FLORIDA POWER CORPORATION

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302 /LICENSE NUMBER DPR-72

ENCLOSURE

SP-5145: HUMAN FACTORS DESIGN CONVENTIONS FOR THE CONTROL ROOM SPECIFICATION AND CRITERIA

3694

HUMAN FACTORS DESIGN CONVENTIONS

FOR THE CONTROL ROOM

SPECIFICATION AND CRITERIA

SP-5145

Revision 3

Prepared For

Florida Power Corporation

Crystal River Unit 3

M. D. Lord M.D. Lord — 8/3/00
Design Engineer — Date

L.D. Loose L.D. LOOSE — 8/15/00
Verification Engineer — Date

P.M. Rubio P.M. RUBIO — 8/15/00
Supervisor — Date

SP-5145

RECORD OF CHANGES

Revision 3

Revision No.	Description
3	Page 30. Revise the annunciator priority definitions to agree with the wording suggested by Interoffice Correspondence OP99-0105 and Precursor Card 99-1310 Corrective Action #7. Revise the text to eliminate references to Priority 3, which is being deleted in this revision at the recommendation of the above documents.

RECORD OF CHANGES

Revision 2

REV. 2 Page 8. Under Engineered Safeguards Status Lights: Add "ES Equipment Actuated" under Green. Deleted same from Blue.

SP-5145

RECORD OF CHANGES
Revision 1
December 4, 1987
Sheet 1 of 1

Revision 1 includes updated pages only incorporating all changes made to-date. The latest changes are indicated in the right hand margin.

Revision No.	Description
1	Page 15. Add new sub-paragraph 4.4.4.D to specify physical placement of zone markings. (Commitment from pre-implementation audit 10/21/87).

TABLE OF CONTENTS

		Page
INTRODUCTION		iv
SECTION 1. PANEL LAYOUT		1
1.1	Assigning Panel Contents	1
1.2	Enhancing Recognition and Identification	1
1.3	Logical Arrangement	1
1.4	Consistent Layout	2
1.5	Strings or Clusters of Similar Components	2
1.6	Control and Display Placement	2
1.7	Exceptions to Coding Conventions	2
SECTION 2. ASSOCIATED CONTROLS AND DISPLAYS		3
2.1	Location	3
2.2	Association	3
2.3	Controls and Displays Used in Sequence	3
2.4	Controls and Displays in Adjacent Planes	3
2.5	Multiple Controls, Single Display	3
2.6	Single Control, Multiple Displays	4
SECTION 3. CONTROLS		5
3.1	General Considerations	5
3.1.1	Overall Criteria	5
3.1.2	Prevention of Accidental Actuation	5
3.1.3	Separation of Controls	6
3.1.4	Visibility	6
3.1.5	Indication of Actuation	6
3.1.6	Direction of Movement	7
3.1.7	Emergency Controls	7
3.2	Color Coding	7
3.3	Shape Coding	8
3.4	Specifications for Specific Controls	8
3.4.1	Pushbuttons	8
3.4.2	Legend Pushbuttons	9
3.4.3	Key-Operated Controls	9
3.4.4	Continuous Adjustment Rotary Controls	9
3.4.5	Rotary Selector Controls	9
3.4.6	Thumbwheels	10
3.4.7	Slide Switches	10
3.4.8	Toggle Switches	10
3.4.9	Rocker Switches	11

SECTION 4. VISUAL DISPLAYS 12

4.1 General Considerations 12
4.1.1 Overall Criteria 12
4.1.2 Direction of Movement 12
4.1.3 Visibility 12
4.1.4 Demand Information Versus Status Information 13
4.1.5 Display Failure 13
4.1.6 Display Response Time Lag 13
4.2 Color Coding 13
4.3 Printing on the Display Face 13
4.4 Scales 14
4.4.1 Usability of Displayed Values 14
4.4.2 Scaled Marking 14
4.4.3 Orientation of Scale Markings 15
4.4.4 Zone Marking 15
4.4.5 Pointers 15
4.5 Specifications for Specific Visual Displays 16
4.5.1 Display Selectors 16
4.5.2 Light Indicators 16
4.5.3 Non-Legend Light Indicators 16
4.5.4 Legend Light Indicators 17
4.5.4.1 Visibility Factors 17
4.5.4.2 Legend Design 17
4.5.5 Graphic Recorders 17
4.5.5.1 Continuous Recorders 18
4.5.5.2 Discrete Recorders 18
4.5.6 Drum-Type Counters 19
4.5.7 Electronic Counters 19

SECTION 5. LABELS AND LOCATION AIDS 21

5.1 General Considerations 21
5.1.1 Hierarchical Scheme 21
5.1.2 Controls and Displays Used in Sequence 21
5.1.3 Control Positions 21
5.1.4 Access Openings 22
5.1.5 Danger, Warning, and Safety Instrumentation Labels 22
5.2 Label Location 22
5.2.1 Placement 22
5.2.2 Mounting 22
5.2.3 Spatial Orientation 22
5.2.4 Visibility 22
5.3 Label Content 22
5.3.1 Kinds of Information 23
5.3.2 Word Selection 23
5.3.3 Consistency 23
5.3.4 Symbols 23
5.4 Temporary Labels 23
5.4.1 Control of Temporary Labels 24

5.5 Mimics 24
5.5.1 Color 24
5.5.2 Mimic Lines 25
5.5.3 Symbols 25
5.6 Demarcation 26
5.6.1 Color 26
5.6.2 Size 26
5.7 Lettering 26
5.7.1 Character Dimensions 27
5.7.2 Type Style 27
5.7.3 Spacing 27
5.7.4 Readability 28

SECTION 6. ANNUNCIATORS 29

6.1 General Considerations 29
6.2 Alarm Parameters 29
6.3 Prioritization 30
6.4 Visual Alarm Identification 30
6.5 Window Legends 31
6.6 Annunciator Controls 31

SECTION 7. REFERENCES 33

INTRODUCTION

The purpose of this document is to ensure that control room design changes enhance safe and efficient plant operation. To accomplish this aim, the changes must meet the human factors specifications and criteria which follow. When making design changes in the control room, it is important to consider how changes will affect the operator in terms of the availability of necessary information, the adequacy of controls for the tasks perfomed, the efficiency of the overall panel layout, and the suitability of the control room environment. Within the context of this document, the word should is used to depict a recommended practice. Deviation from these recommendations require assessment to establish their potential safety implications.

