer that tracks upward.

- o Controls have scales located to the left of their thumbwheel switches.

- o When controls are turned clockwise, the associated display moves up or increases.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.7: The location and arrangement of instruments in recurring functional groups should be similar from panel to panel.

Explanation: If functional groups of instruments are arranged similarly each time they are used, operator action patterns will transfer positively from one group to another. Many functional instrument groups, such as instruments for pumps and associated valves, are used over and over within the control room.

Guidance: McCormick and Sanders, 1982, Chapter 12
MIL-STD-1472C, 5.4.1.3
NUREG-0700, 6.8.2.4

Examples of methods that might be used to support this principle include the following:

- All pump groupings have the supply valve on the left and the discharge valve on the right.

- All turbines have the supply valve on the left and the exhaust valve on the right.

3.1 GENERAL

3.1.1 Physical Characteristics

Principle 3.1.1.8: Critical or frequently used controls and displays should be placed in the primary operating area.

Explanation: Placement of critical or frequently used controls and displays on back panels decreases efficiency of operation and may force operators to leave the primary operating area during certain operational sequences.

Guidance: McCormick and Sanders, 1982, Chapter 12
Van Cott and Kinkade, 1972, Chapter 9
MIL-STD-14726, 5.2.1, 5.4.1.3.3
NUREG-0700, 6.1.1.1b

Examples of methods that might be used to support this principle include the following:

- o Frequently used controls and displays are placed on front panels.

- o Controls and displays used for actions in which timing is critical are placed on front panels.

- o Displays that must be monitored continuously are placed on front panels.

3.1 GENERAL

3.1.2 Equipment Status

Principle 3.1.2.1: Consistent and unambiguous methods should be used to display the status of equipment.

Explanation: The status of many components can be "check" read quickly and accurately when the status of each component is displayed clearly.

Guidance: McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, Chapter 3, Chapter 8
NUREG-0700, 6.4.4.3d, 6.4.4.4b, 6.4.4.5d, 6.4.5.1a, 6.4.5.4a, 6.5.1.1e, 6.5.1.6d

Examples of methods that might be used to support this principle include the following:

- o Color is used consistently to indicate fluid flow--red for flow, green for no flow.

- o Pistol grip switch handles remain in their actual position and do not return to a non-indicating position.

- o Indicator lights located above each switch display the current status of the equipment controlled by that switch.

3.1 GENERAL

3.1.2 Equipment Status

Principle 3.1.2.2: Failed instruments should be easily recognizable as having failed.

Explanation: When an instrument has failed, the operator will be more likely to notice the failure if it produces an obviously wrong indication. Failed instruments can mislead an operator, especially during high workload periods.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.15.2.4, 5.9.17.1
NUREG-0700, 6.5.1.1f

Examples of methods that might be used to support this principle include the following:

- o Redundant displays are provided to allow cross-checking.
- o Instruments are labeled by sensor location and power source.
- o Different types of displays are provided for the same information.
- o Indicators are designed so they do not remain in the normal operating range if they lose power or their input signal.

3.1 GENERAL

3.1.2 Equipment Status

Principle 3.1.2.3: "Off-normal" indication should be displayed in a consistent and unambiguous manner.

Explanation: Response times to off-normal indications will be decreased and errors, if committed, can be detected and corrected more quickly when off-normal status is displayed clearly. When any plant parameter is out of its normal operating range, that condition should be readily apparent to operators. Error checking, procedure verification, and plant status determination will be expedited by such practices.

Guidance:
McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, Chapter 3
NUREG-0700, 6.5.2.3, 6.5.3.1b and d

Examples of methods that might be used to support this principle include the following:

- o Meters have a red band to show out-of-limit conditions.
- o Warning lamps are illuminated when controllers are set outside normal limits.
- o CRT displays change color to indicate out-of-limit conditions.

3.1 GENERAL

3.1.2 Equipment Status

Principle 3.1.2.4: Equipment for detecting and dealing with control room emergencies, transients, and abnormal conditions should be inspected or tested periodically (i.e., annunciator alarms, fire-fighting equipment, personnel protective equipment, communication equipment).

Explanation: To be effective, equipment for handling abnormal situations in the control room must be functional.

Guidance: NUREG-0700, 6.1.4.1c, 6.1.4.2a, 6.2.1.1b, 6.3.4.1d.2

Examples of methods that might be used to support this principle include the following:

- o Auditory alarms and annunciators are tested once per shift.
- o Fire-fighting equipment, radiation monitoring equipment, and personnel protective equipment is inspected monthly.
- o Control room communication equipment is tested weekly.

3.1 GENERAL

3.1.3 Physical Arrangement

Principle 3.1.3.1: Work stations should be arranged to allow an unobstructed view of the control board.

Explanation: Secondary work areas such as desks should allow operators visual access to the main control board displays. Many operators are required to perform duties in addition to direct plant control. Since these other duties are already distracting, additional interference may impact safety negatively.

Guidance: McCormick and Sanders, 1982, Chapter 11
NUREG-0700, 6.1.1.3a, 6.1.1.6

Examples of methods that might be used to support this principle include the following:

- The shift supervisor's (SS) office has a large glass panel through which the SS can see the control boards.
- The operator's desk faces the control boards.
- Bookcases are located against back walls so the operator does not have to look over them to see the control boards.

3.1.3 Physical Arrangement

Principle 3.1.3.2: Work stations should be arranged so access to control boards by operators is not impeded.

Explanation: Operators, but not necessarily other personnel, must be able to reach their control boards quickly. Secondary work areas used by operators or others should allow operators rapid physical access to operating positions. This principle does not preclude the use of such areas as barriers to non-operator personnel.

Guidance: McCormick and Sanders, 1982, Chapter 11
NUREG-0700, 6.1.1.3c, d, e, and f, 6.1.1.6

Examples of methods that might be used to support this principle include the following:

- o A separate area is provided for administrative activities, such as filling out tags.

- o Files are located in the back of the control room.

3.1 GENERAL

3.1.3 Physical Arrangement

Principle 3.1.3.3: Adequate storage for personal and infrequently used items should be provided to eliminate control room clutter.

Explanation: Cluttered work areas can cause injuries and increased response time in emergencies. Control rooms often are called upon to house occasionally used items. Personnel will have items such as hard hats, cold weather gear, lunches, etc., and storage should be provided for them.

Guidance: McCormick and Sanders, 1982, Chapter 11
NUREG-0700, 6.1.4.3, 6.1.5.6

Examples of methods that might be used to support this principle include the following:

- o Lockers are provided for personal items.
- o Shelves and hangers are installed next to the control room entrance to hold hard hats and coats.

3.1 GENERAL

3.1.3 Physical Arrangement

Principle 3.1.3.4: Storage and work space for necessary references should be provided.

Explanation: Reference materials such as plant and instrument drawings (P&IDs), procedures, drawings, etc., are often needed. Additional materials to support training may be in the control room. Inadequate provision for these materials leads to using the control board to hold them. Safe, easier use of such material may increase their use, as well as reduce inadvertent actuations.

Guidance: McCormick and Sanders, 1982, Chapter 11
NUREG-0700, 6.1.1.4

Examples of methods that might be used to support this principle include the following:

- o A roll-around cart is used for procedures.
- o A blank area of the control board is marked off for holding procedures.

3.1 GENERAL

3.1.3 Physical Arrangement

Principle 3.1.3.5: In multiunit control rooms, equipment arrangement should be such that unit operators do not interfere with each other during equipment operation.

Explanation: Operation of equipment from one control area should not be allowed to affect operation of the other unit detrimentally. When equipment is shared by more than one unit, the status and availability data for this equipment should easily be observable from each control room. The responsibility for operation of common equipment should be defined clearly.

Guidance: McCormick and Sanders, 1982, Chapter 11
NUREG-0700, 6.1.3.1, 6.1.3.2

Examples of methods that might be used to support this principle include the following:

- Status and availability data for shared equipment are displayed to all control areas.

- Administrative procedures are used to assign responsibility for control of shared equipment to a single control area.

- The distinction among different units is heightened, for example, by use of different color schemes.

3.1 GENERAL

3.1.3 Physical Arrangement

Principle 3.1.3.6: Working areas in the control room should provide adequate working space and promote operator comfort.

Explanation: Inadequate working space may result in task error or in tasks that are not completed in a timely manner. Uncomfortable working areas can cause operator fatigue that can, in turn, result in operator error.

Guidance: McCormick and Sanders, 1982, Chapter 11
NUREG-0700, 6.1.2.6, 6.1.2.7, 6.1.2.8, 6.1.5.7a

Examples of methods that might be used to support this principle include the following:

- o Desks provide sufficient working space for all materials required for task performance.

- o Chairs have appropriate backrests, armrests, cushioning, and seat areas.

- o General control room decor promotes a comfortable working environment.

- o A rolling bookcase is provided for storing and using procedures at the console.

3.1 GENERAL

3.1.3 Physical Arrangement

Principle 3.1.3.7: A sufficient inventory of easily accessible spare parts, expendables, and related tools should be available to the control room operator.

Explanation: Instrumentation and other control room equipment may require spare parts (i.e., bulbs, ribbons, etc.) to remain functional. An easily accessible supply of such parts reduces the time such equipment is likely to be unavailable to operating personnel.

Guidance: MIL-STD-1472C, 5.5.6.1
NUREG-0700, 6.1.1.5a, 6.1.1.5b, 6.1.1.5c, 6.1.1.5d, 6.1.1.5e, 6.1.1.5f

Examples of methods that might be used to support this principle include the following:

- An inventory system is used to maintain supplies.

- Spare parts are identified clearly and distinctively.

- Sufficient accessible storage space exists for spare parts.

3.1 GENERAL

3.1.4 Environment

Principle 3.1.4.1: Temperature and humidity should be controlled within acceptable limits to provide a comfortable environment.

Explanation: Control of temperature and humidity will reduce health risks and fatigue. Optimum temperature and humidity levels are a function of, at least, physical activity, clothing, and individual differences. However, the references listed in the guidance section contain tables to establish adequate temperature and humidity levels. Not only extremes of temperature and humidity, but also sudden changes in either should be avoided.

Guidance: McCormick and Sanders, 1982, Chapter 14
NUREG-0700, 6.1.5.1
ASHRAE 1981 Fundamental Handbook

Examples of methods that might be used to support this principle include the following:

- o Operators are comfortable when working in shirtsleeves.

