PRELIMINARY ASSESSMENT:
HUMAN FACTORS ENGINEERING REVIEW
OF THE
BYRON GENERATING STATION CONTROL ROOM

SUBMITTED BY:

COMMONWEALTH EDISON COMPANY

IN RESPONSE TO
TASK ACTION PLAN ITEM
I.D.1, CONTROL ROOM DESIGN REVIEWS

NOVEMBER 1981

Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

November 12, 1981

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Byron Station Units 1 and 2
Preliminary Design Assessment
Byron Station Control Room
NRC Docket Nos. 50-454 and 50-455

Dear Mr. Denton:

Please find enclosed the Byron control room human factors review Preliminary Assessment Report. This report is being submitted in response to NUREG-0660 item I.D.1.

During our meeting on November 3, 1981, with members of the Human Factors Engineering Branch (HFEB), we transmitted color photographs and a complete set of color-coded drawings of the Byron control boards. With the submittal of this report, we believe we have met the necessary requirements for the HFEB review of the Byron control room scheduled for November 17 through November 19, 1981.

We are also of the understanding that the HFEB review of the control room will encompass the review of the control board, including all the design modifications to which we have committed to date.

One (1) signed original and fifty-nine (59) copies of this letter and the attachment are provided for your use. Please address further questions regarding this matter to this office.

Very truly yours,

F. D. Lentine

for T. R. Tramm
Nuclear Licensing Administrator

Enclosure
2869N

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1. INTRODUCTION

Several special inquiry groups were established by the Nuclear Regulatory Commission (NRC) to investigate the cause and consequences of the accident at Three Mile Island Unit #2(TMI-2). It became clear during these investigations that human error played an important role throughout the accident. Therefore, special attention was focused toward the extent to which factors incorporated within the discipline of human factors engineering (e.g., man-machine interface design, procedures, manning, and training) were influential in causing or contributing to the cause of the accident.

The primary conclusion reached by the human factors engineering investigation was that human errors were due, in large part, to poor equipment design, information presentation and operator training. The results of this study were documented in NUREG/CR-1270, "Human Factors Evaluation of Control Room Design and Operator Performance at Three Mile Island-2" (Volumes 1, 2, and 3).

Following this human factors review and the assessment of other inquiry groups, the NRC deemed it necessary that a human factors engineering review be performed on all nuclear power plant control rooms. This requirement was documented in NUREG-0660, "NRC Action Plan Developed as a result of the TMI-2 Accident," NUREG-0694, "TMI Related Requirements for New Operating Licensees," and NUREG-0737, "Clarification of TMI Action Plan Requirements."

Task I.D.1 of NUREG-0660 requires near term operating plants who are unable to conduct reviews prior to fuel loading to complete a preliminary assessment of their control rooms to identify significant human factors engineering and instrumentation problems and establish a schedule approved by the NRC for correcting deficiencies.

The following report presents the methodology, findings and conclusions from a preliminary human factors engineering assessment of the Byron Generating Station Control Room. The review was conducted by the Commonwealth Edison Company (CECo) Control Room Review Task Force. This report was prepared to show compliance with Task I.D.1 of the TMI Action Plan.

2. OBJECTIVE

The objective of this review, in accordance with Task I.D.1, was to make a preliminary assessment of the Byron Generating Station Control Room to identify significant human factors and instrumentation problems and to establish a schedule approved by the NRC for correcting discrepancies.

3. REVIEW METHODOLOGY

The objective of the preliminary human factors engineering assessment was accomplished by applying the skills and training of the control room review task force to identify and resolve control room design deficiencies and by developing a comprehensive control room review procedure. The composition of the task force and a detailed description of the procedures implemented are discussed below.

It should be mentioned, however, that a considerable number of analyses and reviews were performed prior to the preliminary assessment. These reviews were conducted by Byron Station Operations and CECo Engineering. The methodology employed and the results of the previous human factors/Operating assessment review are discussed in Appendix 6.2.

3.1 Commonwealth Edison Company Control Room Review Task Force.

The preliminary human factors engineering assessment was conducted by the CECo Control Room Review Task Force. Task Force members included individuals from:

1. CECo Production Training
2. CECo Station Nuclear Engineering
3. Byron Station Project Engineering
4. Byron Station Operations
5. Braidwood Station Operations
6. Sargent and Lundy
7. Advanced Resource Development (ARD) Corporation

Individuals were selected because of their experience and training in engineering, plant operations, training, and human factors engineering. Human Factors Engineering support was provided by a full-time CECo Human Factors Engineer and consultants from the Human Factors Technology Group of ARD Corporation.

3.2 Review Approach

Four techniques were utilized during the preliminary human factors engineering design assessment of the Byron Generating Station Control Room. These were:

1. Operator Questionnaire
2. Operator Control Board Review
3. Human Factors Engineering Checklist Review
4. Procedure Walk-Through

3.2.1 Operator Questionnaire

An operator questionnaire was developed to obtain operator comments to identify potential operator/control board interface problems. The objective of the review was to identify design improvements which would assist the Byron Station operators in recognizing and controlling normal and abnormal plant conditions. Major questionnaire categories included the control room environment, workspace arrangement, visual displays, auditory displays, controls, control/display integration, operator-computer interface and dialog, performance aids, and communications.

Since Byron Station was not operational, the questionnaire was distributed to individuals that were licensed reactor operators and licensed senior reactor operators at the Zion Station. Byron and Zion Stations are both pressurized water reactor plants with highly similar plant system. Consequently Zion Station operating experience was expected to be applicable to the Byron Station control board. Problem areas identified by the Zion operators would contribute to the investigation of potential Byron Station control board design problems.

The questionnaire was developed to assist operators in recalling potential control board/interface problems. The questions were generated by using operational and human factors engineering experience from the LaSalle County Station review and draft criteria of NUREG-0700. Nine areas of human factors concern were used to generate 45 questions. A copy of the questionnaire is included in Appendix 6.6. Thirty-three questionnaires were used for the operating experience review. The experience levels of the operational personnel are presented below:

	Licensed Experience (Years)		
Type of License	Total	Average	Range
Reactor Operator	53.5	3.3	.5-12
Senior Reactor Operator	60.5	4.0	0-8

The answers to the questionnaire were summarized by the CECo Human Factors Engineering Section and distributed to the CECo Review Team Members. The summary and results of the questionnaire were reviewed by a human factors engineer and a senior reactor operator to verify the applicability of the Zion Station operator comments to the Byron Station control room. Results of the questionnaire were incorporated into the board modifications prior to the preliminary human factors engineering assessment.

3.2.2 Operator Control Board Review

Three licensed Byron Generating Station Operators participated in an independent review of the control boards. Each operator used piping and instrumentation drawings (P&ID), control board drawings, operational procedures, and a review guide to evaluate the boards. These tools were used to determine where design improvements could be implemented. The operators were asked to indicate where the operability of the boards could be improved with the addition of particular components; the elimination of unnecessary hardware; the rearrangement of selected controls, displays, alarms and/or indicators; or the use of mimics. The operators were assisted by a human factors engineer who reviewed the operator's findings and recommendations following the identification of a particular design or operational problem. This review considered each recommended design change against the following criteria:

1. Proper functional grouping of controls and displays,
2. Frequency of use and control/display placement,
3. Sequence of use,
4. Control and display criticality,
5. Consistency of control and display arrangements, and
6. General operability of plant system/subsystems.

The operator was requested to document the control board problem, the improvement, and the purpose of the improvement. Results of this review were incorporated into the board modification prior to the preliminary human factors engineering assessment.

3.2.3 Human Factors Engineering Checklist Review

A human factors engineering review of the Byron Generating Station Control Boards was conducted using a draft of Section 6 of NUREG-0700 (Control Room Human Engineering Guidelines). The objective of this review was to perform a systematic comparison of the control room design features with accepted human factors design standards. The review was conducted by human factors engineers experienced with these and several other standard human engineering checklists. Cold certified Operating personnel assisted the engineers conducting the checklist review.

As potential or existing deficiencies were identified, appropriate notations were made on the actual checklist.

It should be noted that the stage of the Byron Generating Station construction program, at the time of the preliminary assessment, precluded the review of particular sections of the checklist. These areas are discussed in further detail in Section 5 of this document.

3.2.4 Procedure "Walk-Throughs"

A simulated "walk-through" and analysis was conducted by station operating and human factors personnel to identify control board operating interface discrepancies associated with specific plant events. Personnel qualified to fill the normal operating crew positions of one senior reactor operator and two reactor operators were used to simulate a "walk-through" on existing control boards for the subsequent analysis.

To perform the analysis, video tapes were prepared of control room "walk-throughs" using General, Emergency, and Abnormal operating procedures. The procedures used are listed in Table 1.

These "walk-throughs" represent an approximation of operator activity (operator location and movement, control activation, and display identification) expected during actual operational conditions.

The objective of the "walk-through" review was to identify potential human engineering problems associated with the control board design. During the subsequent video tape analysis, cold licensed trained operators and supervisors were present to evaluate the accuracy and completeness of the procedures. They were teamed with an experienced human factors specialist to evaluate the interface between operator performance and control board design.