Sections 1 and 2 of this specification contain many guidelines which apply to all control room design changes. Section 1 provides specific human factors criteria related to panel layout. In general, controls and displays should be grouped in a way that reflects functional organization and minimizes operator movement. For instance, components which belong to the same system should usually be located together. A series of controls which are used in sequence should usually be positioned in sequence on the control panel. A logical panel layout reduces the time needed to perform a task and the chance of operator error.

Section 2 discusses associated controls and displays. Important considerations include ensuring that the operator can read a display while operating related controls, and labeling associated controls and displays clearly and consistently.

Section 3 contains human factors criteria specific to controls. The operator should be able to perform required tasks easily with the controls available. Accidental actuation of a control should be prevented. The intended use of a control should be clear from its label, location and shape/color coding.

Criteria for visual displays are included in Section 4. Displays should be clearly identified and easy to locate and read. Scales should cover the appropriate range of operating values and provide the degree of precision needed for operation. Indicator lights should be clearly on or off. The overall intention is to provide the operator with necessary information and to minimize unnecessary information which may lead to distraction or confusion.

Section 5 provides criteria related to labels and location aids. A labeling scheme which includes labels for systems, subsystems, and individual panel elements allows the operator to quickly locate a component. Labels should use clear and consistent terminology. Where full words do not fit into the avalable space abbreviated words following SP-5132 should be used. Mimic lines may be used to make functional relationships among controls and displays clear.

Section 6 provides criteria related to the annunciator system.

An annunciator system is the primary interface to promptly alert the operator to out-of-tolerance changes in plant conditions. The annunciator system consists of an auditory alert, visual alarm, and acknowledge subsystems. Together these three subsystems should be designed to provide a preferred operational sequence.

These guidelines do not cover changes to the control room workspace, including general layout and environmental conditions such as lighting, noise, temperature, humidity, and ventilation, or CRT display or process computer software or hardware. NUREG-0700 includes guidelines for ensuring that these areas of the control room meet human factors criteria. This specification also does not include standard abbreviations; the abbreviations listed in the Crystal River Guide SP-5132 should be used.

A matrix is provided below to assist in locating sections which cover the design change being made.

Task	Section 1	Section 2	Section 3.1-3.3	Section 3.4	Section 4.1-4.4	Section 4.5	Section 5	Section 6
Add/move control(s)	ALL	ALL	ALL	*			ALL	
Add/move display(s)	ALL	ALL			ALL	*	ALL	
Directly replace control(s)			ALL	*			5.2	
Directly replace display(s)					ALL	*		
Add/replace label(s)					4.3	4.55	ALL	
Add/change annunciator window								ALL

* Refer to subsection related to specific control or display type (See Table of Contents)

SECTION 1 - PANEL LAYOUT

1.1 Assigning Panel Contents

The following issues are important considerations for grouping controls and displays in control room panels:

A. It is of primary importance that controls and displays be assigned to panels according to SYSTEM FUNCTION. In so doing, easy understanding of the relationship between controls and corresponding systems will be facilitated.

B. Within the constraints of grouping by SYSTEM FUNCTION, controls and displays should be assigned to panels according to their IMPORTANCE AND FREQUENCY OF USE. To accomplish this, controls or displays which are neither important to plant safety nor frequently used should be installed in secondary panel locations.

C. Within the constraints of grouping by IMPORTANCE AND FREQUENCY OF USE, controls and displays should be assigned to panels according to TASK SEQUENCE to the extent that it is possible. This will enable operators to perform routine tasks and time sensitive emergency tasks with a minimum of movement from panel to panel.

1.2 Enhancing Recognition and Identification

Preferred techniques for enhancement are spacing and demarcation. These techniques are:

SPACING - Spacing implies physically separating components on a panel to the extent that the boundaries of each group are obvious. The minimum space between groups should be at least the width of a typical control or display in the group. Where possible, there should not be more than 5 components in an unbroken row. (See 1.5.C).

DEMARCATION - Demarcation consists of circumscribing functional or selected groups of controls and displays with a contrasting line applied to the panel. Color of demarcation lines should be consistent for functionally related instruments.

1.3 Logical Arrangement and Layout

The arrangement of controls and displays should be logical whenever possible within the constraints of panel layout described above. Logical arrangements are generally based on operator expectations. In general, these expectations are that related displays and components have a left-to-right or top-to-bottom arrangement and are identified in alphabetic or numeric sequence (ORDER AND LABELING).

Where OTHER EXPECTATIONS can be identified, components should be arranged to match these expectations.

Well designed mimics help to direct and satisfy operator expectations.

Arrangement of components on the Main Control Board may be limited by separation and seismic design considerations. Separation requirements can be found in Reference 1. These limitations could prevent placement of controls and/or displays in their optimum locations. The use of mimics, demarcation, and labeling can minimize these effects.

1.4 Consistent Layout

The location and arrangement of recurring functional groups and of individual components of those groups should be similar between panels and within a panel. The layout of identical control or display sets should be consistent across all locations where they are used (REPEATED FUNCTIONS).

Layouts of repeated functions should not be arranged in mirror image configurations. Mirror imaging is when controls and displays are arranged in a mirror image of each other from a center line. This can lead to serious confusion for an operator switching from one side to the other (MIRROR IMAGING).

1.5 Strings or Clusters of Similar Components

When large groups of similar components must be arranged together in strings, matrices or other clusters, the following should be followed:

A. ORIENTATION - Horizontal rows of displays or components should be used rather than vertical columns.

B. STRING LENGTH - Strings of small displays should not exceed about 20 inches on the control board.

C. NUMBER OF COMPONENTS - There should not be more than 5 similar components in an unbroken row. If this must be done, the string or cluster should be broken up by techniques such as physical spacing or demarcation as mentioned above (Section 1.2).

1.6 Control and Display Placement on Vertical Panels

Controls should be placed between 34 and 70 inches above the floor. Controls requiring precise or frequent operation and emergency controls should be placed in an area between 34 and 53 inches above the floor.

Displays should be placed between 41 and 70 inches above the floor. Displays that must be read frequently or precisely should be placed in an area between 50 and 65 inches above the floor.

1.7 Exceptions to Coding Conventions

Controls or displays which do not follow color or shape coding conventions should be identified and reviewed with the operators when that system is reviewed during training sessions.