- o Static electricity discharges from people to equipment do not occur frequently.

3.1 GENERAL

3.1.4 Environment

Principle 3.1.4.2: Adequate ventilation should be provided.

Explanation: Operators who are physically comfortable will perform better than those who are made uncomfortable by heavy particulates or distracted by odors. Ventilation considerations include the suppression of toxic gases, odorants, and particulate materials; the supply of sufficient oxygen and humidity; and the regulation of air flow velocity and direction. Tables can be found in the "Guidance" section references that supply specific temperature, humidity, and velocity suggestions.

Guidance: McCormick and Sanders, 1982, Chapter 14
NUREG-0700, 6.1.5.2
ASHRAE 1981 Fundamental Handbook

Examples of methods that might be used to support this principle include the following:

- Control room air is mixed with fresh air.
- Ventilation is provided in the control room.

3.1 GENERAL

3.1.4 Environment

Principle 3.1.4.3: Adequate lighting should be provided.

Explanation: Illumination can be both too bright and too dim. Levels should provide adequate contrast ratios between background and markings. Control boards should be illuminated at a level compatible with use. Areas using displays that are self-illuminating should be lighted differently from areas that are reflective. Areas used for reading printed materials or writing should be illuminated differently. Tables in the "Guidance" section references can provide specific suggestions. Adequate lighting is necessary for both normal and other than normal conditions.

Guidance: McCormick and Sanders, 1982, Chapter 13
NUREG-0700, 6.1.5.3, 6.1.5.4
IES Lighting Handbook, 1981

Examples of methods that might be used to support this principle include the following:

- o CRTs do not have makeshift glare reduction hoods attached.
- o Operators do not have to use desk lamps for supplemental lighting.
- o No dark shadows are cast on critical operating areas.
- o The emergency lighting system is simply the normal lighting system powered from an emergency bus.

3.1 GENERAL

3.1.4 Environment

Principle 3.1.4.4: Glare should be minimized.

Explanation: Glare causes the operator to have frequent shifts in accommodation that can cause fatigue. Glare is the mirror-like reflection of light from a surface. It appears as if the surface is a light source. When present on displays, it may interfere with reading. When present on other surfaces, it may decrease contrast with displays. Although glare cannot be eliminated completely, the use of anti-glare sprays, moving the light sources, or changing the angle of reflective surfaces can minimize glare.

Guidance: McCormick and Sanders, 1982, Chapter 13
NUREG-0700, 6.1.5.3f

Examples of methods that might be used to support this principle include the following:

- o No highly polished metallic surfaces are used.
- o *Lights are positioned above curved-faced meters.
- o Antiglare sprays are used on chart recorder windows.
- o Panels are painted with matte finish and lustreless (flat) paint.

3.1 GENERAL

3.1.4 Environment

Principle 3.1.4.5: Background noise should be minimized.

Explanation: Noise affects operators in at least two ways. First, noise makes communications difficult. By interfering with communications among operators, noise may cause errors and increase response times. Second, noise causes fatigue. Operators subjected to continuous high noise levels are less responsive to changes in noise level. The type of noise is also important. For example, speech is more difficult when the noise is other speakers than when the noise is ventilation equipment.

Guidance: McCormick and Sanders, 1982, Chapter 15
NUREG-0700, 6.1.5.5

Examples of methods that might be used to support this principle include the following:

- o Alarm printers are housed in acoustic enclosures.
- o All noisy equipment is located in an acoustically isolated room.
- o Noisy equipment is sound-insulated.

3.1 GENERAL

3.1.4 Environment

Principle 3.1.4.6: Easily accessible restrooms and eating areas should be provided within or near the control room.

Explanation: To avoid fatigue, excessive operator absence from the control room area, and to maintain high morale, an effort should be made to provide easily accessible restroom and eating facilities.

Guidance: NUREG-0700, 6.1.5.7b, c

Examples of methods that might be used to support this principle include the following:

- Designated restrooms and eating areas are within or near the control room isolation boundary.

- A breakroom containing restrooms and simple kitchen facilities is located just off the control room.

3.1 GENERAL

3.1.5 Hazards

Principle 3.1.5.1: The control room should be free of personnel hazards.

Explanation: Such hazards pose a danger not only to personnel directly but also to the plant. Tripping hazards such as telephone lines and power cords should be eliminated. Electric shock sources should be protected. A falling person may grasp a control to steady himself causing an inadvertent control activation.

Guidance: McCormick and Sanders, 1982, Chapters 11 and 17
NUREG-0700, 6.1.1.3c

Examples of methods that might be used to support this principle include the following:

- o All cabling is run under raised flooring.
- o Sound-powered phone cables are coiled.
- o All desks and panels have rounded edges.
- o A special ladder/platform is provided to allow annunciator light replacement without standing on the control board or a chair.

3.1 GENERAL

3.1.6 Manning

Principle 3.1.6.1: Control room manning and task assignment should ensure complete and timely coverage of controls, displays, and other equipment required during all modes of operation.

Explanation: Inadequate or incorrect task assignments may result in personnel interfering with one another or, at the other extreme, in tasks not getting done. Tasks performed infrequently or under stress such as those that occur under emergency operations may be affected particularly.

Guidance: McCormick and Sanders, 1982, Chapter 17
NUREG-0700, 6.1.1.2

Examples of methods that might be used to support this principle include the following:

- o Task analyses and walk-through/talk-throughs indicate sufficient manning levels exist to preclude excessive operator workload.

- o Vacations, leaves, etc., are scheduled so operators do not have to work overtime frequently.

3.1 GENERAL

3.1.7 Protective Equipment

Principle 3.1.7.1: Operators should have access to protective equipment and be trained in its use.

Explanation: Operators must be protected against hazardous conditions if they are to man the control room during fires and in other emergency situations. Knowledge of the availability, effectiveness, and use of such protective equipment also should increase the likelihood that operators will manage the plant effectively under marginal conditions.

Guidance: MIL-STD-1472C, 5.13
NUREG-0700, 6.1.4.1a, 6.1.4.1b, 6.1.4.1d

Examples of methods that might be used to support this principle include the following:

- o A supply of protective equipment adequate to outfit the shift crew is maintained.

- o Operators have received training in the use of protective equipment.

3.2 CONTROLS

The following principles relate to the characteristics of the controls found in a nuclear power plant control room. The contents of this section are listed below.

3.2.1 Physical Characteristics

- o Stereotypical Control Movement
- o Number of Control Settings
- o Indication of Current Position
- o Force Required to Operate
- o Redundant Coding

3.2.2 Arrangement

- o Recognition of Control Status
- o Location of Controls and Related Displays
- o Orientation of Arrays of Controls
- o Obscuring Other Controls
- o Accessibility of Controls
- o Frequency-of-Use Location Priority
- o Controls Used for Emergency Operation
- o Simultaneous Control Operation
- o Inadvertant Activation

3.2.3 Scales

- o Natural Numerical Scale Progession
- o Appropriate Units
- o Multiple Controls for Same Parameter
- o Limits and Setpoints

3.2 CONTROLS

3.2.1 Physical Characteristics

Principle 3.2.1.1: Control manipulation should follow population or plant stereotypes consistently.

Explanation: Controls designed to follow stereotypes are more likely to be operated correctly than controls that do not take stereotypical behavior into account. When a particular activity is performed the same way over and over, the manner in which it is performed is said to be "stereotyped." During stressful or time-constrained situations, humans tend to perform according to stereotype for certain behavior.

Guidance: McCormick and Sanders, 1982, Chapter 8
Van Cott and Kinkade, 1972, p. 404
MIL-STD-1472C, 5.4.1
NUREG-0700, 6.4.1.1., 6.9.1.2

Examples of methods that might be used to support this principle include the following:

- o All rotary controls turn clockwise for "increase."
- o All toggle switches move up for "on."
- o All valve controls turn clockwise for "open."

3.2 CONTROLS

3.2.1 Physical Characteristics

Principle 3.2.1.2: Controls should have the least possible number of settings.

Explanation: Discrete controls with a large number of possible settings are more likely to be set incorrectly. Discrete controls generally are used to select one state or equipment configuration, from a number of possible states. Such controls can have a significant impact on operation if set incorrectly.

Guidance: McCormick and Sanders, 1982, Chapter 9
Van Cott and Kinkade, 1972, p. 361
MIL-STD-1472C, 5.4.2.1.1.4
NUREG-0700, 6.4.4.5

The following is an example of a method that might be used to support this principle:

- o If more than 10 settings are required, multiple controls are used that select decades, digits, etc.

3.2 CONTROLS

3.2.1 Physical Characteristics

Principle 3.2.1.3: Controls should indicate their current positions when check reading is required.

Explanation: When controls somehow indicate their current position, controls can be "check read" very quickly. Knowledge of the current position, or state, of controls is sometimes necessary for operators to do their jobs effectively. Such knowledge can be critical during certain operational modes.

Guidance: MIL-STD-1472C, 5.4.2.2.2.4
NUREG-0700, 6.4.4.5, 6.4.5.3, 6.9.1.2

Examples of methods that might be used to support this principle include the following:

- o Control handles remain pointed to their actual state.

- o Return-to-center controls are equipped with large position flags.

3.2 CONTROLS

3.2.1 Physical Characteristics

Principle 3.2.1.4: The force required to operate controls should be high enough to avoid inadvertant actuation but not high enough to cause muscular fatigue or operational difficulties.

Explanation: The forces required by some types of switches are much higher than necessary and can cause muscular fatigue. The force required of an operator is a function of both the required torque and the control handle length. This principle is especially applicable to switches that have to be held in one position for an extended period or operated frequently.

Guidance: McCormick and Sanders, 1982, Chapter 9
Van Cott and Kinkade, 1972, p. 350 & pp. 353-354
MIL-STD-1472C, 5.4.1.8, 5.4.2.2.2.3, 5.4.2.2.2.6, 5.4.4
NUREG-0700, 6.4.1.2, 6.4.5.2

Examples of methods that might be used to support this principle include the following:

- o All SBM-type switches use 2.75" J-handles.
- o All turn-and-hold thumb switches have permanently affixed extenders or "gloves."

3.2 CONTROLS

3.2.1 Physical Characteristics

Principle 3.2.1.5: Redundant coding of controls is desirable.

Explanation: A redundant coding scheme allows some coding to be retained even after one coding dimension is lost. Commonplace things that are coded generally are coded in more than one dimension. For instance, traffic lights are coded by color <u>and</u> by position.