Readily observable human engineering criteria were developed and used to identify apparent discrepancies associated with the operator-control room interface activities. These criteria were general and limited to subjective determinations of apparent interface discrepancies.

The criteria employed for the off-line evaluation of the video tapes are described in further detail in Appendix 6.3.

AOP1	Excessive Primary Plant Leakage
AOP2	Reactor Coolant Pump Seal Malfunction
AOP8	Loss of Component Cooling
EOP0	Safety Injection/Accident Diagnosis
EOP1	Reactor Trip Procedure
EOP3	Feed Water Pump Malfunction
EOP7	Station Black Out Operation
EOP8	Main Steam Liner Feed Liner Break
EOP9	Loss of Reactor Coolant Accident/Cold Leg Injection
EOP10	Steam Generator Rupture
EOP12	Failure of Reactor to Trip
BOA100-8	Essential Service Water System Malfunction
BGP100-2	Plant Start-Up
BGP100-1	Plant Heatup
BGP100-4	Plant Shut Down
BEP100-X	Reactor Trip

TABLE 1. PROCEDURES REQUIRED DURING THE OPERATOR "WALK-THROUGHS"

4.0 Control Room Findings, Improvements and Implementation Schedule

The following section provides detail information regarding identified problem areas, proposed improvements and an implementation schedule. Areas investigated include:

Section	Topic
4.1	Control Room Workspace
4.2	Communications
4.3	Annunciator Warning Systems
4.4	Controls
4.5	Visual Displays
4.6	Labels and Location Aids
4.7	Panel Layout
4.8	Control-Display Integration

Wherever possible, the guideline from Chapter 6 of NUREG 0700 corresponding to the selected finding has been cited. In addition, panel locations have been provided for ease of reference.

4.1 Workspace

1. Finding:

   Center desk design requires (in some cases) approximately 30' of movement to traverse a 10' straight line distance to operate controls or respond to annunciator alarms on the HVAC panel. Operators can not reach all work stations without having to overcome obstacles, and control room arrangement does not facilitate unobstructed movement and communication. (6.1.1.3 C1, D1)

   Improvement:

   The center desk design is being reviewed to determine the center desk personnel tasks, responsibilities and communications requirements.

   Implementation:

   The results of the center desk review will be available by January 2, 1982 and will determine implementation.

2. Finding:

   All controls are not within the reach radius of 5th% females. At a height of 36" at benchboard edge the distance to the board is 27", not the recommended 21". At a height of 49.4" eye height of 5th% female at benchboard edge, the distance to the board if 30", not the recommended 25.2". (6.1.2.2 B1, 6.1.2.2C, 6.1.2.2 D2)

   Improvement:

   Guard rails are being evaluated to alleviate the possibility of such a person inadvertently actuating a switch by bumping it.

Workspace (cont.)

Implementation:
The results of the evaluation will be available by May 1, 1982 and will determine implementation.

3. Finding:
Some controls on the vertical panels are mounted below 34" and above 70" from the floor. On the in-core instrumentation panels the lowest display is 23" from floor and the highest is 86" from floor while the lowest control is 13" from the floor and the highest is 87" from the floor. (6.1.2.5A1, 6.1.2.5B1,B2). This requires operators to stoop or stretch or even use a step-stool to reach the instruments. This increases the possibility of accidental activation and inaccurate operation. A step stool or other tool should never be necessary to operate a switch except for maintenance or surveillance.

Improvement:
No emergency or critical controls involved. Controls not in compliance are used by technical staff, not the operators.

Implementation:
Accept as is.

4. Finding:
Annunciator acknowledge control buttons on common vertical panels: OPM01J and OPM02J, are 77" from the floor making operation of this control cumbersome. (6.1.2.5A2).

Improvement:
This control does not require precise nor frequent operation and it is not an emergency control.

Workspace (cont.)

Implementation:
Accept as is.

5. Finding:
No procedures exist for combination emergencies. This could lead to operator confusion in such situations about which emergency takes precedence. There should be a written, administratively approved procedure for each type of emergency or combination of emergencies. (6.1.4.2D).

Improvement:
Emergency procedures are being re-written to agree with owners group criteria, prior to fuel load.

Implementation:
Accept as is.

4.2 Communications

1. Finding:

   Sound power phones do not have self-retracting or spiral cords to prevent tripping hazards. Sound power headsets are not comfortable when worn for long periods of time. (6.2.1.2B3, 6.2.1.3B1, 6.2.1.3B2).

   Improvement:

   Current plans call for the replacement of sound powered phones with a squawk box system.

   Implementation:

   Prior to fuel load.

2. Finding:

   PA does not have a long enough cord for use at the control board. The same is true, of course, of the conventional phone system cord as the handset is used in both systems. (6.2.1.2B4)

   Improvement:

   Install longer cord.

   Implementation:

   Prior to fuel load.

3. Finding:

   Press to talk and channel select switches are located too low to be operated effectively.

   Improvement:

   Relocate press to talk and channel select switches.

Communications (cont.)

Implementation:

Engineering will make change prior to fuel load.

4.3 Annunciator Warning System

1. Finding:
There is no turbine-generator system first-out panel (1PM02J). A separate first-out panel similar in function to the recorder system panel is not available. (6.3.1.3B).

Improvement:
The sequence of events recorder should provide sufficient information to the operator.

Implementation:
Accept as is.

2. Finding:
There is only one location for the display of first-out alarms. All first-out alarms should be available immediately above the associated panel. (6.3.1.3C).

Improvement:
Provide border within existing annunciator window boxes to emphasize first-out tiles. Segregate safety injection annunciators from the reactor trips.

Implementation:
First-out annunciators will be logically grouped within a single window box. Functional grouping and marked-up points will be provided to Project Engineering by 3/82.

3. Finding:
First, second, and third priority alarms are not displayed in the control room. (6.3.1.4.A2, 6.3.1.4B).

Annunciator Warning Systems (cont.)

Improvement:
Computer (Equipment Status Display System for bypass and inoperable status indication) provides sufficient information to the operators to set priorities.

Implementation:
Accept as is.

4. Finding:
Tiles on the following annunciator panels are not readable from acknowledge buttons: Panels UL-AN026, 003, 007, 008, 012, 014, and 015. Not all annunciator alarms are located above related controls and displays. Annunciator organization does not reflect proper functional grouping, axis labeling, or patterned arrangement. Annunciator labeling abbreviations are inconsistent with display and/or control labeling abbreviations. No procedure exists for cases where an annunciator tile must be "ON" for extended periods of time. (6.1.2.2E2, 6.3.3.1A, 6.3.3.3A,B,C,D, 6.5.1.4D, 6.3.3.2.F).

Improvement:
Carefully examine all board/tile relationships, develop proper labeling conventions (size, type, etc.) and functionally group all tiles using drawings initially, followed by implementation and test and evaluation.

Implementation:
Operating will review all annunciator tiles to evaluate their grouping, labeling and arrangement by 12/1/81. Human Factors Engineering and Operating will develop a guideline for the design of control room annunciators by 12/1/81.

5. Finding:
Operator aids for lamp replacement are not available. (6.3.3.1C3, 6.5.3.1A3).

Annunciator Warning Systems (cont.)

Improvement:
Provide a lamp replacement tool in the control room.

Implementation:
Prior to fuel loading.

6. Finding:
A separate alarm horn is needed for each section of the control board.

Improvement:
Install separate annunciator horns, one horn for each of the following panels:

a. Engineered Safeguards (1PM06J)
b. Reactor and Chemical Volume Control (1PM05J)
c. Balance of Plant (Feedwater, Condensate, Turbine, etc.) (1PM04J, 1PM03J, 1PM02J)
d. Generator and Aux Power (Diesels included) (1PM01J)
e. Switchyard (0PM03J)
f. HVAC (0PM02J)
g. General Services (0PM01J)

Each alarm horn should be located at or near the center of its associated annunciator panels (Section 6.10).

Implementation:
By January 1982.

4.4 Controls

1. Finding:

   Three controls have deficiencies which make adjustment to the required level of accuracy cumbersome. Specifically: M/A Station Switches - For third level accuracy, the operator must lean over the board. In addition, the control was designed for left handed operators, i.e., dial and pushbuttons are to left of linear scale which right handed operators cover with their hand when setting dial. Hagan Control Station Switches - scale markings are difficult to read and dust/dirt accumulates in scale window aggravating the problem. Boric acid/primary water batch make-up thumbwheel counters are difficult to set because they do not conform to the size specifications of Section (6.4.1.1A2).

   Improvement:

   These are non-critical, non-time dependent adjustments. The problem does not warrant modifying or replacing module.

   Implementation:

   Accept as is.

2. Finding:

   The J-handle switches close to the edge of the bench-board in the heater drain and turbine control areas, panels 1PM02J, and all switches on the common vertical panels: OPM01J, OPM02J, and OPM03J could accidentally be activated. (6.4.1.1A, 6.4.1.1D2).