SECTION 2 - ASSOCIATED CONTROLS AND DISPLAYS

2.1 Location

Controls and displays which are normally used together should be located close to each other, with the display above or to the left of the control. Position of displays should be located and separated sufficiently so that the display is not obstructed during the operation of the control.

2.2 Association

Control-display relationship should be made apparent through:

A. Proximity

B. Labeling

C. Coding

D. Demarcation

E. Consistency with operator expectations

2.3 Controls and Displays Used in Sequence

To the extent possible, the arrangement of controls and displays should be consistent with the order of operation and simultaneously similar to each other so that a given display will be associated with the proper control during a sequential procedure.

2.4 Controls and Displays in Separate Adjacent Panels

When on separate panels, the positions of the related controls and instrumentation should correspond to each other on the two panels.

2.5 Multiple Controls, Single Display

When several interacting controls are associated with a single display, the following conditions should be met:

A. The controls should be mounted below or to the right of the display.

B. The controls should be centered on the display.

C. The controls should be grouped in a line or matrix.

D. Where there is a normal order of use, controls should be arranged in left-to-right, top-to-bottom, or other natural sequence.

E. For situations in which the above conditions cannot be met, layout enhancement techniques described earlier (Section 1.2) should be used.

2.6 Single Control, Multiple Displays

Where several displays are associated with a single control, the following conditions should be met:

A. Displays should be mounted above the control, or to the left of the control if this is not possible.

B. The control should be placed as near as possible to the display array, preferably underneath the center of the array.

C. Displays should be arranged horizontally or in a matrix.

D. Where there is a normal order of use, displays should read from left-to-right, top-to-bottom or in other natural sequence.

E. For situations in which the above conditions cannot be met, layout enhancement techniques described earlier (Section 1.2) should be used.

F. The arrangement should allow for manipulation of a control without the displays being obscured.

SECTION 3 - CONTROLS

3.1 General Considerations

3.1.1 Overall Criteria

Controls should be selected to ensure ease of operation and to minimize operator errors. In achieving these aims, the following criteria should be met:

A. Each control should provide a sufficient range of control.

B. Each control should be easy to adjust to within the required level of precision.

C. There should be no unnecessary or spare controls.

D. Each control should be as simple as possible; the precision and range of control should not greatly exceed the need.

E. Controls should be suited to the anthropometric and ergonometric characteristics of the expected operator population.

F. The types of controls used should conform to conventional practice; they should be of a kind expected by operators for a specific purpose, and they should match other controls which have the same function.

G. The controls should be durable enough to retain their appearance, feel and integrity throughout their service lives.

H. The control should be located so that the operators hand does not obstruct the associated display during actuation. (Section 2.5 and 2.6).

I. If a control is used with a display (e.g., channel select for a recorder), appropriate labels should indicate their functional relationship.

3.1.2 Prevention of Accidental Actuation

The accidental actuation of controls should be prevented by one of the following methods. The use of one or more of these methods will depend on the need for rapid operator access and the seriousness of the consequences of accidental operation of a control.

A. PROPER LOCATION of controls in their functional group is important so that the operator is not likely to operate them unintentionally.

B. Controls may be entirely contained within shielded, or other kinds of FIXED PROTECTIVE STRUCTURES.

C. Controls may be covered with hinged barriers as long as the barriers do not hinder the operation of the control when in the open position, or the operation of adjacent controls.

D. INTERLOCKING CONTROLS may be used so that a control may not be operated without extra movement (e.g., pull-to-engage), or prior to operation of a related or locking control.

E. Controls should be provided with sufficient RESISTANCE TO MOVEMENT so that distinct or sustained effort is required for actuation.

F. When a strict sequential operation is necessary, controls should be equipped with locks to prevent them from passing through the proper position.

G. Rotary controls are preferred in situations in which pushbuttons or linear controls would be subject to inadvertent actuation.

H. Safety and lock wires should be avoided.

3.1.3 Separation of Controls

Controls should be separated such that access to controls is possible without accidental actuation of adjacent controls.

Simultaneous actuation should be allowed for when necessary.

Electrical separation of components and circuits associated with different safety channels should also be considered when locating controls of different electrical trains.

3.1.4 Visibility

The control should be visible during normal and emergency operation and the functional result of control movement should be indicated. (Section 3.1.5).

3.1.5 Indication of Actuation

A source of feedback should be provided to the operator as a result of the operation of a control. The feedback should take the form of any of the following:

A. Snap feel (resistance)

B. Audible click

C. Integral light

D. Pointer, if rotary control

3.1.6 Direction of Movement

Direction of Control movement should follow the following conventions:

Function	Control Action
On, Start, Run, Open, Breaker Close	Up, right, forward, clockwise, pull
Off, Stop, Close, Breaker Trip	Down, left, backward, counterclockwise, push
Right	Clockwise, right
Left	Counterclockwise, left
Raise	Up
Lower	Down
Increase	Forward, up, right, clockwise
Decrease	Backward, down, left, counterclockwise

3.1.7 Emergency Controls

Emergency controls should be given distinctive enhancement as described in Section 1.2.

3.2 Color Coding

Color coding may be used to provide unambiguous, easily discriminable information to the operator, and to aid in the following:

1. Perception of warning signals
2. Identification of functional relationships
3. Association of displays with related controls
4. Organization of information
5. Coding of low probability or very important events

The use of more than eleven colors for coding should be avoided.

The meaning of a particular color should be consistent throughout the control room, whether applied to panel surfaces or projected in signal lights or on CRTs, within and among systems. Colors should be recognizably different from each other and contrast well with the background on which they appear.

The color code for non-legend light indication associated with controls shall be in accordance with the following color coding:

Color	Status
Red	Running, Open, Breaker Closed
Green	Not Running, Closed, Breaker Open
White	Status (Power Available, Permissive)
Amber	Warning

The color code for Engineered Safeguards Status Lights is as follows:

Color	Status
Amber	Channel Bypassed, ES Equipment Not Actuated
Blue	Bistable Tripped, Manual Actuation
Red	Test Relay Status
White	Bypass Permit,Bypass Reset Permit, Power Supply Status
Green	Channel Function Enabled, Bypass Reset, ES Equipment Actuated

REV. 2

REV. 2

When color coding is used to relate a control to its corresponding display, the same color should be used for the control and the display. The color of a control should contract with the panel background.