Guidance: McCormick and Sanders, 1982, Chapter 9
Van Cott and Kinkade, 1972, pp. 313-320
NUREG-0700, 6.4.2.2

Examples of methods that might be used to support this principle include the following:

- o All feedwater valves are controlled by Brand X cane-handle controls and are located on the feedwater panel.

- o All main steam isolation valves use one-inch pushbutton controls and are colored fluorescent orange.

- o For valve indications, the red light on the right means "open," and the green light on the left means "closed."

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.1: Control status should be recognizable from control operating locations.

Explanation: Operations can be performed more quickly and safely if the operators can determine the status of controls without changing position and then returning. In many plant evolutions, operators maintain fixed positions at the control panels. This is particularly true for start-up, cooldown, and some emergency operations.

Guidance: Van Cott and Kinkade, 1972, p. 399
NUREG-0700, 6.6.3.8

Examples of methods that might be used to support this principle include the following:

- Operators can determine the status of the AFW controls from the HPI panel.

- The status of the turbine EHC controls is visible from the reactor panel.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.2: Controls should be located so the related displays can be used to provide feedback.

Explanation: Placing related controls and displays near each other reduces the likelihood of a control being misadjusted due to an incorrect interpretation of a display. Controls generally are manipulated to change some plant parameters, such as flow, level, or temperature. Direct feedback to the operator allows control adjustments to be made swiftly and accurately.

Guidance: McCormick and Sanders, 1982, Chapter 8
Van Cott and Kinkade, 1972, pp. 397-401
MIL-STD-1472C, 5.1
NUREG-0700, 6.9.2.2

Examples of methods that might be used to support this principle include the following:

- o Flow controllers are located directly below the associated flow indicators.
- o Control rod position displays are located directly above the associated controls.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.3: For one-to-one control/display relationships, arrays of controls should be oriented the same as arrays of related displays.

Explanation: The arrangement of controls and displays should be as similar as possible so a given display can be associated with the proper control. Ideally, a display should be located directly above its related control. However, other design constraints may preclude such an arrangement and favor controls being placed in one array and displays in another.

Guidance: McCormick and Sanders, 1982, Chapter 8
Van Cott and Kinkade, 1972, pp. 349-350
MIL-STD-1472C, 5.4.1.3, 5.1.2
NUREG-0700, 6.9.1.2, 6.8.2.1

Examples of methods that might be used to support this principle include the following:

- o Steam generator level indicators are placed in a vertical line on the control board, and the associated level controllers are placed one above the other on the bench board.

- o Reactor coolant pump (RCP) breaker switches are placed in a mimic on the bench board. RCP ammeters are placed in a similar arrangement on the vertical board.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.4: Controls should be located so their operation does not obscure other related controls or displays.

Explanation: The placement of controls so neither they nor the operators' hands obscure other necessary indications ensures that required information will not be obscured while the control(s) is being manipulated. It is often necessary to operate a control and read a display simultaneously. Likewise, the status of related controls sometimes must be determined while operating another control.

Guidance: McCormick and Sanders, 1982, Chapter 12
NUREG-0700, 6.9.1.1b

Examples of methods that might be used to support this principle include the following:

- o Controls are located below their associated displays.
- o Simultaneously operated controls are located so they can be operated easily.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.5: Controls should be located so they are reachable and accessible.

Explanation: To be useable, controls must be within the physical reach of all operators, and they must be accessible to operators. No physical barriers should prevent a control from being manipulated.

Guidance: McCormick and Sanders, 1982, Chapter 12
MIL-STD-1472C, 5.7, 5.1.2
NUREG-0700, 6.1.2.2b, 6.1.2.3b, c, 6.1.2.4, 6.1.2.5

Examples of methods that might be used to support this principle include the following:

- o All controls are located on the surface of bench boards.

- o All controls are located within 30 inches horizontally from the front edge of control panels.

- o A footstool is available in the control room.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.6: The location of controls should be based on their use.

Explanation: Controls used most often in normal operation should be the most accessible to reduce operation fatigue and error. However, controls used for emergency operation or controls that must be accessed rapidly may be found to have higher priority. Overall plant operation should be considered.

Guidance:
McCormick and Sanders, 1982, Chapter 12
Van Cott and Kinkade, 1972, pp. 400-404
MIL-STD-1472C, 5.1.2
NUREG-0700, 6.8.1.1, 6.8.2.1

Examples of methods that might be used to support this principle include the following:

- o Demineralizer controls are located near the rear of the control board.

- o Feedwater valve controls are located in the center of the control board, and the feedwater bypass valve control is located near the front edge.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.7: Controls critical for emergency operation should be clearly discriminable.

Explanation: Some controls are used mainly for abnormal or emergency operation. If such controls are coded so they are clearly different from controls used mainly in normal operation, then they will be more easily locatable during high-stress situations.

Guidance:
McCormick and Sanders, 1982, Chapter 12
Van Cott and Kinkade, 1972, p. 352
MIL-STD-1472C, 5.1.2.1.1.3
NUREG-0700, 6.4.2.2, 6.8.1.3d

Examples of methods that might be used to support this principle include the following:

- o Emergency controls have a red spot on their labels.
- o Scram buttons are painted red.
- o The safety injection (SI) system is grouped together and demarcated plainly.
- o SI in PWRs and standby liquid control (SLC) in BWRs are never used in normal operation.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.8: Control placement should allow simultaneous operation of adjacent controls where required.

Explanation: For efficient operation of controls to decrease operator task load and manning requirements, simultaneous activation of adjacent controls (where required) should be possible. Procedures sometimes require the near-simultaneous actuation of two different controls.

Guidance: McCormick and Sanders, 1982, Chapter 12
MIL-STD-1472C 5.4.1.3.1
NUREG-0700, 6.8.3.1

The following is an example of a method that might be used to support this principle:

- o Control separation does not preclude simultaneous operation of adjacent controls where required.

3.2 CONTROLS

3.2.2 Arrangement

Principle 3.2.2.9 Control placement should not cause inadvertent activation of other controls.

Explanation: Control placement that increases the likelihood of inadvertent control activation also increases the probability that plant systems unintentionally will be placed in service or taken out of service. This is a potentially dangerous situation, particularly during transient conditions.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C 5.4.1.8
NUREG-0700 6.4.1.2, 6.8.3.1

Examples of methods that might be used to support this principle include the following:

- o Plastic barriers have been added between controls that are too close together.
- o A "bumper" rail has been attached to the front of the benchboard to lessen the likelihood of operators bumping protruding J-handle controls.

3.2.3 Scales

Principle 3.2.3.1: When controls are positioned according to a numerical scale, the scale should have divisions with a natural numerical progression.

Explanation: Scales that progress in other than natural steps (1, 2, 5, 10, etc.) often are misread. Scale multipliers often are misapplied and, if used, should be integral powers of 10.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.1.3
NUREG-0700, 6.6.3.8

Examples of methods that might be used to support this principle include the following:

- The control that selects the scale multiplier for nuclear instrumentation is marked $x10^1$, $x10^2$, $x10^3$, $x10^4$, $x10^5$.

- Multiple-turn potentiometers are calibrated, 10-turn type.

3.2.3 Scales

Principle 3.2.3.2: Control scale values should be in appropriate units.

Explanation: Where controls have associated scales, the scale units should correspond to the physical parameters being adjusted. If the control action is verified with a display, then the control and display scales should be in the same units.

Guidance: MIL-STD-1472C, 5.1.3
NUREG-0700, 6.5.1.2

The following is an example of a method that might be used to support this principle:

- Where possible, controller setting value displays are labeled in engineering units.

3.2 CONTROLS

3.2.3 Scales

Principle 3.2.3.3: Redundant and multiple controls for the same parameter should have consistent scales, units, and zero points.

Explanation: Transfer among controls is facilitated by using consistent scales and units, where this is possible. It is confusing to have two or more controls apparently controlling the same thing but having different zero points or scale units.

Guidance: MIL-STD-1472C, 5.2.3
NUREG-0700, 6.5.1.2, 6.5.1.5

The following is an example of a method that might be used to support this principle:

- o All feedwater regulation valve controllers have identical scale values.

3.2 CONTROLS

3.2.3 Scales

Principle 3.2.3.4: Limits and setpoints should be presented in a clear and unambiguous manner.

Explanation: This practice frees operators from having to memorize numbers and setpoints.

Guidance: Van Cott and Kinkade, 1972, p. 349
NUREG-0700, 6.5.2.3

Examples of methods that might be used to support this principle include the following:

- o RCS pressure indicators are marked to show where PRZR heaters and spray are activated.

- o In a BWR, the RV-level indicator is marked to show the levels at which various equipment is automatically activated or tripped.

3.3 DISPLAYS

The following principles relate to the characteristics of displays located in a nuclear power plant control room. The contents of this section are listed below.

3.3.1 Physical Characteristics

- o Stereotypical Display Presentation
- o Number of Scales
- o Update Interval
- o Indication of Current Status
- o Selection Based on Information Requirements
- o Light Intensity of Illuminated Indicators

3.3.2 Arrangement

- o Readability
- o Location Near Related Controls
- o Displays Used for Emergency Operation
- o Obscuring Other Displays
- o Discriminability

3.3.3 Scales

- o Appropriate Units
- o Range
- o Natural Numerical Progression
- o Consistency
- o Resolution
- o Multiple Displays for Same Parameter
- o Pointer/Scale Mismatch

3.3.4 Recorders

- o Readability
- o Multi-Pen Recorders
- o Switched Displays
- o Obscuring Other Displays
- o Direction of Movement
- o Appropriate Scale Paper

3.3 DISPLAYS

3.3.1 Physical Characteristics

Principle 3.3.1.1: Displays should follow general population or plant stereotypes.

Explanation: Displays designed to follow such stereotypes are more likely to be understood correctly than displays that do not take stereotypical behavior into account. During stressful or time-constrained situations, humans tend to perform according to stereotype for certain behavior. When information is repeatedly and consistently displayed, the manner in which it is displayed is said to be "stereotyped."

Guidance: Van Cott and Kinkade, 1972, p. 404
MIL-STD-1472C, 5.4.1
NUREG-0700, 6.4.1.1, 6.5.2.1, 6.9.1.2

Examples of methods that might be used to support this principle include the following:

- o All dial meters move clockwise for "increase."
- o All edge meters move up for "increase."
- o All bar graphs move right for "increase."