Controls (cont.)

Improvement:
The J-handles identified are on electrical oil pumps for C/CB pump startup. These are non-critical since they are turned off after mechanical oil pump on C/CB pump is providing oil pressure when C/CB is running.

Implementation:
Accept as is.

3. Finding:
The Star Handle Discrete Rotary switches' operation involves covering the discrete position labels with the operator's hand. This could result in an erroneous setting. (6.4.1.2A, 6.4.2.2E).

Improvement:
After identifying problem areas, change the discrete position plaque on these controls to move the discrete positions out from the shaft of the controls. Consider approaches used for similar problems at other CECo stations.

Implementation:
Station will review all Star Handle Discrete Rotary Switches to determine impact of current design on operator performance. To be completed by 5/1/82.

4. Finding:
Feedwater Pump Turbine Control Panel, 1PM04J, pushbuttons are not arranged in a natural, stereotypical, or logical sequence increasing the probability of inadvertant/accidental activation of the wrong control. (e.g., valve open button is to left of valve closed button.) (6.4.2.1, 6.4.3.1).

Controls (cont.)

Improvement:
Operating should investigate requirements to determine the effect on operator performance.

Implementation:
Station operating will provide to Project Engineering marked up prints showing specific changes by 4/1/82.

5. Finding:
100% readings on some M/A Station Switches indicates valves are 100% open, on others it indicates that valves are 100% closed. This could cause incorrect valve operation if the operator forgets or confuses switch characteristics. (6.4.2.1).

Improvement:
Standardize indicator meanings. Make a 100% indication mean either that a valve is 100% open or 100% closed. Check status of on-going plant investigation. Already under consideration.

Implementation:
The station is sending their recommendations for a fix to Engineering Dept. by 4/1/82.

6. Finding:
The Rod Speed linear scale indicator increases down rather than up. This is inconsistent with other indicators and could lead to confusion. (6.4.2.1).

Controls (cont.)

Improvement:
Change the Rod Speed linear scale indicator so that increases are registered in the up direction and decreases in the down direction.

Implementation:
Drawing changes will be implemented by 5/1/82.

7. Finding:
The Fractional Rotation knobs on the In-Core Vertical Instrumentation panel are not of the shape codes depicted for knobs of this type on page 6.4-10 of the checklist. (6.4.2.2E).

Improvement:
The controls are infrequently used, are not time critical, and are not used by the operators.

Implementation:
Accept as is.

8. Finding:
All legend pushbuttons and indicator lights are removable from the front of the panel for bulb replacement, but they are also interchangeable within a particular panel or display. It is therefore possible that inadvertant switches will be made in the locations of the pushbutton/indicator lights when more than one bulb is replaced. (6.4.3.3C4. 6.5.3.1.C2).

Controls (cont.)

Improvement:
Cover panels and pushbutton/indicator lights should be permanently color keyed. A matrix code utilizing color, displayed evidently but not prominently would mark the row and column of each indicator in a matrix and/or the adoption of an administrative procedure requiring removal of only one indicator at a time.

Implementation:
Color coding to be developed by Station and Human Factors Engineering by 5/1/82.

9. Finding:
The EGC (ADC) Panel pushbuttons, which are contiguous, have no guards or barriers between them thereby enhancing the prospect of accidental/inadvertant actuation of a wrong pushbutton. (6.4.3.3D1).

Improvement:
Operation of indicated systems is not critical and does not create a safety problem if accidental actuation of pushbuttons occurs.

Implementation:
Accept as is.

10. Finding:
On Unit Two the Safety Injection Pumps Discharge Isolation Valve control is a keyed control and the key control was mounted upside down so that the open/close positions are at 4 o'clock and 8 o'clock. The other two key controls have the open close positions at 10 o'clock and 2 o'clock. This switch is properly installed on Unit One. (6.4.4.3D).

Controls (cont.)

Improvement:
This particular switch should be properly re-installed to be consistent with the other key switches on the board. The 10 and 2 o'clock orientation is consistent with all other valve controls on board and therefore is not a problem, though it is a discrepancy from the above specification.

Implementation:
Keylock switches will be replaced with pushbutton (on/off) type switches, if that does not constitute a plant safety problem, prior to fuel load.

11. Finding:
The three key controls on both Units One and Two can be operated by the same key. In addition, the key can be inserted and removed regardless of the switch position. This could result in valves being accidentally left open or closed. (6.4.4.3E).

Improvement:
Replace key locks with alternative non key lock controls.

Implementation:
Keylock switches will be replaced with pushbutton, on/off, type switches, if they do not constitute a plant safety problem, prior to fuel load.

12. Finding:
The fractional control knobs on the In-Core Instrumentation Panel should be round in shape with knurled or serrated edges. (6.4.4.4A)

Controls (cont.)

Improvement:
Used too infrequently to warrant further consideration.

Implementation:
Accept as is.

13. Finding:
There is no pointer on the NIS pen rotary selector switch (6.4.4.5D2).

Improvement:
Install a pointer knob on the NIS pen Selector switch.

Implementation:
The plant operating management will evaluate the impact on operator performance by 2/82.

14. Finding:
The boric acid/primary water batch make-up thumbwheels do not conform to the human engineering guidelines stated. They are much smaller than required which could cause operating difficulty. (6.4.5.1D2).

Improvement:
These are non-critical, non-time dependent adjustments. The problem does not warrant modification or replacement of module.

Implementation:
Accept as is.

Controls (cont.)

15. Finding:

The toggle switch (thermocouple switches) on the In-Core panel switches do not SNAP into position nor do they provide any feedback on either direction of movement of activation. To minimize the possibility of inadvertent activation or setting between control positions, toggle switches should have an elastic resistance that increases as the control is moved and drops as the switch snaps into position. Toggle switches should emit an audible click, or provide some other source of feedback on activation. (6.4.5.34,B).

Improvement:

Non critical situation that does not warrant retrofit.

Implementation:

Accept as is.

16. Finding:

A zero to eight hundred pound RCS pressure gauge by the let down/charging system is needed for low pressure operations on RHR.

Improvement:

Install the 0-800 lbs. gauge needed, attending to human factors concerns regarding control/display placement.

Implementation:

Operating will provide Project Engineering with a marked-up drawing by 10/15/81.

Controls (cont.)

17. Finding:
Labeling is unclear on 3-way valves, i.e., what is 100% divert, or letdown.

Improvement:
Labeling should be reviewed to ensure that it is consistent with valve operation.

Implementation:
Operating will complete the review by 1/82.

18. Finding:
The Tave and delta T defeat switches did not have to be pulled to actuate like the Zion Station switches.

Improvement:
Change color of Tave and delta T defeat switches to train operator that he is removing a function from controllers.

Implementation:
Station to select color and change by January, 1982.

19. Finding:
It is difficult to memorize whether a valve is throttleable, an open/close valve, or a throttle open seal close valve.

Improvement:
Leave open/closed valve handles as they are. Coat the entire projecting portion of throttleable valve handles with white platisol or a textured sleeve material. Coat just the tip of the valve handle with white plastisol for throttle open-seal closed valves.

Implementation:

Prior to fuel load.

4.5 Visual Displays

1. Finding:

   RCP seal flow control is adjusted while monitoring header pressure indicators, PM05J. The displays and controls are not located within reasonable proximity to effect simultaneous action. (6.5.1.1D).

   Improvement:

   Provide either a redundant control or a redundant set of displays in order to establish a proximal relationship. When the operator must manipulate controls while monitoring a display, the controls should be placed close to and below that display.

   Implementation:

   Relocate position of HCV - 182 controller on the control board prior to fuel loading.

2. Finding:

   All displays should indicate values in a form immediately usable by the operator without requiring mental conversion. The RCP Seal water flow, RHR-HX water flow, and RC Loop flow require the operator to mentally convert the information presented (6.5.1.2.B).

   Improvement:

   Discussions with Operating revealed that mental conversions were not a requirement in monitoring the displays.

   Implementation:

   Accept as is.

Displays (cont.)

3. Finding:
Inconsistent type styles are evident on the displays throughout the control room. (6.5.1.3B2).

Improvement:
Control board displays manufactured by different manufacturers use different "type styles". Since each "type style" is clear and legible the difference does not constitute a safety hazard. The displays will not be changed to meet this guideline.

Implementation:
Accept as is.

4. Finding:
The meaning assigned to particular colors should be consistent across all applications within the control room, whether applied to panel surfaces, projected in red, green, and amber colored lights, or on CRT's. Color should be reserved for specific uses. Greenboard, RAD monitors, permissives, and system status are not in compliance. (6.5.1.6C2, 6.5.1.6D1, 6.5.1.6D2).

Improvement:
The green board is an accepted alternative, but its utilization and its affect on operator behavior should be considered while establishing standardized color selection for the remainder of the control room. Modify all color coding schemes to adhere to acceptable human engineering principles and practices.

Displays (cont.)

Implementation:
Byron Station operating will develop a standard color-code convention in conjunction with Human Factors Engineering by 4/1/82.