3.3 Shape Coding

At times an operator must manipulate a control in a "blind" fashion such as when a display must be simultaneously monitored and the control is outside his field of view. In these situations, it is important to differentiate controls by shape.

Coded shapes for controls should be both VISUALLY IDENTIFIABLE and TACTUALLY IDENTIFIABLE.

3.4 Specifications for Specific Controls

3.4.1 Pushbuttons

A. Pushbuttons in a row or matrix should be positioned in a logical sequence or in an order relevant to procedural sequence.

B. Pushbuttons should provide a positive indication when pushed far enough to actuate, such as a snap feel (resistance to movement), an audible click, or an internal light.

C. The surface of a pushbutton should be slip resistant.

3.4.2 Legend Pushbuttons

Legend pushbuttons should be readily distinguishable from legend lights and should be designed so that the operator can easily and accurately select the correct control.

See Section 4.5.4 under Legend Light Indicators for additional information.

3.4.3 Key-Operated Controls

A. Key-Operated controls should only be used when they are justified in terms of security. They should never be used solely as a form of shape coding.

B. Keys with a single row of teeth should be inserted into the lock with the teeth pointing up or forward. If keys have a double row of teeth, they should fit the lock with either side up or forward.

C. Locks should be oriented so that the switch is off when the key is in the vertical position.

D. Locks should not allow key removal unless they are in the OFF (or SAFE) position.

E. All control positions should be labeled.

3.4.4 Continuous Adjustment Rotary Controls

A. Continuous adjustment rotary controls are appropriate to ensure precise control along a continuous variable.

B. Knobs with knurled or serrated edges are preferred.

C. All control positions should be labeled.

3.4.5 Rotary Selector Controls

A. Rotary Selector Controls should be used when three or more detented positions are necessary, and are also appropriate for applications utilizing two-detented positions.

B. A detent should be provided at each control position, and it should not be possible to position a control between detented positions.

C. Stops should be provided at the limits of the control range so that the control may not be placed in an unused position.

D. To maximize READABILITY, rotary controls should have a moving pointer and fixed positions.

E. Position indications should take the form of one or more of the following:

1. Illuminated indicator lights.

2. A line engraved on the top of the knob and down the side.

3. A pointer shape.

F. Pointers on the knob should be mounted close to the settings to which they point so that there can be no confusion between the position of the knob and the position markers on the panel.

G. If the selector controls are spring loaded, the knobs should be large enough so that they may be easily held against the spring torque for as long as necessary to accomplish the required control actions.

3.4.6 Thumbwheel

A. Thumbwheel readouts should be readable from the thumbwheel operating position.

B. If the thumbwheel is used as an input device, the OFF, ZERO, or NORMAL position should be coded to facilitate visual recognition of status.

C. If the thumbwheel has an OFF position, a detent should be provided for feedback at that point.

D. Thumbwheel controls which have discrete settings should be detented between positions.

3.4.7 Slide Switches

A. The surface of slide switches should be serrated or knurled.

B. Slide switch separation should be as follows:

1. Single finger operation - 3/4 to 2 inches

2. Sequential operation - 1/2 to 1 inch

3. Simultaneous operation - 5/8 to 3/4 inch

C. Slide switches should be designed to provide some kind of feedback of control setting such as associated indicator lights, control pointer and position markings.

3.4.8 Toggle Switches

A. To minimize the possibility of accidental operation, toggle switches should have an elastic resistance that increases as the control is moved and drops as the switch snaps into position.

B. When actuated, toggle switches should emit an audible click, or provide some other form of feedback.

3.4.9 Rocker Switches

A. Rocker switches should be oriented vertically unless it is absolutely essential that they are horizontal.

B. Activation of the upper part should control the ON or INCREASE function. In this position, the top of the switch should be flush with the panel surface.

C. Feedback of actuation should be provided in the form of a snap feel, an audible click, or an integral light.

D. Control resistance should gradually increase, then drop to zero when the control snaps into position. This should decrease the possibility of the switch being placed between positions.

SECTION 4 - VISUAL DISPLAYS

4.1 General Considerations

4.1.1 Overall Criteria

Displays should provide operators with all the information about system status and parameter values that is needed to meet task requirements in normal, abnormal, and emergency situations.

Displays should provide the operator with only the information necessary; displays should not overload operators with extraneous information or excess precision.

4.1.2 Direction of Movement

The direction of movement of the display should be clearly indicated.

4.1.3 Visibility

Displays should be easy for the operator to locate visually, and read from the normal operating position. All displays should be mounted in accordance with Section 1.6.

Additionally, all displays should be mounted so that the angle from the line of sight to the display face plane is 45 degrees or greater. All displays should be mounted so that they are in the upper limit of the visual field (75° above the horizontal line of sight). See Figure 1 below.

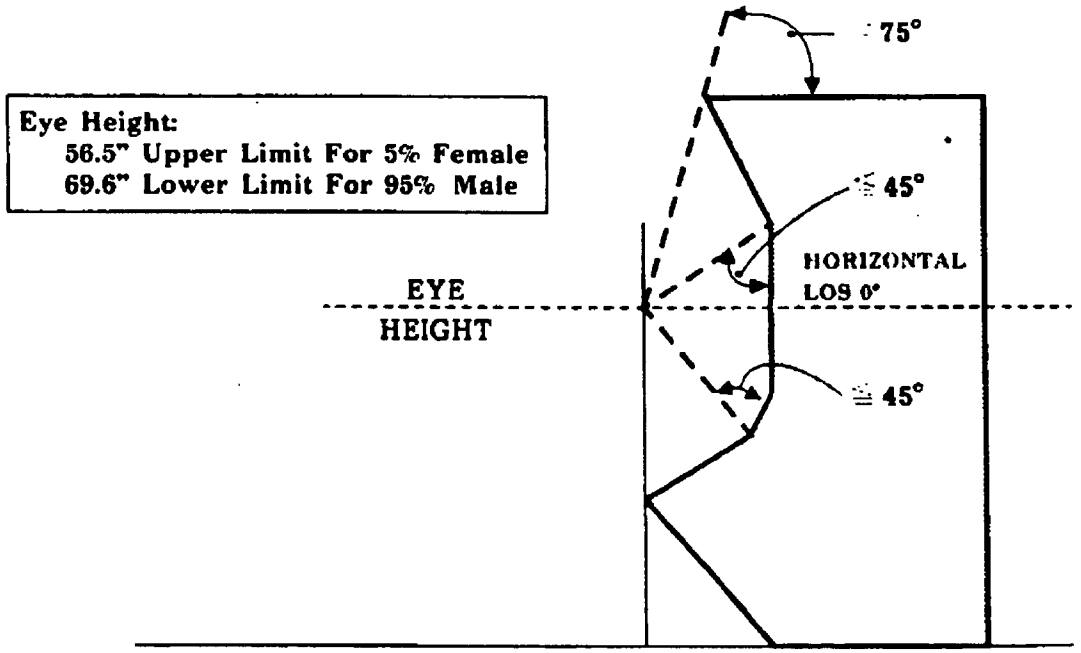

FIGURE 1

4.1.4 Demand Information Versus Status Information

Displays should be identified as to whether they give status or demand information.