3.3 DISPLAYS

3.3.1 Physical Characteristics

Principle 3.3.1.2: Individual displays should have only one scale.

Explanation: Accurate reading of displays is necessary for operators to do their jobs effectively. Rapid understanding can be critical during certain operational modes.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.3
NUREG-0700, 6.5.1.5f

Examples of methods that might be used to support this principle include the following:

- o Linear and logarithmic scales are not used on the same indicator.

- o When CRT pages are used to display trend information, all the parameters shown simultaneously have the same horizontal and vertical scale.

3.3 DISPLAYS

3.3.1 Physical Characteristics

Principle 3.3.1.3: Digital displays should update at intervals appropriate for function and readability.

Explanation: Operators must be able to believe that displayed values are current. Displays should update with sufficient frequency to allow observation of trends and to ensure that the displayed value reflects the current state of the parameter being monitored. Digital displays that "count up" or flicker are not desirable.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.6.2, 5.2.6.8
NUREG-0700, 6.5.5.2b, 6.5.1.1b, 6.5.1.2f

Examples of methods that might be used to support this principle include the following:

- Time display on a CRT is updated at one-minute intervals.

- Digital display of steam generator levels are updated at five-second intervals to eliminate some level oscillations, while still providing a fairly rapid update during transient conditions.

- Barometric pressures are updated at one-hour intervals.

3.3 DISPLAYS

3.3.1 Physical Characteristics

Principle 3.3.1.4: Displays should allow system status to be determined when scanned from operating locations.

Explanation: Displays that allow "check reading" by operators allow the plant status to be reviewed quickly.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.3.1.10
NUREG-0700, 6.1.1.1, 6.1.1.3a, 6.5.1.1e, 6.5.2.5

Examples of methods that might be used to support this principle include the following:

- o Meters are banded.
- o CRT traces change color.
- o Similar meters all read mid-range under normal conditions.

3.3 DISPLAYS

3.3.1 Physical Characteristics

Principle 3.3.1.5: Display type should be selected for the information to be displayed.

Explanation: Certain information is displayed more appropriately on specific types of displays. For example, digital displays minimize reading time for exact values. However, digital displays are not suitable for observation of trends or simple check readings.

Guidance: MIL-STD-1472C, 5.2.1.3, 5.2.2.1.1, 5.2.3.1.2, 5.2.6.2.1
NUREG-0700, 6.5.1.2, 6.5.1.4, 6.5.5.1

Examples of methods that might be used to support this principle include the following:

- o Turbine speed display is digital.
- o Turbine governor valve position indication is analog.
- o Pressure setpoint display is digital.
- o Subcooling margin is displayed digitally.

3.3 DISPLAYS

3.3.1 Physical Characteristics

Principle 3.3.1.6: Light intensity of illuminated indicators should allow easy discrimination between on/off conditions, and light color should be identifiable and consistent with color-coding conventions.

Explanation: Illuminated displays, including indicating lights, jewel lights, and legend lights require a light intensity sufficiently greater than the surrounding panel. Such displays usually employ color-coding in addition to light intensity.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.2.1.9, 5.2.2.1.12
NUREG-0700, 6.5.3.2, 6.5.3.3

Examples of methods that might be used to support this principle include the following:

- o Light intensity of illuminated indicator is sufficiently greater than surrounding panel to determine when it is lit.

- o Tinted cover glass is chosen so the color of the light is clearly identifiable.

3.3 DISPLAYS

3.3.2 Arrangement

Principle 3.3.2.1: Displays should be readable to the required precision from the operating locations.

Explanation: An operator should not have to change his position to read a display and then return to his original position. If a display is needed only for trending or general information, then it need not be designed for precise reading.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.1.3.2, 5.2.1.4.11, 5.2.1.4.12
NUREG-0700, 6.1.1.3, 6.1.2.5, 6.5.1.2, 6.5.1.3, 6.5.2.4

Examples of methods that might be used to support this principle include the following:

- The T_{ave} indicator is readable from the main operating console.

- The reactor vessel (RV) level indicator is readable from the high pressure coolant injection (HPCI) operating panel.

- Torus level is readable from the residual heat removal (RHR) operating location.

3.3 DISPLAYS

3.3.2 Arrangement

Principle 3.3.2.2: Displays should be located near related controls.

Explanation: Direct feedback to the operator allows control adjustments to be made swiftly and accurately. Displays generally are read to provide feedback from some change in plant parameters made by a control input, such as flow, level, or temperature. Placing related controls and displays near each other reduces the likelihood of a control being misadjusted due to an incorrect interpretation of a display.

Guidance: McCormick and Sanders, 1982, Chapter 8
Van Cott and Kinkade, 1972, pp. 397-401
MIL-STD-1472C, 5.1
NUREG-0700, 6.9.2.2

Examples of methods that might be used to support this principle include the following:

- o Flow indicators are located directly above the associated flow controllers.

- o Control rod position displays are located directly above the associated controls.

3.3 DISPLAYS

3.3.2 Arrangement

Principle 3.3.2.3: Displays critical for emergency operation should be clearly discriminable.

Explanation: Some displays are used mainly for abnormal or emergency operation. If such displays are coded so they are clearly different from displays used mainly in normal operation, the chance of misuse is reduced.

Guidance: McCormick and Sanders, 1982, Chapter 12
Van Cott and Kinkade, 1972, 9.5.1
MIL-STD-1472C, 5.2.1.4.9
NUREG-0700, 6.8.1.1.c, 6.8.1.3

Examples of methods that might be used to support this principle include the following:

- o Emergency displays have a red spot on their labels.

- o SI in PWRs and SLC in BWRs are never used in normal operation.

3.3 DISPLAYS

3.3.2 Arrangement

Principle 3.3.2.4: Displays should be located so the operation of a related control does not obscure the display.

Explanation: It is sometimes necessary to operate a control and read a display simultaneously. The placement of controls so neither they nor the operator's hands obscure a display ensures that the display can be read in an accurate and timely manner.

Guidance: McCormick and Sanders, 1982, Chapter 12
NUREG-0700, 6.9.1.1

The following is an example of a method that might be used to support this principle:

- o Controls are located below their associated displays.

3.3 DISPLAYS

3.3.2 Arrangement

Principle 3.3.2.5: In a string of displays, each individual display should be discriminable and readable.

Explanation: Operators easily can confuse displays that are not discriminable, and lack of readability may cause errors in reading displays.

Guidance: MIL-STD-1472C, 5.2.1.4
NUREG-0700, 6.6.1.2, 6.8.3.2

The following is an example of a method that might be used to support this principle:

- o Groups of pressure, temperature, and flow indicators are always arranged with pressure on the left, temperature in the middle, and flow on the right.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.1: Display scale units should be appropriate to the required use of the display.

Explanation: Where displays have associated scales, the scale units should correspond with procedures. If the display has an associated control, then the control and display scales should be in the same unit.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.1.3.3
NUREG-0700, 6.5.1.2

The following is an example of a method that might be used to support this principle:

- A procedure calls for operator action when the torus level is 146 inches. The torus-level display scale has markings for every inch, and the scale is labeled in inches.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.2: Displays should have a scale range adequate for the conditions under which the display is to be used.

Explanation: A display that is off-scale is not supplying the operator with the value of the measured parameter; it is merely telling him that the value is beyond the scale of that display. For an operator to determine actual parameter values, a display scale should cover all anticipated operating conditions.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.1.3
NUREG-0700, 6.5.1.2

Examples of methods that might be used to support this principle include the following:

- o A fuel zone water-level meter displays the range above and below top of active fuel (TAF).

- o Multiple water-level indicators are used for BWRs to display the required range.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.3: Displays should have scale divisions with usual numerical progressions.

Explanation: Scales that progress in other than the usual 1, 2, 5, 10 order often are misread. Multipliers often are misapplied and, if used, should be only integral powers of 10.

Guidance:
McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, pp. 81-95
MIL-STD-1472C, 6.2.6
NUREG-0700, 6.5.1.5c

Examples of methods that might be used to support this principle include the following:

- 0-25 amp meters have major scale divisions at 5-amp increments.

- RPI indicators are scaled in 20-inch increments.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.4: Displays should have scales for which units of rate, volume, etc., are consistent, at least within systems.

Explanation: A system in which flow is in pounds/hour and volume is expressed in gallons is difficult to understand. Unit conversion should be avoided.

Guidance: McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, p. 404
MIL-STD-1472C, 5.2.3
NUREG-0700, 6.5.1.5d

The following is an example of a method that might be used to support this principle:

- o For each steam generator, the feed-flow and steam-flow indicators are located in the same area and have the same range, scale, and zero.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.5: Displays should have scales consistent with the resolution required to operate the system.

Explanation: Operators cannot be expected to take action when parameters reach specific values unless the indicator for that parameter is readable to the required precision. The finest resolution available on an analog display is one-half the smallest scale division. Digital displays are readable to the least significant digit (LSD), but the circuitry that converts analog signals to digital form usually is precise to only $\pm$ 1/2 LSD.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.3
NUREG-0700, 6.5.1.2, 6.9.3.2

The following is an example of a method that might be used to support this principle:

- o Torus water-level must be read at 27.5 inches. The scale has markings at 27 inches and 28 inches.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.6: Multiple displays of the same parameter should have consistent scales, units, and zero points.

Explanation: Deviations among multiple displays of the same parameter are easier to detect if all the displays have the same range, scale, and zero. It is confusing to have two or more instruments apparently measuring the same thing but having different zero points. Transfer between instruments and understanding is difficult.

Guidance: MIL-STD-1472C, 5.2.3
NUREG-0700, 6.5.1.5d

Examples of methods that might be used to support this principle include the following:

- o There are three redundant display channels for displaying SG level, each with the same range, scale, and zero.

- o There are two redundant display channels for pressurizer level, each with the same range, scale, and zero.

3.3 DISPLAYS

3.3.3 Scales

Principle 3.3.3.7: Displays should avoid arrangement and scale design that allow mismatching scale and pointer.

Explanation: Such confusion is a source of operator error. Mismatching scale and pointer can be caused by excessive parallax, poor pointer design, a wide gap between pointer tip and scale markings, and other design or layout problems.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.3.1.7, 5.2.3.2.3.6
NUREG-0700, 6.5.2.2

Examples of methods that might be used to support this principle include the following:

- o Curved, vertical edge meters are located in a narrow height band that approximates average eye height.