5. Finding:
Byron Station vertical meter pointer tips do not extend to within 1/16" at (but not overlap) the smallest graduation marks on the scale. Guidelines support pointer tips extending to within 1/16" of smallest graduation points. (6.5.2.2B1)

Improvement:
Potential experimental evaluation. The problem does not appear to be severe.

Implementation:
Accept as is.

6. Finding:
General legend design should be consistent throughout the control room. The lube oil reservoir linear scale display has no label indicating what is being read, (e.g., inches, lbs., percent, etc.) and scale range is 0 to 120. (6.5.3.3B1)

Improvement:
Develop requirement for scale to read from Ø to 1ØØ in percents. Data sheet to be prepared by PED no later than 1/82.

Displays (cont.)

Implementation:
Accept as is.

7. Finding:
Recorder design should ensure that all data will be visible through the window of the recorder and not require open-door operation to expose it. Recorder not designed to permit monitoring all data without open-door operation. (6.5.4.1K)

Improvement:
To be investigated further. Long-term trends not always readily visible.

Implementation:
This condition is acceptable for this non critical non time dependent information.

8. Finding:
If more than four digits are required, they should be grouped and the groupings separated as appropriate by commas, decimal point or by an additional space. The primary water control pre count groupings are not separated. (6.5.5.1A3)

Improvement:
The control setting and the resultant flow are non critical, non time dependent.

Implementation:
Accept as is.

Displays (cont.)

9. Finding:
The line voltage meters have too large a scale for accuracy of required reading (6.5.1.2).

Improvement:
Consider banding or substitutions of an alternative display.

Implementation:
A green band will be installed within the safe operating range of bus meters by 5/82.

10. Finding:
The centrifugal charging pump mini-flow valves are required to be closed when reactor pressure falls below 2000 psig following a safety injection. With no mini-flow available there is a possibility of overheating the pumps if system pressure increases. During this activity the operator is required to remember to monitor the Reactor Coolant System Pressure to assure it does not exceed a set point.

Improvement:
Two alternatives are available: 1) Have the valve automatically open on 1970 lb. set point in coincidence with safety injection 2) Provide an annunciator to alert the operator when the pressure gets to the response set point. Care should be taken to provide an interlocking of the alert signal to occur only during a safety injection.

Implementation:
Station has request into engineering to determine the feasibility of alternative 1.

Displays (cont.)

11. Finding:

Zion Station operating experience indicated a semi-gloss flourescent orange pointer on the vertical meters appeared to improve pointer recognition when presented on a white or green band background.

Improvement:

Change control room vertical meter pointers from black to semi-gloss flourescent orange (#28915 from Federal Standard 595A, colors).

Implementation:

Prior to fuel load.

12. Finding:

Zion Station operating experience indicated that the use of a green normal operating band would alert operators to abnormal conditions when the pointer was not in the appropriate range.

Improvement:

The Station will identify normal operating ranges of meters and instruments after initial startup and add green temporary transparent tape to the surface of selected meters. Once the temporary green banding is verified as being the correct range and helpful to the operator, it will be permanently applied to the face of the meter under the pointer during normal calibration.

Implementation:

Prior to fuel load.

4.6 Labels and Location Aids

1. Finding:

Control 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. One hundred thirty-four controls on Safeguards panel, 1PM06J, are unlabeled. Also the motor current meters for safety injection pumps are unlabeled. (6.6.1.1)

Improvement:

Provide standard labels on control and displays presently unlabeled.

Implementation:

Operating will check for missing labels and provide standard labels on controls and displays presently unlabeled by 4/1/82.

2. Finding:

Labels should be used to identify functional groupings and should be placed above each group. To assist the operator by reducing confusion, search time, etc; hierarchical labeling should consider ranking and better graduation. In addition, information presented on labels should be consistent with intended viewing for each control board component. (6.6.1.2A1-4, 6.6.2B1-4, 6.6.3.7A,B).

Improvement:

Labeling problems will be corrected with the development and implementation of a hierarchial labeling standard for Byron Station.

Labels (cont.)

Implementation:
HFE and Operating will complete details by March 1982. New and replacement labels to be installed prior to fuel load.

3. Finding:
Hagan controllers are not labeled as other controls. The MA station switches have redundant labeling. Also, labels should be placed above the panel element(s) they describe. (6.6.2.1A).

Improvement:
All Hagan controllers will be reviewed by Operating. Where redundant labels are found, they will be removed. Where labels do not exist, they will be added.

Implementation:
Operating will complete the improvement by 4/1/82.

4. Finding:
Use of out of service cards should not obscure label of the non-operable device nor any adjacent device or their labels. A review procedure should be available to determine use and content of tags. In addition, present tags and procedures obscure component labeling and no procedure has been established to address the factors delineated in guidelines. (6.6.5.1FGH, 6.6.5.2B).

Improvement:
The out of service cards and procedures for using them are presently being reviewed by station operating.

Labels (cont.)

Implementation:
Operating will complete the review by 1/82.

5. Finding:
Labels should be mounted in such a way to preclude accidental removal and to avoid curved patterns. The mock-ups violate labeling guidelines (6.6.2.2A, 6.6.2.3B, 6.6.5.1C).

Improvement:
Violations occur on mock-up labels and should be corrected when changes are made to the control board.

Implementation:
Accept as is.

6. Finding:
Label words should express the intended action clearly and directly, they should have a commonly accepted meaning, avoid technical terms, and be correctly spelled. The AC Distribution Board has no standardized abbreviations. (6.6.3.2A-F).

Improvement:
A standardized system of word selection and abbreviations should be established and maintained by administration. The standard word/abbreviation selection should: express the identity of the individual component messages should be clear and direct and the words should have commonly accepted meaning for all individual users. The labels on the control board will comply with Byron standard.

Labels (cont.)

Implementation:
Prior to fuel load.

7. Finding:
The lines of demarcation are not permanently attached. (6.6.6.2C)

Improvement:
The demarcation lines are mocked-up and will be permanently attached prior to fuel load.

Implementation:
Accept as is.

4.7 Panel Layout

1. Finding:

Physical separation of panel components should allow enough space between groups so that boundaries of each group are obvious. Spacing between groups should be the width of a typical control or display in the group. The Power Generation Panel, 1PM01J, is not presently separated between groups of displays by appropriate spacing or lines of demarcation. (6.8.1.3A)

Improvement:

After a thorough analysis has been conducted and final configuration established, demarcation lines of the functional or selected groups of controls and displays should be established including lines of demarcation and background shading.

Implementation:

Control board changes including lines of demarcation, mimics and relocation are already approved and engineered and will be made starting in October 1981. Simplified mimics representing the system give the operator a clear presentation of the system and its status.

2. Finding:

When there is a set of related controls and displays, the layout of displays should be symmetrical with the controls they represent. The Power Generation Panel 1PM01J does not reflect the symmetry required between sets of controls and displays. Layouts of repeated functions should not be mirror imaged as are the water isolation valves, mini flow valves for RHR pumps 2A and 2B, and activated valves. (6.8.2.1A3, 6.8.2.3B, 6.8.3.3, 6.9.2.2D).

Panel Layout (cont.)

Improvement:
Color-coding, background shading and rearrangement of selected display/controls will improve the deficiences in symmetry.

Implementation:
Accept as is.

4.8 Control-Display Integration

1. Finding:

A visual display to be monitored during a control manipulation should be located sufficiently close to an operator so that it can be read clearly and without parallax from a normal operating posture. Displays should be located above the controls. The seal injection flow indicators are located on the left panel at the top (1PM05J). The HCV 182 controller is on the left front diagonal panel at the bottom of the vertical display panel (1PM05J). When adjusting the controller and simultaneously reading the seal injection flow indicators the operator places himself in an awkward position. This position can readily lead to a parallax problem. (6.9.1.1A, 6.9.1.2B1).

Improvement:

Realign the HCV 182 controller into the proximity of the injection flow indicators and provide a dead mimic.

Implementation:

Operating will provide Project Engineering with a mocked-up drawing by 1/82.

2. Finding:

Displays should read off-scale (not zero) when not selected especially if zero is a possible parameter displayed. Power Distribution Panel displays do not reflect this requirement. However, further analysis is required before the extent of the discrepancy is known and the appropriate improvement identified. (6.9.1.2C4).

Control-Display Integration (cont.)

Improvement:

The parameters (amps, volts, and watts and vars) displayed on the power distribution panels are primary readings. A very small proportion of the parameters being measured are diverted to each of these displays to move the indicator.

Since this "diverted" energy is the only energy required to move the pointer to its indicated value, this information is presented to the operator reliably and independent of any other plant equipment. This can be important to human safety.

The zero indicated values are not critical values. The important considerations are:

a) Is the equipment energized;
b) Is the equipment overloaded; and
c) Is it permissible to connect this energized equipment to other energized equipment?

Historically these simple, direct measurements are more reliable, trouble free, economical, and maintain their accuracy longer than the "secondary" measurement required in the rest of the plant. A change is not recommended.