A. Demand information indicates that equipment has been put in a particular state or level.

B. Status information shows the state or level actually in effect at a given time.

C. Visual displays of actual system/equipment status should be displayed for all important parameters.

4.1.5 Display Failure

When panel instruments such as meters, fail or become inoperative, the failure should be apparent to the operator (e.g., off-scale indication). An exception to this is indicators and recorders which receive signals from the NNI and ICS. These devices can fail at mid scale; however, replacement of the NNI and ICS was not required as a result of the CRDR. Additions to the MCB should avoid use of these signals where practical.

4.1.6 Display Response Time Lag

A. To the extent possible, displays should directly reflect the time lag between the actuation of the control and the change in system condition.

B. There should be no time lag between a system condition change and the display indication. An exception to this are repeat alarms from local panels which are delayed to provide sufficient time for a local operator to respond.

4.2 Color Coding

Color coding of displays should be in accordance with Section 3.2.

4.3 Printing on the Display Face

A. The information printed on a display face should be limited to the identification of units and indication of transformation (if any) required in reading. If it is not feasible, transformation and units may be added on the component label.

B. Extraneous printing such as patent or manufacturer information or any information not directly necessary in reading the display should not obscure necessary information or detract from the readability of the display.

C. When it is necessary to print transformation information, the operation and result derived should be clearly indicated.

D. The standard abbreviations listed in Crystal River Unit 3 Abbreviations List (SP-5132) should be used.

4.4 Scales

4.4.1 Usability of Displayed Values

A. Scales should be graduated and numbered so that readings relate in a direct and practical way to the operator's tasks.

B. The scale units should be consistent with the degree of precision and accuracy needed by the operator.

C. Displays should give information that is immediately usable by the operator without requiring mental conversion.

D. Percentage indications should only be used if they reflect the parameter in a meaningful way.

E. The scale should be selected to span the expected range of operational parameters, employ appropriate scale ranging techniques, or be supported by appropriate wide-range instruments.

F. The scale size may be expanded or contracted by multiplying by powers of ten, as long as such scales are clearly marked as to the power of ten used.

G. The sensitivity of the display should be selected so that it does not register normal random variations in the equipment.

H. Logarithmic scales should be avoided unless they are necessary to display a large range of values.

I. Multiscale indicators are confusing and should be avoided if at all possible.

4.4.2 Scale Marking

A. To avoid confusion of the operator, more than nine graduations separating numerals in a scale should be avoided.

B. Major and minor scale graduations should be used if there are up to four graduations between numerals.

C. Major, intermediate, and minor graduations should be used if there are five or more graduations between numerals.

D. Successive values indicated by unit graduations should be one of those shown below or those values multiplied by a power of 10 (See also 4.3.C).

Good					Fair				
1	2	3	4	5	2	4	6	8	10
5	10	15	20	25	20	40	60	80	100
10	20	30	40	50					

Recommended progression of values (McCormick, 1976)

4.4.3 Orientation of Scale Markings

A. To facilitate reading of meters, individual numerals on circular and fixed scales should be vertical.

B. If pointer movement is more than 360°, the zero should be located at the 12 o'clock position.

C. If positive and negative values are displayed around a zero or null point, the zero or null point should be located at the 12 o'clock position.

D. If a circular scale covers less than a complete rotation of a pointer, scale endpoints should be indicated by a break in the scale of at least one numbered interval in length. This should be included at the 6 o'clock position.

4.4.4 Zone Marking

A. Conspicuous zone markings may be used to show the operational implications of various readings, i.e., "Danger Range", "Upper Limit", etc.

B. Zone markings should be conspicuous and distinctly different from each other, and should not interfere with the reading of the scale markings of the instrument.

C. If color is used to differentiate zones, the color should be related to operator expectancies and plant color conventions. Typical zoning color codes are green for normal operating range, amber for marginal band, and red for out-of-tolerance band.

D. Zone markings shall be placed directly on the instrument scale and not on the instrument face in order to eliminate parallax errors.

4.4.5 Pointers

A. Pointer tips should be simple rather than stylized. They should be selected so that they conceal as little of the scale as possible.

B. The pointer tip should extend to within about 1/16 inch of the smallest scale graduations without overlapping.

C. Pointers should be mounted close to the surface of the scale to avoid parallax errors.

D. The size of the pointer and its contrast with the background of the instrument should be such that rapid and accurate recognition of the position of the pointer can be made.

E. Moving-scale, fixed pointer meters should be avoided.

4.5 Specifications for Specific Visual Displays

4.5.1 Display Selectors

Control position sequence should be consistent with display sequence; the two should have corresponding labels.

Displays should read off-scale (not zero) when not selected.

4.5.2 Light Indicators

Because light is the means by which light indicators communicate a message, it is essential that the light be physically reliable. For this reason, the following precautions should be met.

A. Dual-bulb light assemblies or dual-filament bulbs should be used where possible.

B. Bulb-test capabilities should be provided where possible.

C. The design of the indicator should encourage immediate replacement of burned-out bulbs by providing for bulb replacement with power on.

D. Ambient light sources should be controlled so that they cannot, through reflection or refraction, make indicators appear to be glowing when they are not or vice versa.

E. To avoid misinterpretation, system/equipment status should only be inferred by illumination, never by a lack of illumination.

F. Provisions in maintenance procedures should be made to prevent the inadvertent interchange of indicator lenses.

G. Alerting operators to unfavorable status should be the function of the Sequence of Events Recorder/annunciator, and not of indicator lights.

4.5.3 Non-Legend Light Indicators

Non-legend light indicators are represented by conventional pilot lights, bulls-eyes, and jewel lights.