- o Displays with pointers are designed so the pointer appears almost to touch the scale markings but does not obscure them.

3.3 DISPLAYS

3.3.4 Recorders

Principle 3.3.4.1: Recorders used as indicators should meet the same readability requirements as any other display.

Explanation: Recorders may be used as a primary display during operation. When so used, a recorder is as important as any other display and should be as usable. Even if the recorder is used only for trending, reading errors can cause confusion and delay.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.6.4
NUREG-0700, 6.5.4.1, 6.5.4.2

Examples of methods that might be used to support this principle include the following:

- o Strip chart recorders have a moving pointer indicator affixed to the pen mechanism.
- o Strip chart paper has the same number of gradations as related meters.
- o The turbine vibration eccentricity recorder is scaled clearly and is easy to interpret.
- o The T_{ave} recorder is readable from the reactor control operating location.

3.3.4 Recorders

Principle 3.3.4.2: Multi-point or multi-pen displays should create unambiguous records.

Explanation: Ambiguous trend plots can cause misinterpretation of recorded data. Data from several channels may be recorded on one chart recorder strip. When only two or three are recorded, different colored ink (e.g., red, blue, green) can be used. If more than three traces are used, they usually are encoded by printing a single number or letter. In either case, a label should tie the code (or color) to the channel. Printing recorders, as opposed to tracing recorders, should print with sufficient frequency to allow identification of channel and trend.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.6.4
NUREG-0700, 6.5.4.2

Examples of methods that might be used to support this principle include the following:

- o Each pen in a multi-pen recorder is color-coded to match the ink color it uses.
- o Impact recorders have no more than six input points.

3.3.4 Recorders

Principle 3.3.4.3: Switched displays should indicate clearly the input displayed.

Explanation: When more than one input is switched to a recorder, the current data source should be indicated. The data source also should be identifiable on earlier portions of the recording. Such information is helpful in identifying faults and understanding historical records.

Guidance: MIL-STD-1472C, 5.5.6.2
NUREG-0700, 6.5.4.2

Examples of methods that might be used to support this principle include the following:

- o Different colored pens are used to trace two different channels.
- o When switched, a numerical identifier is printed.
- o Procedures require the operator to write the number of the selected channel on the chart strip.

3.3 DISPLAYS

3.3.4 Recorders

Principle 3.3.4.4: Recorders should not obscure other displays or controls.

Explanation: Although most recorders retain records internally, some do not. Some recorders are modified to allow paper to exit the machine. Recorders may drip ink or require external inking supplies. Such expedients should not interfere with operation.

Guidance: MIL-STD-1472C, 5.2.6.4
NUREG-0700, 6.5.4.1, 6.5.4.2

Examples of methods that might be used to support this principle include the following:

- o External ink supplies, which have been added to ensure continuous ink flow, are attached above and adjacent to the recorder.

- o Paper that exits a strip chart recorder is rolled up every hour.

- o Dripping ink pens are repaired within two shifts.

3.3 DISPLAYS

3.3.4 Recorders

Principle 3.3.4.5: All recorders should have consistent scale direction.

Explanation: Consistent scale direction makes recorders much easier to check-read and less likely to be misinterpreted. Scale and paper movement direction should be established as a control room design convention for future control room modifications.

Guidance: Van Cott and Kinkade, 1972, pp. 81-95
MIL-STD-1472C, 6.2.6
NUREG-0700, 6.5.4.1, 6.5.4.2

Examples of methods that might be used to support this principle include the following:

- o Strip chart recorders show increase to the right or up.

- o Strip chart recorders show the current value at the top or the right edge, depending on whether the paper moves vertically or horizontally, respectively.

3.3 DISPLAYS

3.3.4 Recorders

Principle 3.3.4.6: Recorders should be filled with the apppropriate scaled paper.

Explanation: Recorders can be filled with paper not having the correct scale. Operators then have to convert traces to the correct scale. This is time-consuming and can cause error, especially under stress.

Guidance:
McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.1.3
NUREG-0700, 6.5.4.1, 6.5.4.2

Examples of methods that might be used to support this principle include the following:

- o Procedures list the type of chart paper for each graphic recorder by stock number.
- o Recorders have a tag inside that tells what kind of chart paper they use.

3.4 ANNUNCIATORS

The following principles relate to the characteristics of annunciators located in a nuclear power plant control room. The contents of this section are listed below.

3.4.1 General

- o Conditions Requiring Annunciation
- o Normal Status Annunciation
- o Spurious Annunciation

3.4.2 Physical Characteristics

- o Dark Board Concept
- o Brightness
- o Flash Rate
- o Redundant Coding
- o Audible Tone Discrimination
- o Audible Tone Loudness
- o Location Cues
- o Prioritization

3.4.3 Tile Legends

- o Legend Readability
- o Description of Annunciated Condition
- o Multiple Inputs
- o Consistency of Language
- o Out-of-Service Annunciators

3.4.4 Arrangement

- o Location Near Related Controls
- o Grouping to Aid Diagnosis
- o Acknowledgement

3.4.5 Presentation

- o Number of Annunciators
- o Re-flash Capability

3.4 ANNUNCIATORS

3.4.1 General

Principle 3.4.1.1: Annunciators should be used to alert operators to conditions that require their attention.

Explanation: Only conditions requiring immediate operator attention need to be acknowledged and should interrupt ongoing activities. It is neither necessary nor desirable to annunciate each change of status as an alarm. Annunciators' usefulness declines if noncritical conditions are alarmed.

Guidance: McCormick and Sanders, 1982, Chapter 5
MIL-STD-1472C, 5.3.1.1
NUREG-0700, 6.3.1.1

Examples of methods that might be used to support this principle include the following:

- o Sump pump operation is not annunciated.
- o HI HI sump level is annunciated.

3.4 ANNUNCIATORS

3.4.1 General

Principle 3.4.1.2: Annunciators should not be used for normal system status indication.

Explanation: When a component or subsystem responds normally, its operation should be indicated but not alarmed. If frequent operation or unsuccessful operation of such a system meets Principles 3.4.1.1 and 3.4.1.3, then the frequent or unsuccessful operation may be annunciated.

Guidance: McCormick and Sanders, 1982, Chapter 5
MIL-STD-1472C, 5.2.2.1.1, 5.3.2
NUREG-0700, 6.3.1.1, 6.3.1.2a

The following is an example of a methods that might be used to support this principle:

- A sump pump cycles on to empty a sump. The sump alarm remains inactive. The pump runs for 15 minutes and does not lower the sump level. The sump alarm actuates. The pump fails to start, allowing the sump level to rise. The sump alarm actuates.

3.4 ANNUNCIATORS

3.4.1 General

Principle 3.4.1.3: Annunciators should not alarm spuriously or frequently.

Explanation: Repeated, erroneous stimuli are rapidly ignored or defeated. The operators' detection threshold for unrelated, valid stimuli also may be raised. Increased response times and failure to respond to genuine system problems may occur.

Guidance: McCormick and Sanders, 1982, Chapter 5
MIL-STD-1472C, 5.2.2
NUREG-0700, 6.3.1.2a, 6.2.2.7b

Examples of methods that might be used to support this principle include the following:

- o Sump pumps cycle without being annunciated.
- o HI sump level exists for 30 minutes with pump in operation, initiating an alarm.
- o Pump discharge pressure alarms under the following conditions:
  - -- pump is running but pressure is low
  - -- pump trips
  - -- after delay, on pump start

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.1: Annunciators should remain unlit when conditions are normal for a particular operating mode.

Explanation: Annunciators that remain "on" distract from actual alarm conditions and make identification of off-normal states more difficult. In the ultimate application of this principle, annunciators are driven by logic that senses operating mode to determine alarmed conditions. A less complicated approach is to establish "normal operation" as full power with systems in their most typical lineup.

Guidance: MIL-STD-1472C, 5.2.2.1.4, 5.2.2.1.8, 5.2.2.1.12
NUREG-0700, 6.3.3.2e

Examples of methods that might be used to support this principle include the following:

- o Steam generator LO level remains off under normal conditions.
- o Annunciator for start-up range NI goes out when operator blocks source range monitors.

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.2: Lighted annunciators should have sufficient brightness to stand out from unlit annunciators.

Explanation: To function as intended, lighted annunciator tiles must be distinguishable from unlit tiles. Annunciator luminance levels should be chosen with the control room, and adjacent panel illumination taken into account. However, annunciators should not be so bright that they distract, annoy, or lower legibility.

Guidance: McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade 1972, pp. 78-81, pp. 299-304
MIL-STD-1472C, 5.2.2
NUREG-0700, 6.3.3.2d

The following is an example of a method that might be used to support this principle:

- From the normal operating position, all shift personnel can discriminate between lit and unlit annunciators.

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.3: Annunciators should have flash rates sufficient to alert the operator.

Explanation: Annunciators that flash too rapidly or are either "on" or "off" for too high a percentage of time are not very attention-getting. Studies have shown that a 40-60 percent "on" versus "off" time is highly perceptible.

Guidance:
McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, pp. 78-81, pp. 299-303
MIL-STD-1472C, 5.2.2.1.19
NUREG-0700, 6.3.3.2a, b

Examples of methods that might be used to support this principle include the following:

- o The alarm flash rate for annunciators is three flashes/second.

- o When a flasher fails, the annunciators using that flasher remain steadily lit when actuated.

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.4: Flash rate, by itself, should not be used to differentiate among alarm severity states or between the "alarm" and "return-to-normal" states.

Explanation: Humans are not well-suited to determine flash rates. Flashing lights are useful for alerting or attracting operators. Humans, especially in their peripheral vision, are highly sensitive to flashing stimuli. Information should not be encoded so operators have difficulty in making discriminations.

Guidance: McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, pp. 78-81, pp. 299-303
MIL-STD-1472C, 5.2.2.1.19
NUREG-0700, 6.3.1.4b

Examples of methods that might be used to support this principle include the following:

- The alarm state of an annunciator is indicated by a warble sound and a flash rate of four/ seconds.

- Return-to-normal condition is indicated by a flash rate of one/second and a chime.

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.5: Annunciators having an audible tone should be discriminable from other audible signals under all anticipated operating conditions.