Implementation:
Accept as is.

3. Finding:
Before the operator stops the reactor coolant pumps he must verify that at least one of the centrifugal charging or safety injection pumps is in operation (1PM05J, 1PM06J).

Control-Display Integration (cont.)

He/she must also verify when the wide range RCS pressure drops below 1300 psig. When the operator begins to depressurize the Reactor Coolant System to a value equal to the steam generator pressure it requires a repetitive process involving control manipulation (right front) and monitoring the wide range pressure indicator (left front). Depressurizing the reactor coolant system to a value equal to the steam generator pressure is time critical. The control and display necessary for this task are not located in proximity with one another.

Improvement:
An existing wide range pressure indicator (405) is to be relocated to eliminate the discrepancy.

Implementation:
Prior to fuel load.

5. REVIEW PLAN FOR NON-OPERATIONAL CONTROL ROOM SYSTEMS AND SUBSYSTEMS

Construction of the Byron Station control room has not been entirely completed. A number of systems and existing system components are currently non-operational. These include:

1. Control room equipment required by NUREG's 0660, 0696, 0737 and Reg. Guide 1.97.
2. Analysis of multi-failure events included in the PWR Owner's Group emergency procedure criteria.
3. Normal and emergency lighting.
4. Air conditioning and ventilation systems.
5. Annunciators corresponding to non-operational systems.
6. Process computer.
7. Operator workspace.

The review of these open items will be completed as each system becomes operational. The results of these reviews will be provided in a supplemental report to be completed prior to fuel load. This report will also contain the results of the validation of the control board with the PWR Owner's group emergency procedure criteria.

6. APPENDICES

6.1 Control Room Layout and Panel Identification

6.2 Design Modifications Implemented Prior to the Preliminary Human Factors Assessment

6.3 Walk-through Procedure and Analysis

6.4 Hierarchical Labeling Guide

6.5 Indicator Zone Banding

6.6 Operator Experience Questionnaire

6.7 Mimics and Demarcation Lines

6.8 Background Shading

6.9 Color Coding Approach

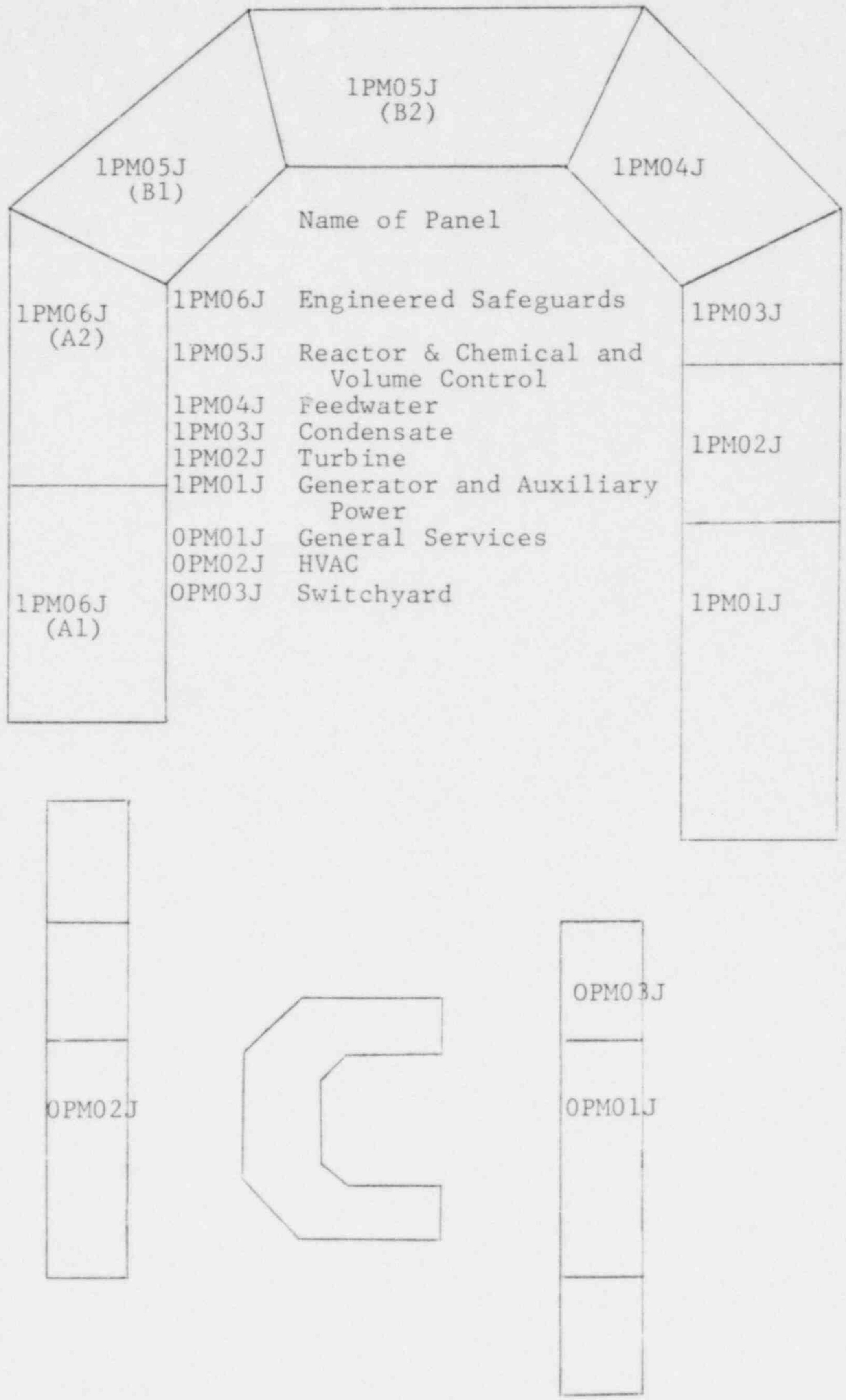
6.10 Auditory Coding Approach

6.11 List of Abbreviations

6.12 Reference Photographs

6.13 Bibliography

6.1 Control Room Layout and Panel Identification



6.2 Design Modifications Implemented Prior to the Preliminary Human Factors Assessment

Prior to the preliminary human factors review of the Byron Generating Station control room, a number of modifications to the control boards were recommended. These recommendations were a result of an extensive review of the boards by Byron Station Operations, Project Engineering, and Sargent and Lundy. Assistance was also provided by a CECo Human Factors Engineer. Problems indentified by the review team were found to be categorized into four (4) areas:

1. Insufficient use of board mimics;
2. Minimal use of system/subsystem demarcation lines;
3. Little use of control and display functional grouping aids; and,
4. Problems in control/display relations.

The following discussion provides a summary of the recommended modifications to the control boards. These modifications were later implemented in the form of a mock-up applied to the boards on Byron Generating Station Control Room Unit #2. Each modification was reviewed by CECo Engineers, Byron Station Operations and Engineers, and Sargent and Lundy. All changes that were judged to improve the operability of the boards and the performance of the operator were accepted and scheduled for final board implementation. The report detailing further the results of this Commonwealth Edison Company and Byron Station review effort is available upon request.

6.2.1 Insufficient use of board mimics.

The following mimics were added:

1. Pressurizer Pressure Relief Valve Operation (1PM05J)

2. Pressurize Relief Tank Operation (1PM05J)

3. 4KV Board - simplified existing mimic (1PM01J)

4. 6.9KV Board - simplified existing mimic (1PM01J)

5. CVCS Mimic (1PM05J)

6. Boric Acid Mimic (1PM05J)

7. ECCS Mimic (1PM06J)

6.2.2 Minimal use of system/subsystem demarcation lines.

Uses of demarcation lines have been implemented on the following systems and/or subsystems:

1. Engineered Safeguards Panel (1PM06J)

    Auxillary Feedwater
    Essential Service Water
    Feedwater Isolation Valves
    Component Cooling
    Containment Spray
    Reactor Containment Fan Coolers
    Accumulators
    Safety Injection
    RHR System

2. Reactor and Chemical and Volume Control (1PM05J)

   Charging Pumps and Boric Acid Tank
   Rod and Power Control
   Pressurizer System
   Reactor Coolant System

3. Feedwater Panel (1PM04J)

   Steam Generators (demarcation between generators)
   Feedwater Pump System

4. Condensate (1PM03J)

   Condenser Valves
   Circulating Water Pump

5. Turbine Control (1PM02J)

   Turbine Steam
   Gland Steam
   Bearing Oil System
   Seal Oil

6. Generator and Auxiliary Power Panel (1PM01J)

   Essential Buses
   Non-essential Buses
   6.9 KV Bus
   Auxiliary Transformers

6.2.3 Limited use of control and display functional grouping aids.

Background color shading will be implemented on the following boards:

Color shading

1. Engineered Safeguards Panel (1PM06J)

   Essential Service Water
   Auxillary Feedwater

2. Reactor and Chemical and Volume Control (1PM05J)

   Letdown System
   Charging Systems

3. Generator and Auxiliary Power Panel (1PM01J)

   ESF Buses

4. Trip Switches

5. Annunciator Control Switches

6.2.4 Problems in control/display relations.

A number of modifications to the placement of controls and displays were recommended by the review team. Emphasis was placed on proper control/display relations, sequence of use and frequency of use. The following systems and subsystems will be modified.