A. When the meaning of a non-legend light indicator is not apparent, labeling should be provided close to the light indicator showing the message intended by its glowing.

B. The color of the light should be clearly identifiable, and should conform to the general color code established for the control room.

C. Light intensity of the illuminated indicator should be at least 10% greater than the surrounding panel as measured by a spot photometer.

4.5.4 Legend Light Indicators

4.5.4.1 Visibility Factors

A. Light intensity of the illuminated indicator should be at least 10% greater than the surrounding panel as measured by a spot photometer.

B. Legends should be legible under ambient illumination with indicator lights off.

C. Legend lettering should contrast well with background under both ambient and transilluminated lighting.

4.5.4.2 Legend Design

A. General legend design should be consistent throughout the control room.

B. Legend text and symbols should be concise and unambiguous. Legend messages should contain no more than three lines of text.

C. Legends should be worded so that they tell the status indicated by the glowing light.

D. Legend indicators should be readily distinguishable from legend pushbuttons by form, size, etc.

E. The color code of the legend background should conform to the general color code of the control room.

F. Character dimensions should be as described in Section 5.6.

4.5.5 Graphic Recorders

In general, two types of graphic recorders (continuous and discrete) are used to record trend information and material which may be needed for later reference. Regardless of the type of recorder, the following characteristics apply.

A. The pen, ink, and paper should be of a high enough quality so that they produce a clear, distinct record, and should be readily available at all times.

B. The scales on the recording paper should be compatible with the scales of the recorder.

C. The scales should be designed as described in Section 4.4.

D. The recorder should be designed to include a take-up spool, a means for tearing off completed recordings, and the capability to allow quick and easy replacement of paper and ink.

E. The recorder design should ensure that all data is visible through the window of the recorder, and allow for easy access of the data for annotation, i.e., date, paper speed, parameter, etc.

F. The paper speed should be adjustable so that rate-of change information can be indicated.

G. Recorders that display critical information should be placed in primary operating areas for easy viewing and access.

H. Failure of the display or the display circuit should immediately be apparent to the operator.

I. Parameters with significant statistical variations (i.e. radiation monitoring channels) should not exceed six inputs to a single recorder, where possible.

4.5.5.1 Continuous Recorders (pen type)

A. Labels should be used to identify the parameters recorded.

B. In the case of multiple-pen recorders, parameters should be listed in the order of the associated scales on the recorder.

C. Each pen should use a different color of ink to permit identification of recorder channels from ink color. These colors should be distinctively different from each other and should provide good contrast with the recording paper.

4.5.5.2 Discrete Recorders (point type)

A. These recorders should not be loaded beyond their designed channel capacity (i.e., multiple inputs to a single point), as this adds complexity to the analysis and prolongs sampling cycle time.

B. Discrete recorders should be equipped to display in an easily viewed manner the channel being plotted.

C. Provision should be made to select any single channel for immediate display without awaiting the completion of a sampling cycle.

D. Number-printing mechanisms should provide consistent, clear, sharp, and small numbering.

E. For multipoint recorders that print information on the chart paper, each trace should have a unique identification number printed periodically adjacent to it. The identification number and parameter of the point if abbreviated should follow the standard Crystal River 3 Abbreviations List (SP-5132).

4.5.6 Drum-Type Counters

This type of instrument is used when it is necessary to provide a quick, precise reading of quantitative value. Where possible an electronic counter (Section 4.5.9) is preferred.

A. Multi-digit numbers formed by several counter drums should be read horizontally.

B. To adequately compensate for the curvature of the drum, counter numerals should have a width-height ratio of 1:1.

C. When more than four digits are displayed, they should be separated by commas, and/or a decimal point as appropriate.

D. The color of the numerals and the drum background should be chosen to yield a high contrast. Black numerals on a white background is recommended.

E. The surface of the drums should have a matte finish to minimize glare.

F. Drum-type counters should be mounted perpendicular to the operator's line of sight, since the angle for adequate viewing is more restrictive than most displays.

G. The counter should be mounted as close as possible to the panel surface to minimize shadows and maximize the viewing angle.

H. The window of the counter should be aligned and sized to allow no more than one digit per drum to be seen in the window at any one time.

I. Numbers should change by snap action rather than by continuous movement.

J. Counter drums should move upward with increasing values.

K. Failure of counters should immediately be apparent to the operator.

4.5.7 Electronic Counters

Counters using "Nixie" tubes, light emitting diodes (LED's) or the like are preferable to drum counters for many control room applications.

A. Multi-digit electronic counters should read horizontally from left to right.

B. Simple and consistent character fonts should be used. Other types should be avoided.

C. The height of the numerals should be such that they subtend a visual angle of 15 minutes from the farthest anticipated viewing distance.

D. The width-to-height ratio of the numerals should be approximately 3:5.

E. The horizontal spacing between numerals should be between on-quarter and one-half the numeral width.

F. If the operator is expected to read the numerals consecutively, the numerals should not change faster than 2 per second.

G. The contrast of the character-to-background should be between 15:1 and 2:1 (preferred) as measured by a spot photometer.

SECTION 5 - LABELS AND LOCATION AIDS

5.1 General Considerations

Controls, displays, and other equipment items that must be located, identified, or manipulated should be appropriately and clearly labeled to permit rapid and accurate human performance.

5.1.1 Hierarchical Scheme

A hierarchical labeling scheme will reduce operator search time, confusion, and redundancy.

A. Major labels should be used to identify major systems or operator work stations.

B. Subordinate labels should be used to identify subsystems or functional groups.

C. Component labels should be used to identify each discrete panel or console element.

D. Labels should not repeat information contained in higher level labels.

E. The size of the letters in the labels should be distinctly different between the three hierarchical levels. The size of the lettering should be 25% larger than the next lower level, and/or 25% smaller than the next higher level.

F. Labels should contain all capital letters rather than lower case or mixed.

5.1.2 Controls and Displays Used in Sequence

A. Controls and displays used in sequence should be labeled in alphabetic or numeric sequence.

B. Controls and displays used in the same sequence should be labeled with the same alphabetic or numeric sequence.

5.1.3 Control Positions

A. All discrete functional control positions should be identified.

B. For continuous motion rotary controls, the direction of motion (increase, decrease) should be labeled.

C. Control position labels should be easily readable during the operation of the control.

D. For valves which are positioned (i.e., throttled open or closed) by momentary switch action, red "T" labels should be located on the switch escutcheon plate.