Explanation: Operators must be alerted under all operating conditions in which such an audible tone is important. The audible annunciator tone must be discriminable from other signals, tones, or noises found in the control room. Audible tones are necessary to alert operators to an annunciator's change of state. Such tones must be sufficiently unique and of sufficient volume to alert operators.

Guidance: McCormick and Sanders, 1982, Chapter 5
Van Cott and Kinkade, 1972, pp. 299-304, Chapter 4
MIL-STD-1472C, 5.3.3, 5.3.4.3, 5.3.4.4, 5.3.4.5
NUREG-0700, 6.2.2.1c, 6.2.2.2, 6.2.2.3a, 6.2.2.4b, 6.2.2.5, 6.3.2.1

Examples of methods that might be used to support this principle include the following:

- A warble tone is used for an alarm going on.
- A bell tone is used for an alarm clearing.

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.6: Annunciators with an audible tone should not be so loud that they adversely affect operators' performance.

Explanation: Overly loud audible annunciator tones can startle or disorient operators and possibly make verbal communication difficult. However, annunciator systems with adjustable sound levels should be designed so it is not possible to set the sound level too low to be effective.

Guidance: McCormick and Sanders, 1982, Chapter 5
MIL-STD-1472C, 5.3.3.2
NUREG-0700, 6.2.2.6, 6.3.2.1c

The following is an example of a method that might be used to support this principle:

- o Annunciator tones are 10 db above ambient sound levels at the front of the control board.

3.4 ANNUNCIATORS

3.4.2 Physical Characteristics

Principle 3.4.2.7: Annunciators having audible tones should provide location cues.

Explanation: Sound sources spatially associated with annunciator panels reduce operator reaction time. Audible tones may be a necessary adjunct to annunciators. When there are several annunciator panels, where annunciator panels are widely separated, or where several annunciators are in the alarm state, help in locating the latest alarm is desirable.

Guidance: McCormick and Sanders, 1982, Chapter 5
MIL-STD-1472C, 5.3.2.4
NUREG-0700, 6.2.2.1b, 6.3.2.1f, 6.3.2.2a

The following is an example of a method that a might be used to support this principle:

- o Each of three main annunciator panels has its own alarm tone speaker.

3.4.2 Physical Characteristics

Principle 3.4.2.8: Operators should be able to quickly differentiate important or significant alarms from less important ones.

Explanation: The large numbers of annunciators typically found in control rooms and the likelihood that numerous alarms may come in concurrently requires that some means of prioritization be employed.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.3.4.3.1, 5.3.4.3.2
NUREG-0700, 6.3.1.3, 6.3.1.4

Examples of methods that might be used to support this principle include the following:

- Separate first-out panels are provided for the turbine generator and reactor systems.

- Alarms may be prioritized using physical grouping, color-coding, etc.

3.4.3 Tile Legends

Principle 3.4.3.1: Annunciator tile legends should be readable from operating locations.

Explanation: Operators should not have to lean over the boards or change their operating position to read annunciators. If such actions are required for annunciators to be readable, they will not be read, and users will assume they recognize which annunciator is alarming. Proper tile legends will increase use, especially under stress.

Guidance: McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972
MIL-STD-1472C, 5.2.1.4.11, 5.2.2.2.5
NUREG-0700, 6.3.3.5

The following is an example of a method that might be used to support this principle:

- Steam generator-level alarm annunciators are readable from the FW regulation valve controls.

3.4 ANNUNCIATORS

3.4.3 Tile Legends

Principle 3.4.3.2: Annunciator tile legends should describe the annunciated condition completely and correctly.

Explanation: Correct, complete, and unambiguous title legends reduce the chances that an annunciator will be misinterpreted when it is read.

Guidance: MIL-STD-1472C, 5.2.2.1.3
NUREG-0700, 6.3.3.4

The following is an example of a method that might be used to support this principle:

weak	strong
HI HI LEVEL	CONTAINMENT SUMP HI HI LEVEL

3.4 ANNUNCIATORS

3.4.3 Tile Legends

Principle 3.4.3.3: Multiple-input annunciators should be so indicated on the tile.

Explanation: Operators are reminded that there can be more than one cause for the annunciators. Annunciators are intended to alert operators and only secondarily to aid in diagnosis. However, if annunciators have more than one initiating condition, ambiguity should be minimized. Refer to principle 3.4.5.2.

Guidance: Van Cott and Kinkade, 1972, pp. 352-353
NUREG-0700, 6.3.1.2c

The following is an example of a method that might be used to support this principle:

- o The containment sump HI water alarm annunciator is labeled as follows:

```
********************
* SUMP HI WATER    *
* SUMPS 1, 2, OR 3 *
********************
```

3.4 ANNUNCIATORS

3.4.3 Tile Legends

Principle 3.4.3.4: Annunciators should use the same nomenclature, symbols, and abbreviations as controls and displays.

Explanation: Common language use will decrease errors, memory requirements, and learning time. Because of their small size, annunciator tiles often use abbreviations or symbols. If these are not the same as the abbreviations or symbols used for controls and displays elsewhere in the control room, operators have to learn an additional nomenclature.

Guidance: Van Cott and Kinkade, 1972, p. 109
MIL-STD-1472C 5.5.4.2, 5.5.6
NUREG-0700, 6.3.3.4d, 6.6.3.3

The following is an example of a method that might be used to support this principle:

- o Controls, current meters, and annunciators all refer to reactor coolant pumps as "RCPs."

3.4 ANNUNCIATORS

3.4.3 Tile Legends

Principle 3.4.3.5: Out-of-service annunciators should be labeled clearly and unambiguously.

Explanation: Misinterpretation of nonfunctional annunciators can be avoided by labeling out-of-service annunciators on the annunciator tile. Operators should be able to read the tile legend but should be made aware that a particular annunciator is out-of-service.

Guidance: NUREG-0700, 6.3.3.3e

The following is an example of a method that might be used to support this principle:

- o Out-of-service annunciators have their lights removed and a yellow dot on the legend plate.

3.4 ANNUNCIATORS

3.4.4 Arrangement

Principle 3.4.4.1: Annunciators should be located near related systems on the control board.

Explanation: Annunciators function to alert operators that something requires their attention <u>and</u> to draw their attention to the vicinity of the questionable parameter(s). Placing annunciators near related systems on the control board allows operators to verify quickly the annunciator indication and take necessary actions.

Guidance: Van Cott and Kinkade, 1972, 399-401
NUREG-0700, 6.3.3.1a

The following is an example of a method that might be used to support this principle:

- o SG-level alarms are located near the SG-level indicators.

3.4 ANNUNCIATORS

3.4.4 Arrangement

Principle 3.4.4.2: Annunciators should be functionally grouped to aid diagnosis.

Explanation: If annunciators are grouped appropriately, then an operator can determine system status quickly by glancing at the annunciators. This is an extremely quick, powerful way to determine status. Individual annunciator failures will not impact the overall pattern.

Guidance: MIL-STD-1472C, 5.2.1.4.7, 5.2.2.1.5
NUREG-0700, 6.3.3.3b

Examples of methods that might be used to support this principle include the following:

- All feedwater alarms are grouped together.
- There is a reactor first-out panel near the reactor controls.

3.4 ANNUNCIATORS

3.4.4 Arrangement

Principle 3.4.4.3: Annunciators should be acknowledged only at locations from which they can be identified.

Explanation: An operator should be able to acknowledge only those alarms within his field of view. Alarms should not be acknowledged from a location that does not allow identification of the alarm. When multiple alarms occur, widely separated alarms should not be silenced simultaneously because some alarms could be missed.

Guidance: MIL-STD-1472C, 5.2.1.4.1, 5.3.6
NUREG-0700, 6.3.4.1b

The following is an example of a method that might be used to support this principle:

- o Acknowledge buttons are located on the same board section as their associated annunciators.

3.4 ANNUNCIATORS

3.4.5 Presentation

Principle 3.4.5.1: The number of annunciator tiles should be minimized.

Explanation: The existence of a large number of annunciator tiles increases the probability that important information will be missed or misinterpreted. In transient situations, many current annunicator systems display status information intermixed with alarm information, increasing the probability of operator overload.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.2.1.19
NUREG-0700, 6.3.1.2

Examples of methods that might be used to support this principle include the following:

- Only immediate-action situations are annunciated. Status indications are not annunciated but are grouped in a separate area.

- Status display windows are retained without the acknowledge/audio signal. Annunciators are grouped separately from information display windows to eliminate confusion.

3.4 ANNUNCIATORS

3.4.5 Presentation

Principle 3.4.5.2: Each input in a multiple-input annunciator should be capable independently of causing the annunciator to alarm or re-alarm.

Explanation: Operators must be made aware of any condition requiring their attention. An annunciator that has a number of alarm conditions or inputs should be able to recommence flashing and sound audible alarm when an alarm condition occurs subsequent to the initial alarm.

Guidance: MIL-STD-1472C, 5.3.2
NUREG-0700, 6.3.1.2c

Examples of methods that might be used to support this principle include the following:

- A master high radiation annunciator can be actuated and re-actuated by any rad monitor located in a back panel area.

- Each master annunciator tile on the main control panel can be actuated by any annunciator on its associated local panel.

3.5 CONTROL ROOM EQUIPMENT

The following principles relate to the equipment found in the control room of nuclear power plants, such as typewriters, computer consoles, telephone switchboards, etc. The contents of this section are listed below.

3.5.1 Location

- Purpose
- Accessibility

3.5 CONTROL ROOM EQUIPMENT

3.5.1 Location

Principle 3.5.1.1: Control room equipment should be located so it can be used for its intended purpose.

Explanation: Equipment conveniently located with respect to its intended use will be used more often than equipment that is difficult to access or move.

Guidance: McCormick and Sanders, 1982, Chapter 12
NUREG-0700, 6.1.1.4, 6.1.1.5, 6.1.4.1g, 6.1.4.2b, 6.1.4.3

Examples of methods that might be used to support this principle include the following:

- All procedures are stored on a rolling rack that has an area on which the procedures can be laid open.

- Fire extinguishers are located near front and back panels and are illuminated by emergency lighting in the event of a power interruption.

3.5 CONTROL ROOM EQUIPMENT

3.5.1 Location

Principle 3.5.1.2: Emergency equipment should be accessible.

Explanation: Even infrequently used emergency equipment must be accessible. Easy accessibility decreases response times in an emergency.