1. 4KV Electrical Control Board (1PM01J)

   a. ESF Bus 131 and Diesel Generator 1A Control Panel
   b. ESF Bus 132 and Diesel Generator 1B Control Panel
   c. Non-ESF Buses 143 and 133
   d. Non-ESF Buses 144 and 134

2. 6.9 KV Electrical Control Board (1PM01J)

3. Main Turbine Generator Panel (1PM02J)

4. Main Condenser Panel (1PM03J)

5. Steam Generator Feedwater Control Panel (1PM04J)

6. Reactor and Chemical and Volume control Systems (1PM05J)

7. Engineered Safeguards System Panel (1PM06J)

A report with detailed discussions regarding individual placement of controls and displays within each panel is available upon request.

6.3 Walk-through validation method and analysis

A video-taped walk-through was completed on the Byron Station control boards as part of the preliminary human factors engineering review. A walk-through procedure and analysis guideline were prepared for this phase of the review and are discussed below.

6.3.1 Control room walk-through procedure.

The purpose of the walk-through procedure is to identify operator control board interface problems that could degrade the operating crew's capability to identify, control, and manage plant normal, abnormal, and accident conditions. Tapes of a trained operating crews' simulated actions, as they walk-through selected Operating Procedures, can be analyzed to identify these problems. The results of this review and control room validation are dependent upon:

1. The fidelity of the control room used in the walk through as compared to the actual, final control room;

2. The quality of the procedures used;

3. The training of the operating crew; and

4. The quality of the video taping and review process.

A trained Byron operating crew reviewed each of the procedures listed in Table 6.3-1 just prior to the walk-through (The list and procedures may be revised as necessary). The intent is to cover the generic procedures and events listed in Table 6.3-1, in so far as possible. The walk-through will be conducted as follows:

1. Define the Operating events to be walked through;

2. Have the control room crew "walk-through" what they would do while following the appropriate procedure, covering the above events. The operator(s) should:

   a. describe the actions they are taking,
   b. identify the information sources,
   c. identify any conversions or uncertainties involved,
   d. identify the controls used,

e. identify the expected system response,
f. identify how those responses maybe verified,
g. identify actions they would take if the expected response did not occur, and
h. describe any additional assistance from personnel outside the control room (as appropriate).

The operator(s) should simulate actions they would take if the event were real. The operator must be cautioned not to activate any live equipment on the control board.

3. Have the video camera person follow the operating crew's actions as closely as possible. The following activity should be monitored, if possible:

a. eye response
b. verbal response
c. action response

Any part of a procedure which indicates confusion, where that confusion is not due to a man-machine interface problem, should be retaped.

4. The completed tapes will be reviewed in detail later to assess the problem areas.

Table 6.3.1 Generic Procedures and Events
Used During the Operator Walk-through

1. Use existing abnormal, emergency, and plant operating, procedures.

2. Use existing boards for the walk throughs and analysis.

3. The following events will be analyzed.

    a. Small break loss of coolant accident
    b. Inadequate core cooling
    c. Main steamline break
    d. Reactor startup
    e. Reactor shutdown
    f. Significant power changes
    g. Tube ruptures in a steam generator
    h. Anticipated transient without scram
    i. Loss of off-site power

6.3.2 Walk-Through Analysis Guideline

The proposed criteria to be used by the human factors engineer during the evaluation process are identified below. However, it should be noted that only general criteria are proposed. These criteria do not represent, by any means, a complete library of human factors engineering design criteria. They have been developed to correspond to readily observable operator activity recorded with a low level of fidelity compared to actual dynamic conditions.

1. Control/Display Relations. (a) All controls and their associated displays should be located in close proximity to each other to avoid confusion in control/display identification or manipulation. (b) A visual display that must be monitored concurrently with manipulation of a related control should be located sufficiently close to the control so that the operator is not required to observe the display from an extreme visual angle.

2. Control/Display Identification. All controls and displays must be easily identified without the appearance of a prolonged operator search.

3. Procedure/Component Design. Procedural sequence of required actions, as well as component and panel designs should not contribute to operator errors of omission, commission, improper control selection, or improper display identification.

4. Mimic. Mimics should be clear and easily interpretable by the operator. Under any condition, the use of a mimic should improve the operability (i.e., decreased time to complete, fewer errors) of a control sequence rather than degrade operability.

5. Essential Instrumentation. All essential instrumentation required for the completion of tasks within a particular subsystem (i.e., RHR, turbine control) should be located within close proximity to each other.

6. Frequency of Use. Controls and displays that are frequently used should be evaluated to facilitate analysis of their proper placement.

7. Sequence of Movement. Sequence of movement of the operator should be evaluated to ensure that, to the extent feasible, operator movements are smooth and continuous in a left-to-right, top-down fashion both within a particular subsystem and across various subsystems.

The preceeding criteria should first be applied on a procedural step-by-step basis. Wherever necessary, more thorough analysis (i.e., link analysis) should be implemented. Such analysis can be completed on available control board drawings.

During the anlysis of the video tapes the human factors engineer should request the following information from the licensed operator review:

1. The actions they are taking

2. Identification of information source

3. Identification of any uncertainties involved

4. Identification of controls used

5. Identification of the expected system response

6. Determine responses

7. Determine the actions the operator would take if the expected response did not occur, and

8. Identify any required assistance from a second operator or other personnel outside of the control room.

If possible, the human factors engineer should tape record the joint operator/human factors engineer review for future reference. Problems or design discrepancies identified should be cited and documented using the attached form (Attachment #1).

Completed and signed forms should be organized into a separate notebook and later integrated into the balance of the control room review material.

Attachment #1

PROBLEM - DESCREPANCY - IMPROVEMENT REPORT

STATION CONTROL ROOM DESIGN REVIEW

SYSTEM ______________________________ NUMBER ______________

PROBLEM: ____

____

____

____

____

Signature ___________________________ Date ________________

DISCREPANCY: ____

____

____

____

____

Signature ___________________________ Date ________________

IMPROVEMENT: ____

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____

Signature ___________________________ Date ________________

TASK FORCE ACCEPTANCE ________ REJECTION ________

Coordinator's Signature ___________________ Date ____________

STATION/PROJECT ENGINEERING ACCEPTANCE ________ REJECTION ________

Coordinator's Signature ___________________ Date ____________

6.4 Hierachial Labeling Guide

The following information is a summary guideline to be followed for labeling system/workstations, subsystem/ functional areas, components, and control positions within the control room.

The characteristics of labels must be such that they provide maximum information to the operator. The various illumination levels of control areas, control locations and restraints on operator position demand that all label characteristics (such as, size, lettering and placement) serve as perceptual aids to information discrimination and processing. The redundancy inherent in such characteristics can serve as a visual code to reduce response time and minimize probability of error. Simple application of a hierarchical method of labeling can reduce confusion, search time, and the need for redundant systems of function identification. The use of size-ranked labels can be used to discriminate among levels of system or functions.

The size of the label lettering should be determined by the relative function of the designated system, subsystem, group, or component and should be uniform across similar functions or systems. Placement of labels should be uniform throughout the system to insure ease of element/control identification and should provide maximum visibility. Labels should be oriented horizontally in order to be read easily, quickly, and accurately and should not be subject to accidental removal.

1. Recommendations - The proposed guidelines (NUREG 0700) require labeling to aid the operator in the location, identification, and handling of controls, displays, and equipment.

Ranking of labels by size should be relative to the significance of system, group, or function and should not contain information available on higher-order labels.