5.1.4 Access Openings

Each access opening should be labeled to identifies the items accessible through it.

5.1.5 Danger, Warning, and Safety Instruction Labels

These labels should be placed in a conspicuous position so they are highly visible to the operator.

5.2 Label Location

5.2.1 Placement

A. Labels should be placed close to and above the panel element(s) they identify.

B. Care should be taken to ensure label visibility in labeling elements located above eye level.

C. Labels should not be placed on the control if the operator's hand would obscure the label for an extended period of time.

D. Adjacent labels should be separated by enough space so that they will not be read as one continuous label.

5.2.2 Mounting

Labels should be mounted on a flat surface in such a way as to eliminate the possibility of accidental removal.

5.2.3 Spatial Orientation

To avoid confusion and delays in location and identification of important controls, the following guidelines should be followed:

A. Labels should be oriented horizontally.

B. If space is limited to the point that labels cannot be horizontal, they may be oriented vertically.

C. Curved patterns of labeling should be avoided.

5.2.4 Visibility

A. Labels should never obscure any other information source such as figures or scales which must be read by the operator.

B. Labels should not be concealed by pieces of equipment.

C. Labels should be visible to the operator during control actuation.

5.3 Label Content

5.3.1 Kinds of Information

The primary function of a label is to describe the function of equipment items. Of secondary importance, a label may describe engineering characteristics.

5.3.2 Word Selection

A. The words in the label should express exactly what action is intended in a clear direct manner.

B. Care should be taken that all words are spelled correctly.

C. Words should be used that have a commonly accepted meaning for the intended users. Unusual technical words should be avoided.

5.3.3 Consistency

A. Where whole words will not fit in the available space, the abbreviations listed in the Crystal River Unit 3 Abbreviation List (SP-5132) should be used. This is an ADMINISTRATIVELY CONTROLLED standard for Crystal River Unit 3.

B. Words, acronyms, abbreviations, and part/system numbers should be used consistently within and across pieces of equipment.

C. Nomenclature used in procedures should be consistent with that used in labels.

5.3.4 Symbols

A. Abstract symbols should only be used if they have a commonly accepted meaning for the intended use.

B. Symbols should be readily distinguishable from each other.

C. Symbols should be used in a commonly accepted standard configuration, the use of which should be consistent within and across panels.

D. The use of Roman numerals should be avoided.

5.4 Temporary Labels

A. Temporary labels should only be used when necessary. When a permanent label becomes available, or if the need for a temporary label no longer exists, the temporary label should be disposed of.

B. Temporary labels should only be used to identify out-of-service equipment, accommodate unique, one-time plant activities, or to improve operator understanding and efficiency.

C. Temporary labels should conform to good human factors principles.

E. Tag-outs should clearly identify out-of-service components and equipment, should be securely affixed, and should not obscure the label associated with the non-operable device or any adjacent devices.

F. Tag-outs should be designed to physically prevent actuation of a control.

5.4.1 Control of Temporary Labels

A. The use of temporary labels should be CONTROLLED ADMINISTRATIVELY.

B. An administrative procedure should be in place to govern the use of temporary labels. This procedure should determine:

1. When temporary labels are needed.

2. How they will be used.

3. How they will be installed.

4. The impact of their use on other system equipment.

5. Documentation requirements.

6. Re-training requirements.

7. A periodic review schedule.

8. Their removal.

5.5 Mimics

Mimics integrate system components into functionally oriented diagrams that reflect component relationships. Mimics may be used to decrease the operator's decision making load.

5.5.1 Color

A. Flow paths should be color coded. Colors should follow the guidelines of Section 3.2.

B. The mimic lines should have adequate contrast with the panel.

C. Mimic lines depicting flow of the same contents (steam, water, electricity, etc.) should be colored the same throughout the control room.

D. Mimic colors to be used on the board are as follows:

Fluid System

Emergency Core Cooling	-	Dark Blue
Condensate/Feedwater	-	Dark Blue
Letdown And Reactor Coolant Drains	-	Dark Blue
Main Steam	-	Light Blue
Reactor Coolant	-	Yellow
Emergency Feedwater	-	Orange

Electrical Distribution

500 KV	-	Blue
230 KV	-	Orange
22 KV	-	Green
6900 KV	-	Red
4160 KV	-	Yellow
480 KV	-	Black

5.5.2 Mimic Lines

A. Different line widths may be used to code flow paths in terms of significance, volume, level, etc.

B. Mimic lines should not overlap.

C. Flow directions should be clearly indicated by arrowheads.

D. All mimic origin and end points should be labeled or begin (or end) at labeled components.

E. All component representations should be labeled on mimic lines.

F. No more than 4 lines should run in parallel if the operator is expected to quickly identify one of the lines.

5.5.3 Symbols

Graphic symbols should be readily understood and of a kind commonly used. Symbols should be used consistently.

5.6 Demarcation

Lines of demarcation may be used to enclose functionally related displays or controls and to group related displays and controls.

5.6.1 Color

A. Color should be dedicated to specific functions or conditions throughout the control room. The color coding scheme should be used consistently throughout the control room.

B. Lines of demarcation should be visually distinctive from the panel background. Colors should follow the guidelines of Section 3.2.

5.6.2 Size

A. Primary demarcation lines should be 1/4 inch wide.

B. Secondary demarcation lines should be 1/8 inch wide.

5.7 Lettering

Character size should conform to the following where possible:

A. Nameplates and subplates

Character Height	Number of Characters Per Inch
3/32"	11
1/8"	10
5/32"	8
3/16"	7
1/4"	5
5/16"	4

B. Micro Switch Legends

Character Height	Number of Character Per Line
7/64"	6 (Vertical Mount)
7/64"	9 (Horizontal Mount)

C. Escutcheon Plates

Character Height	Number of Character Per Inch
1/8 "	10
3/32"	11

Where these guidelines cannot be followed the criteria of 5.7.1 through 5.7.3 should be applied.

5.7.1 Character Dimensions

A. Letter width-to-height ratio should be between 1:1 and 3:5.

B. Numeral width-to-height ratio should be 3:5 except for the numeral "4" which should be one stroke width wider and the numeral "1" which should be one stroke in width.