Guidance: MIL-STD-1472C, 5.13.2.4
NUREG-0700, 6.1.4.3

Examples of methods that might be used to support this principle include the following:

- o Self-contained breathing apparati are mounted on the walls with an appropriately marked area on the floor in front.
- o Respirators are stored in a trunk located in the shift supervisor's office.
- o Periodic inspections ensure accessibility of emergency equipment.

3.6 LABELS

The following principles relate to the labels used to identify instrumentation and equipment in nuclear power plant control rooms. The contents of this section are listed below.

3.6.1 General

- o Relationship Between Labels and Instruments
- o Abbreviations, Symbols, and Numbering Schemes
- o Readability
- o Color-Coding
- o Horizontal Orientation
- o Functional Description
- o Other Information on Labels
- o Labels for Unavailable Equipment
- o Access Openings and Storage Areas
- o Discriminability
- o Temporary Labels

3.6 LABELS

3.6.1 General

Principle 3.6.1.1: The relationship between a label location and the labeled instrument should be unambiguous and consistent.

Explanation: A consistent label placement rule relieves operators from uncertainty about which instrument a particular label identifies. When labels are located consistently in relation to the labeled instruments, the probability of associating a label with the wrong control or display is reduced. This is especially helpful during operation with seldom-used systems.

Guidance: Van Cott and Kinkade, 1972, pp. 94, 400
MIL-STD-1472C, 5.5.6.2
NUREG-0700, 6.6.2.1

Examples of methods that might be used to support this principle include the following:

- o Labels always are placed below the controls or displays they identify.
- o Labels always are placed above the controls or displays they identify.
- o Labels always are placed below displays and above controls.

3.6 LABELS

3.6.1 General

Principle 3.6.1.2: Abbreviations, symbols, and numbering schemes, where used, should be consistent.

Explanation: Consistent use of abbreviations, symbols, and numbering allows operators to interpret procedures, annunciators, and labels unambiguously. Lack of consistent language can cause confusion and may require additional time to interpret uncommon usage.

Guidance:
McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, p. 401; pp. 69-77
MIL-STD-1472C, 5.5.4.2, 5.5.6.2
NUREG-0700, 6.6.3.3

Examples of methods that might be used to support this principle include the following:

- o Heater is always abbreviated "HTR."
- o Numbering progressions on the control boards always follow natural order (1, 2, 3, 4, etc.).

3.6 LABELS

3.6.1 General

Principle 3.6.1.3: Labels should be readable from the normal operating locations.

Explanation: Proper labeling can reduce errors. Operators should not have to lean over the boards or change their operating position to read labels.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.5.4.3
NUREG-0700, 6.6.2.4, 6.6.4.1, 6.6.4.2

The following is an example of a method that might be used to support this principle:

- o Label characters are at least as large as the scale markings on displays.

3.6 LABELS

3.6.1 General

Principle 3.6.1.4: Color-coding for instruments should be used sparingly and should follow the same rules used elsewhere in the control room.

Explanation: One of the chief advantages of color-coding is to relate similar instruments quickly and differentiate dissimilar instruments. As always with color-coding, the best color-coding systems use few colors and use them consistently.

Guidance: McCormick and Sanders, 1982, Chapters 4 and 9
Van Cott and Kinkade, 1972, pp. 352-353
MIL-STD-1472C, 5.4.1.4.5, 5.2.3.1.10
NUREG-0700, 6.4.2.2, 6.8.1.1

Examples of methods that might be used to support this principle include the following:

- All HPCI controls and displays have orange bezels.
- All normal display operating ranges are marked with a green band.
- All throttle valves have a yellow band on their handles.

3.6 LABELS

3.6.1 General

Principle 3.6.1.5: All labels should be oriented horizontally.

Explanation: Vertical writing is more difficult to read and is read more slowly than horizontal writing. Text is normally written and read from left to right.

Guidance: Van Cott and Kinkade, 1972, p. 401
MIL-STD-1472C, 5.5.2.1
NUREG-0700, 6.6.2.3

The following is an example of a method that might be used to support this principle:

INCORRECT	CORRECT
P R E S S U R I Z E R	PRESSURIZER

3.6 LABELS

3.6.1 General

Principle 3.6.1.6: Labels for instruments should describe the function of the labeled instrument correctly and completely.

Explanation: Functional labels provide unambiguous confirmation to the operator that the proper instrument is being used. Labels that display only an instrument tag number, e.g., CV-211, give no information concerning the actual use of that instrument, e.g., feedwater flow control valve, CV-211.

Guidance: Van Cott and Kinkade, 1972, pp. 352-353
MIL-STD-1472C, 5.5.3.1
NUREG-0700, 6.6.3.2

Examples of methods that might be used to support this principle include the following:

- o All valve controls are labeled as suction, discharge, etc.

- o The labels for motor controls indicate the plant system and component for which the motor is used.

3.6 LABELS

3.6.1 General

Principle 3.6.1.7: In addition to function, labels should provide any necessary information.

Explanation: It is often desirable to include information on labels in addition to the plant system and function of the instrument. Such information might include the train designator if multiple physical trains are used, or electrical bus designator, in case a particular bus fails during operation.

Guidance: Van Cott and Kinkade, 1972, pp. 352-353
MIL-STD-1472C, 5.5.3.1
NUREG-0700, 6.6.3.1, 6.6.3.2, 6.6.3.7, 6.6.3.8

Examples of methods that might be used to support this principle include the following:

- o Labels have a letter designator showing channel number.
- o Labels for emergency instruments are designated as such by affixing a red dot to the label.

3.6 LABELS

3.6.1 General

Principle 3.6.1.8: Unavailable equipment and instruments should be tagged unambiguously as such.

Explanation: Clear and unambiguous tags ensure that unavailable equipment and instrumentation will not be relied upon during any operational mode.

Guidance: NUREG-0700, 6.6.5.1

Examples of methods that might be used to support this principle include the following:

- o Tags indicating unavailable equipment physically block the operation of the tagged-out device.

- o Brightly striped tape is placed on any switch or meter connected to unavailable equipment.

3.6 LABELS

3.6.1 General

Principle 3.6.1.9 Access openings and storage areas should be labeled to identify the items inside.

Explanation: Operators should be able to find needed items quickly.

Guidance: NUREG-0700, 6.6.3.9

Examples of methods that might be used to support this principle include the following:

- The spare parts cabinet is labeled on the outside. The label lists the parts inside the cabinet.

- All fuse panel access doors are labeled as such, including listing the circuits fused on each panel.

- Security radios are kept in a labeled storage bin in the front of the benchboard.

3.6 LABELS

3.6.1 General

Principle 3.6.1.10 Labels should be concise and easily discriminated from one another.

Explanation: Similar labels in close proximity to one another can be confused easily.

Guidance: NUREG-0700, 6.6.3.5, 6.6.3.6

Examples of methods that might be used to support this principle include the following:

- o Extraneous words are removed from labels.
- o Acronyms and abbreviations that convey the intended meaning of the label are used.
- o Labels containing similar words, abbreviations, or acronyms are not located in close proximity to each other.

3.6 LABELS

3.6.1 General

Principle 3.6.1.11 Procedures should be used to control both temporary and permanent labeling changes to the control board.

Explanation: One way to help ensure that labels and other control board items are consistent with control room conventions and procedures is to employ procedures to control such changes.

Guidance: NUREG-0700, 6.6.5.2

Examples of methods that might be used to support this principle include the following:

- o An approval process is employed before changes are made in the control board.
- o Changes are verified to make sure they are implemented properly.
- o As part of the approval/verification process, someone is responsible for seeing that control board changes are coordinated with changes in procedures, training, simulator, modification, etc.
- o A mock-up (or simulator) is used to try out significant changes before they are implemented.

3.7 COMPUTERS

The following principles relate to the characteristics of computers used by operators in a nuclear power plant control room. The contents of this section are listed below:

3.7.1 Operation

- o Information Retrieval
- o Availability of Procedures

3.7.2 Displays

- o Consistency
- o Characters, Symbols, and Abbreviations
- o Color-Coding
- o Titles
- o Readability
- o Clutter
- o Refresh Rate
- o Response Time
- o Printers

3.7 COMPUTERS

3.7.1 Operation

Principle 3.7.1.1: Operators should be able to retrieve desired information from the process computer quickly and efficiently.

Explanation: Computer systems that are easy to use will be used more often than those that are cumbersome to use. Speed and memory capacity of a process computer system is not advantageous unless the system is used by operators.

Guidance: McCormick and Sanders, 1982, Chapter 3
NUREG-0700, 6.7.1.1, 6.7.1.2, 6.7.1.3, 6.7.1.4, 6.7.1.5, 6.7.1.6

Examples of methods that might be used to support this principle include the following:

- o Operator input requirements are minimized through the use of abbreviations.
- o Alphanumeric keyboard is configured to support the operator, i.e., conforms to the "QWERTY" arrangement.
- o Multiple computers have standard and simple operator interface requirements.
- o Single-function keys are used exclusively on operator keyboards.

3.7 COMPUTERS

3.7.1 Operation

Principle 3.7.1.2: Computer system operating procedures used by control room personnel should be available in the control room.

Explanation: Procedures for accomplishing infrequently performed tasks generally are not memorized by operators. Procedures should be available for any and all tasks operators are expected to perform using the process computer system. These procedures should be written from the control room operators' perspective and should be as free of computer jargon as possible.

Guidance: NUREG-0700, 6.7.1.8

The following is an example of a method that might be used to support this principle:

- o Computer system procedures are stored in a designated area within the control room.

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.1: Display pages should be consistent.

Explanation: Page consistency will decrease user access time and decrease reading errors. Since CRT displays may have several pages or "screens" of information, users may not be highly familiar with each page. Such items as menus, titles, summaries, etc., should be in the same place on all pages.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.4
NUREG-0700, 6.7.2.4, 6.7.2.5

Examples of methods that might be used to support this principle include the following:

- o Each page has the page name centered at the top of the page.
- o Menu selections are shown across the bottom of each page.
- o Every page shows six squares indicating overall plant status.
- o The current and ending page numbers are located consistently on each display page as "Page _X_ of _Y_."

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.2: Characters, symbols, and abbreviations should be consistent with the control room conventions.

Explanation: Under stressful conditions, consistent and unambiguous nomenclature can save time and reduce the likelihood of errors. It is desirable, and under certain conditions critical, for CRT displays to reference and be referenced in a cc sistent and unambiguous manner. One important aspect of this characteristic is the use of characters, symbols, and abbreviations that conform to those used throughout the control room. Consistency with other displays and labels reinforces the use of terms.