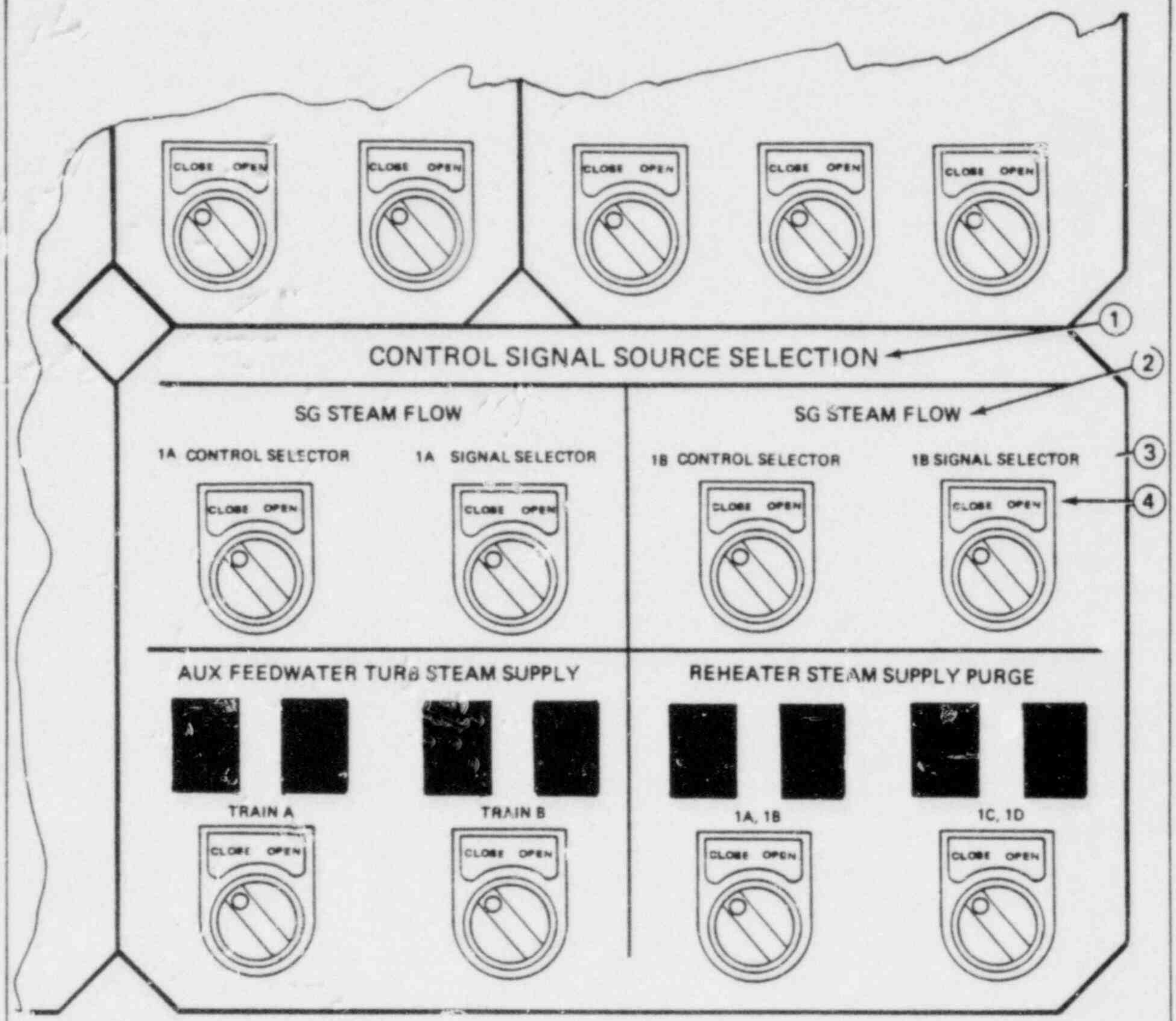
2. Label Hierarchy (See FIGURE 6.4 -1)

Major labels	- Major system or stations
Subordinate labels	- Subsystems or work group
Component labels	- Discrete panel or console elements

3. Letter size and style - Letter size graduation should proceed in 25% increments upward through the hierarchial label scheme.

For room illumination levels above one foot-candle, black lettering on a white background is recommended. This convention should be used throughout except in areas where the illumination levels are below one ft. candle. Under these conditions white lettering on a black background should be used. No whole-label color coding should be employed.

The following general lettering size guidelines should be adhered to as closely as possible:



Label Designation	Location
1. System/workstation label	Centered near top edge of panel
2. Subsystem/functional label	Centered near top of subsection
3. Component label	Above component display or control
4. Control position indicator	Near control

Figure 6.4-1

Hierarchial Coding Scheme Example

Functional hierarchy	*Letter height (inches)
System	1/2
Subsystem	3/8
Function	1/4
Component	1/8
Maintenance/Electrical Bus Information	3/32

* Letter height should be identical for all labels within the same hierarchical level.

Letter Width - 3.5 ratio to height
Stroke Width - 1.6 ratio to height
Print, Word, and Line separation -

Font: one stroke-width
Word: one font width
Line: one-half font width

4. Placement of Labels - Labels are to be placed above the sub-system controls described with placement and proximity to these sub-system controls determined by the optimum visibility. Placement should also provide sufficient space to allow adequate discrimination from adjacent controls and minimum interference with visibility during adjustment or manipulation of controls. Placement should further be such that labels do not obscure or detract from other information sources (see Figure 6.4 -2 and 6.4 -3).

The following recommendations should also be considered:

a. Labels should not appear on the control itself when an adjustment or manipulation is required that

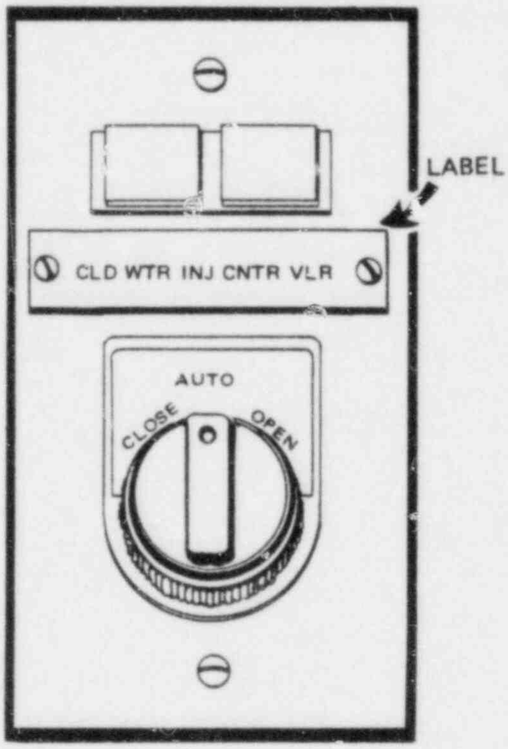


Figure 6.4-2 Label in close proximity to panel element.

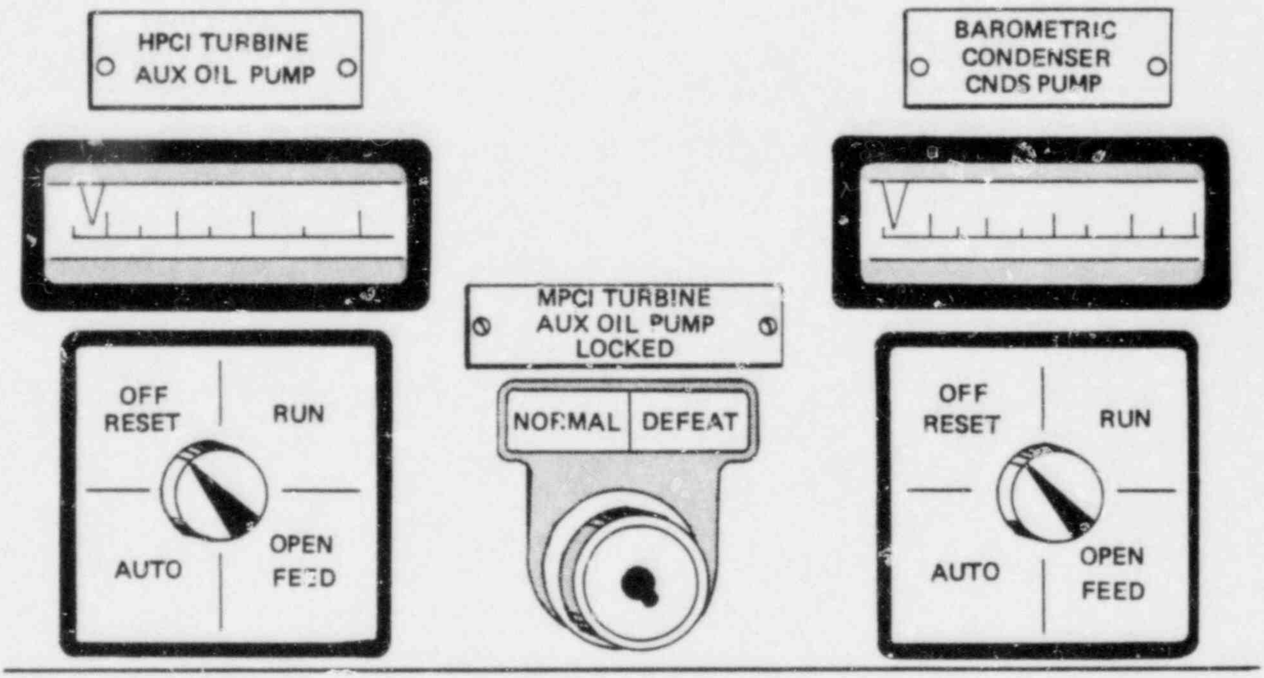


Figure 6.4-3 Adjacent labels with good separation.

causes the operator's hands to obscure the label for an extended time period.

b. Adjacent labels should be separa ed by sufficient space so that they are not read as one continuous label (see Figure 6.4 -4).

c. Labels should be placed below all indicators. This convention should be followed except in cases where there are space contraints.

d. Labels should be placed above controls. This convention should be followed except in cases where there are space constraints. However, consistency, within a subsystem, module or component area, should be the rule.

e. Eliminate, wherever possible, vertically-oriented labels and replace with horizontal labels.

f. Curved patterns of labeling should be avoided.

g. Labels should be mounted to minimize the possibility of accidental detachment.