C. Stroke width-to-character height ratio should be between 1:6 and 1:8.

D. The size of letters used should be consistent between similar components/modules.

5.7.2 Type Style

A. Labels should be composed of capital letters only, no lower case or mixed cases.

B. The design of the letters and numbers should be simple without flourishes or serifs.

C. The type style used should be consistent throughout the control room.

5.7.3 Spacing

The minimum space between label contents should be as follows:

A. One stroke width between characters.

B. One character width between words.

C. One-half character height between lines.

D. One-half character height for top and bottom boarders.

E. One-half character width for side borders.

5.7.4 Readability

A. For the best contrast, and to reduce the possibility of a loss of contrast from accumulation of dirt, dark letters should be used on a light background.

B. If color print is used for coding purposes, the colors should be chosen for maximum contrast against the label background. The following chart should be consulted:

LEGIBILITY RATING	COLOR COMBINATION
Very Good	Black Letters On White Background
Good	Black On Yellow Dark Blue On White Grass Green On White
Fair	Red On White Red On Yellow White On Black
Poor	Green On Red Red On Green Orange On Black Orange On White

SECTION 6 - ANNUNCIATORS

6.1 General Considerations

Annunciator displays should be located, identified, and arranged to permit rapid understanding and response to the alarmed condition.

Plant parameters selected for inclusion in the annunciator warning system and the limits or alarm set ponts for those parameters should be established to ensure compliance with technical specifications and to allow the operator to monitor the status of the plant and respond to out-of-tolerance conditions effectively.

6.2 Alarm Parameters

The set points for initiating the annunciator system should be established to meet the following goals.

A. Alarms should not occur so frequently as to be considered a nuisance by the operators.

B. Set points should be established to give operators adequate time to respond to the warning condition before a serious problem develops.

C. Alarms that require the control room operator to direct an auxiliary operator to a given plant location for specific information should be avoided.

D. If general alarms must be used, they should only be used for conditions that allow adequate time for auxiliary operator action.

E. Annunciators with inputs from more than one plant parameter set point should be avoided, where possible.

F. Where multi-input annunciators must be used, alarm printout capability should be provided. The specifics of the alarm should be printed on an alarm typer with sufficient speed and buffer storage to capture all alarm data.

G. A reflash capability should be provided to allow subsequent alarms to activate the auditory alert mechanism and reflash the annunciator window even though the first alarm may not have been cleared.

6.3 Prioritization

6.3.1 Plant parameters to be alarmed in the control room should be categorized to assist the operator in accessing the importance of action to the alarmed condition. The Crystal River Unit 3 annunciator warning system has three priority levels. They are: REV.3

A. Priority 1* - Transient conditions, critical equipment failures, safety system actuations, or other conditions which require prompt operator action or awareness. REV.3

B. Priority 2 - Conditions which if not corrected, may result in equipment damage, transient conditions or radiation release. This priority also includes annunciators that provide a status of critical plant equipment. REV.3

C. Priority 3 - Deleted. REV.3

D. Priority 4 - Alarms which do not meet the definitions of Priority 1 or 2.

*Note: Priority 1 alarms shall be red. Location within a specific annunciator panel is not critical, but when practical will be located higher than Priority 2 alarms associated with the same functional grouping. Priority 1 alarms will be selected using the expertise of CR-3 licensed operators and concurrence of Operations Management. REV.3

6.3.2 Alarms should be functionally grouped and where possible located above their associated system controls. Where space does not permit all functional groups to be located beside one another, a functional group may be located below another group.

6.3.3 Deleted. REV.3

6.3.4 For the main control board annunciator system, priority 4 alarms should be monitored and alarmed through the sequence of events recorder only. REV.3

6.4 Visual Alarm Identification

A. The specific window(s) on an annunciator panel should use flashing illumination to indicate an alarm condition.

B. Flash rates should be from three to five flashes per second with approximately equal on and off times.

C. There should be high enough contrast between alarming and steady-on windows, and between illuminated and non-illuminated windows, so that operators in a normally illuminated control room have no problem discriminating alarming, steady-on, and steady-off windows.

D. Under normal operating conditions, no annunciators should be illuminated.

E. If an annunciator window must be "ON" for an extended period during normal operations (i.e. during equipment repair or replacement), it should be distinctively coded for positive recognition during this period, and controlled by administrative procedures.

F. Cues for prompt recognition of an out-of-service annunciator should be designed into the system.

G. Blank or unused annunciator windows should not be illuminated (except during annunciator testing).

6.5 Window Legends

Annunciator window legends should be specific and UNAMBIGUOUS. Windows should address SPECIFIC CONDITIONS in concise, short messages.

Abbreviations should be consistent with those used elsewhere in the control room (SP-5132).

6.5.1 Alarm window engraving should consist of no more than 3 lines of text with no more than 14 characters per line.

6.5.2 Characters used for annunciators shall be 0.225 inches high, condensed gothic. The following guide should be used:

A. Letters should be upper-case type

B. Letter width to letter height should be approximately 3:5

C. Stoke width should be between 1/6 to 1/8 of letter height

D. Borders should be 1/2 of letter height (minimum)

E. Spaces between lines should be 1/2 of letter height (minimum)

F. Spaces between letters should be one stroke width (minimum)

G. Spaces between words should be one letter width (minimum)

6.5.3 Alarm window wording should use the following format:

1st line - system/component

2nd line - parameter

3rd line - alarm status

6.6 Annunciator Controls

Controls for operator responses to the annunciator system include acknowledge, reset, and test controls.

A. Repetitive groups of annunciator controls should have the same arrangement and relative location at different panel sections, where possible. This is to facilitate "blind" reaching.

B. Annunciator response controls should be coded for easy recognition using techniques such as:

1. Color coding

2. Shape coding

3. Demarcating the group of annunciator controls

C. Annunciator control designs should not allow the operator to defeat the control. For example, some pushbuttons used for annunciator silencing and acknowledgement can be held down by inserting a coin in the ring around the pushbutton. This undesirable design feature should be eliminated.

SECTION 7 - REFERENCES

1. CR-3-E247-A, Electrical Separation Criteria for Class IE Control Boards, Equipment Cabinets and Relay Racks (DRAFT, FCS-7664).

2. NUREG-0700, Guidelines for Control Room Design Reviews; September 1981.

3. EPRI NP-2411, Human Engineering Guide for Enhancing Nuclear Control Rooms; May 1982.

4. NUREG/CR-3217, Near-Term Improvements for Nuclear Power Plant Control Room Annunciator Systems; April 1983.