Guidance: McCormick and Sanders, 1982, Chapter 4
Van Cott and Kinkade, 1972, p. 109
MIL-STD-1472C, 5.5.4.2, 5.5.6
NUREG-0700, 6.6.3.3, 6.6.3.4

The following is an example of a method that might be used to support this principle:

- o All abbreviations on the CRT are the same as on the control board and in the procedures.

3.7.5 Displays

Principle 3.7.2.3: Color-coding should be used sparingly, and assignments should be consistent across displays and the control board.

Explanation: One chief advantage of color-coding is to relate similar information or systems and differentiate such items quickly. As always with color-coding, the best color-coding systems use few colors and use them consistently. Color consistency in the control room, including controls and displays, is highly desirable, and consistency with other CRT displays is essential.

Guidance: McCormick and Sanders, 1982, Chapters 4 and 9
MIL-STD-1472C, 5.2.3.1.10, 5.4.1.4.5
NUREG-0700, 6.5.1.6

Examples of methods that might be used to support this principle include the following:

- o Red is used only for out-of-tolerance.

- o Red is used only for open valve, closed breaker.

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.4: Each display should have a descriptive title.

Explanation: CRT displays may have several pages or screens of information. Since the appearance and overall layout of these pages may be similar, confusion can occur. CRT displays must be self-labeling, since no standard label can be used. Therefore, each page should meet the intent of display labeling discussed previously.

Guidance: MIL-STD-1472C, 5.15.2.10, 5.15.4.9
NUREG-0700, 6.7.2.4

The following is an example of a method that might be used to support this principle:

- o Each CRT display page has a title one-half inch high, centered at the top of the screen.

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.5: Characters and symbols should be readable from the required viewing locations.

Explanation: Operators should not have to lean over boards or leave their operating positions to read CRT displays. A CRT display should meet the requirements of any display device. However, the purpose of the CRT display should be considered so readability is commensurate with use.

Guidance: McCormick and Sanders, 1982, Chapter 4
MIL-STD-1472C, 5.2.6.9.2, 5.15.4.9
NUREG-0700, 6.5.1.3, 6.7.2.2, 6.7.2.3

The following is an example of a method that might be used to support this principle:

- o Lettering on CRT display pages is at least as large as the lettering on adjacent labels.

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.6: Display pages should not contain so much information that they appear cluttered.

Explanation: Rapid use of these devices is hampered by high densities. CRT displays lend themselves to extremely high information densities.

Guidance: MIL-STD-1472C, 5.15.4.7
NUREG-0700, 6.7.2.5

Examples of methods that might be used to support this principle include the following:

- o Alphanumeric lists are divided into alternating color groups so three lines are one color and the next three are an alternate color, etc.

- o CRT pages are formatted to use no more than 30 percent of the available screen area.

- o On alarm lists displayed on CRTs, all unacknowledged alarms flash.

3.7.2 Displays

Principle 3.7.2.7: CRT displays should have a refresh rate that is adequate to prevent flicker.

Explanation: Flickering displays induce fatigue and headache. Perceived flicker is based upon the response time of the human eye. Above 60 Hz a flickering source appears to remain "on." There is some influence of area or peripheral vision and interference by other flickering sources. However, the 60 Hz requirement usually is adequate. This is especially important if narrow or single lines are used.

Guidance: NUREG-0700, 6.7.2.1g

Examples of methods that might be used to support this principle include the following:

- o All CRT displays are generated at 60 Hz refresh rate, with a non-interlaced raster.

- o All CRT displays are generated at 30 Hz rate, with full interlace. Horizontal lines always are composed of at least two scan lines.

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.8: Computer systems should avoid undue delays in responding to operator inputs.

Explanation: Excessive delays in responding to operator inputs may cause the operator to assume that the input was not accepted, that the input was made incorrectly, or that something is wrong with the computer.

Guidance: NUREG-0700, 6.7.1.7

Examples of methods that might be used to support this principle include the following:

- o Response time for normal query does not exceed three seconds.

- o When response time exceeds three seconds, a delay message is presented to ensure the operator of normal computer operation.

3.7 COMPUTERS

3.7.2 Displays

Principle 3.7.2.9: Printers should be located in the primary operating area to record alarm, trend, and plant status data.

Explanation: Printers provide a permanent, hard-copy record of all parameters monitored by the computer, as well as one type of "real time" display.

Guidance: NUREG-0700, 6.7.3.1, 6.7.3.2

The following is an example of a method that might be used to support this principle:

- o Printer is located in the primary area of the control room.

3.8 COMMUNICATION

The following principle relates to communication among control room operators and support personnel in nuclear power plants:

3.8.1 General

- o Intelligibility

3.8 COMMUNICATION

3.8.1 General

Principle 3.8.1.1: Communication systems should support complete, intelligible voice communication during normal and emergency operating conditions.

Explanation: Adequate communication facilities allow coordination between operators in the control room and support personnel outside of the control room. Such coordination is important to efficient and safe plant operation. Since operators may not use all types of communication equipment on a regular basis, equipment operation instructions should be available near the equipment location.

Guidance: McCormick and Sanders, 1982, Chapter 6
NUREG-0700, 6.2.1.1 through 6.2.1.8

Examples of methods that might be used to support this principle include the following:

- o Instruction is available for use of each communication system, and operators should be trained in their use.
- o Communication systems are tested periodically to ensure adequate sound quality and intensity.

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APPENDIX A

CROSS-REFERENCE OF NUREG-0700

SECTION 6 GUIDELINES AND CRDR

NUTAC REVIEW PRINCIPLES

NUREG-0700 SECTION 6 GUIDELINE NUMBER	NUTAC PRINCIPLE NUMBER
6.1.1.1	3.1.1.8, 3.3.1.4
6.1.1.2	3.1.6.1
6.1.1.3	3.1.3.1, 3.1.3.2, 3.1.5.1 3.3.1.4, 3.3.2.1
6.1.1.4	3.1.3.4, 3.5.1.1
6.1.1.5	3.1.3.7, 3.5.1.1
6.1.1.6	3.1.3.1, 3.1.3.2
6.1.2.2	3.2.2.5
6.1.2.3	3.2.2.5
6.1.2.4	3.2.2.5
6.1.2.5	3.2.2.5, 3.3.2.1
6.1.2.6	3.1.3.6
6.1.2.7	3.1.3.6
6.1.2.8	3.1.3.6
6.1.3.1	3.1.3.5
6.1.3.2	3.1.3.5
6.1.4.1	3.1.2.4, 3.1.7.1, 3.5.1.1
6.1.4.2	3.1.2.4, 3.5.1.1
6.1.4.3	3.1.3.3, 3.5.1.1, 3.5.1.2
6.1.5.1	3.1.4.1
6.1.5.2	3.1.4.2
6.1.5.3	3.1.4.3, 3.1.4.4
6.1.5.4	3.1.4.3
6.1.5.5	3.1.4.5
6.1.5.6	3.1.3.3
6.1.5.7.a	3.1.3.6
6.1.5.7.b,c	3.1.4.6
6.2.1.1	3.1.2.4, 3.8.1.1
6.2.1.2	3.8.1.1
6.2.1.3	3.8.1.1
6.2.1.4	3.8.1.1
6.2.1.5	3.8.1.1
6.2.1.6	3.8.1.1

NUREG-0700 SECTION 6 GUIDELINE NUMBER	NUTAC PRINCIPLE NUMBER
6.2.1.7	3.8.1.1
6.2.1.8	3.8.1.1
6.2.2.1	3.4.2.7, 3.4.2.5
6.2.2.2	3.4.2.5
6.2.2.3a	3.4.2.5
6.2.2.4b	3.4.2.5
6.2.2.5	3.4.2.5
6.2.2.6	3.4.2.6
6.2.2.7	3.4.1.3
6.3.1.1	3.4.1.1, 3.4.1.2
6.3.1.2	3.4.1.2, 3.4.1.3, 3.4.3.3 3.4.5.1, 3.4.5.2
6.3.1.3	3.4.2.7
6.3.1.4	3.4.2.4, 3.4.2.7
6.3.2.1	3.4.2.5, 3.4.2.6, 3.4.2.7
6.3.2.2	3.4.2.7
6.3.3.1	3.4.4.1
6.3.3.2	3.4.2.1, 3.4.2.2, 3.4.2.3
6.3.3.3	3.4.3.5, 3.4.4.2
6.3.3.4	3.4.3.2, 3.4.3.4
6.3.3.5	3.4.3.1
6.3.4.1	3.1.2.4, 3.4.4.3
6.4.1.1	3.2.1.1, 3.3.1.1
6.4.1.2	3.2.1.4, 3.2.2.9
6.4.2.2	3.2.1.5, 3.2.2.7, 3.6.1.4
6.4.4.3d	3.1.2.1
6.4.4.4b	3.1.2.1
6.4.4.5	3.1.2.1, 3.2.1.2 3.2.1.3
6.4.5.1a	3.1.2.1
6.4.5.2	3.2.1.4
6.4.5.3	3.2.1.3
6.4.5.4a	3.1.2.1

NUREG-0700 SECTION 6 GUIDELINE NUMBER	NUTAC PRINCIPLE NUMBER
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NUREG-0700 SECTION 6 GUIDELINE NUMBER	NUTAC PRINCIPLE NUMBER
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NUREG-0700 SECTION 6 GUIDELINE NUMBER	NUTAC PRINCIPLE NUMBER
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6.9.2.3	3.1.1.6
6.9.3.1	3.1.1.6
6.9.3.2	3.3.3.5

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QUESTIONNAIRE

GENERAL

This questionnaire will assist in collecting additional and practical information on the applicability and use of the CRDR implementation guideline. Its value can only be judged by you, the user. Please take a few minutes and comment on the four questions.

QUESTIONS

1. Was this guideline useful? If not, why not?

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2. How did you use this guideline (e.g., in total, as background, selected portions)?

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3. What would you recommend to improve this guideline?

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4. What other sources (if any) did you use to develop your program? (Please include name and telephone number of a contact person.)

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COMPLETED QUESTIONNAIRE

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CRDR NUTAC
Communications Division
Institute of Nuclear Power Operations
Suite 1500
Circle 75 Parkway
Atlanta, GA 30339

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