5. Labeling Visibility - The following guidelines should be adhered to:

   a. Labels should not cover, detract from, or obsure figures or scales which must be read by the operator.

   b. Labels should be visible to the operator during control activation.

6. Label Color Codes - If colored print is used for labeling, it should conform to the established color coding scheme in the control room. Colors should be chosen for maximum contrast against the label background. The guidelines presented in Table 6.4 -1 should be followed. However, if color-coded labels must be

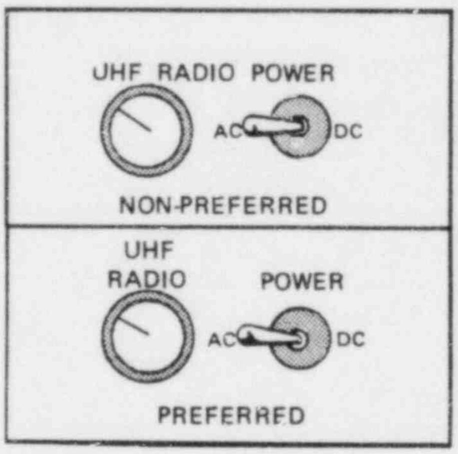


Figure 6.4-4 Preferred and non-preferred label placement.

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

Table 6.4-1 Relative legibility of color combinations.

used (such as vital bus color coding), oval or circular "dots" located on one corner of the label should be used for such purposes.

7. General Guidelines - The following recommendations should be considered:

   a. Labels should describe the function or equipment components.
   b. Words should be used which have a commonly accepted meaning for all intended users; unusual terms should be consistent within and across pieces of equipment. An abbreviation standard should be developed.
   c. Words on labels should be concise yet convey the intended meaning.
   d. Abbreviations should be limited to five or less characters.

6.5 Indicator Zone Banding

1. Summary - The following information is a summary of guidelines to be followed for banding operational zones on visual indicators. The guidelines reflect accepted human factors engineering practice as well as those recommendations documented in NUREG-0700.

   It has been shown that visual coding improves operator performance by providing immediate discrimination of information during normal monitoring procedures and by reducing response time in critical situations.

   Color-coding of functional relationships can be used to present qualitative information accurately and quickly without requiring the operator to cognitively interpret or relate such information to system or component functions. The use of limited single-color codes aids in the perception of warning or emergency status of equipment or systems. Such codes can be used to particular advantage in circumstances which require search, location, or scan of information. Color-coding zone displays on meters enhance operator performance in the monitoring of trends, direction, and rates of change necessary to critical decision-making.

   The following rules-of-thumb should be considered for color-coding operational zones on visual indicators.

   a. For optimal effectiveness, color codes should represent redundant information. The color provides a perceptual alerting aid which meaningfully represents information available in some other mode such as location, orientation, or scale markings.

b. The response benefits inherent in color-coding system information depend on the ready discrimination of such codes and the ease with which they can be learned. To maximize these benefits the number of colors employed should be kept to the minimum necessary to provide adequate information and should provide high contrast relative to the background area of the display.

c. Metered or dial displays should additionally provide singular pointer or indicator/background contrast. Pointer size must permit easy recognition of both pointer position and coded range location.

d. The meaning attached to a given color or set of colors should conform as closely as possible to standard conventions used throughout all operations.

2. Recommendations - The following considerations and recommendations are offered to maximize effectiveness of metered displays.

3. Color Codes - Proposed guidelines (NUREG 0700, 9/81) directed toward Principle of Display Figures 6.5.1a, 6.5.1b, 6.5.1c, 6.5.1d recommend for compliance a maximum of 11 colors for purposes of coding information. To preserve the ready discriminability of color-coded information and facilitate the learning of its meaning in areas of critical function and response it is recommended that: color codes be limited to essentially 3 colors: red, green, and amber; with all values black on a white background to provide high contrast. (Color convention should be as consistent as possible through all control room applications.)

a. Green: Normal range of operations.

b. Amber: Extreme parameters of normal range.

c. Red* (Hatched): Bi-directional indication of emergency or critical range of function (exceeding a set point).

d. Red (Solid): Extreme emergency or critical range.

* Optional zone marking. Where omitted, solid red should be used for emergency or critical range (#s)

4. Zone Markings - Per NUREG 0700 (Figures 6.5.2a, 6.5.2b) zone markings are to be readily discriminable and should not interfere with markings which provide quantitative information. Color-coding of zone markings should conform to system color-code conventions (see above recommendations). It is recommended that zone markings and coded information be presented as follows:

Range	Code	Function
"Low-Low"*	Solid Red	Extreme emergency or critical range
"Low"	Hatched Red**	Approaching extreme emergency or critical range but exceeding a set point
"High-High"*	Solid Red	Extreme emergency or critical range
"High"	Hatched Red**	Approaching extreme emergency or critical range but exceeding a set point
"Normal"	Green	Within normal range
"Normal" (upper and lower parameters of "Normal")	Amber	Extreme parameters of normal range

* Optional zone markings

** Solid red if extreme emergency conditions are not defined

5. Pointer Design - The background area for meters and dials should be white. Proposed guidelines (NUREG 0700;

Pointers 6.5.2.2, NUREG 0700 Figure 6.5.2a) specify that pointer tips should be simple and should be mounted to avoid parallax errors. Pointers or indicators should not interfere with visibility or legibility of any scale markings.

Recommended pointer tip should be narrow bar (line) indicator or blunt-tip bar indicator (see Figure 6.5.2a; preferred pointer tips). A highly reflective international orange pointer tip is recommended.

6. Application Method - Zone markings should be applied to the surface of all meters that are currently operational. Zone markings should be applied to scale surfaces during calibration.

It is recommended that a heat-resistant, transparent acetate material be used for zone markings (see, for instance, Formaline brand charting tape).

6.6 Operator Experience Questionnaires

Self administered questionnaires were developed to identify the views of operating personnel concerning the operation of the plant. Their views were elicited to ascertain those human performance factors that they feel facilitate or impede operation of the plant. The operator responses were examined in light of accepted human factors engineering principles and practices to determine if a control board change was warranted.

Operating Experience Questionnaire

I. The Nuclear Regulatory Commission is requiring a human factors review of every operating control room to guidelines being published as NUREG-0700. The Commonwealth Edison Company approach is to use operators' experience to identify operator/control board interface problem areas. The objective of the review is to identify improvements to assist the operator in recognizing and controlling normal and abnormal plant conditions.

II. To assist operators in recalling control board and interface problem areas, the attached questionnaire was developed using the NUREG-0700 draft criteria. The questionnaire allows the operators to identify areas that are or are not problems based upon their operating experience.

III. We would like your name on the questionnaire, in case additional information is needed, but it is not required. We would appreciate a questionnaire from each licensed individual be returned to the Control Room Review Team Operations member.

Optional Information

Name ______________________________

Height ______________________________

Years R.O. License ______________ years

Years S.R.O. License ____________ years

Control Board Operating Experience ___ years

____
CONTROL ROOM
REVIEW TEAM - COORDINATOR

____
CONTROL ROOM
REVIEW TEAM - OPERATIONS

A. Control Room Environment

1. In what areas in the control room does the air temperature, humidity, or ventilation interfere with your ability to work effectively?

____none or comment:________________________________

____

2. What displays, console surfaces, labels, CRTs, etc. are difficult to read or interpret due to lack of illumination, excessive amounts of illumination, glare, or shadows?

____none or comment:________________________________

____

3. Where do noise levels in the control room interfere with communications or your ability to hear alarms or give operating instructions?

____none or comment:________________________________

____

B. Workspace Arrangement

1. Which procedures are not readily accessible during normal or emergency operations?

____none or comment:________________________________

____

C. Visual Displays

1. What displays are difficult to read or interpret due to orientation or direction of motion of the pointer or scale of the display?

____none or comment:________________________________

____

2. What annunciators consistently produce false alarms?

____none or comment:________________________________

____

3. What improvements and additions to annunciator tiles, meter scales, chart recorders, CRTs, computer printouts, or other visual displays are needed to provide specific and directly usable plant operating information?

____none or comment:________________________________

____

4. On which meters, CRTs, chart recorders or other displays is display or input sensor failure not apparent?

____none or comment:________________________________

____

5. Which functions on equipment that are monitored and controlled by the operator should be machine monitored and result in automatic actions and vice versa?

____none or comment:________________________________

____

6. Which controls and displays that need to be used and viewed simultaneously are located too far apart to use or read accurately?

____none or comment:________________________________

____

7. Which meters or displays are difficult to locate during normal and abnormal operating conditions?

____none or comment:________________________________

____

8. Which labels are difficult to read due to the letter size, style, spacing, or orientation of lettering?

____none or comment:________________________________

____

9. What symbols on labels, mimics, CRTs or other displays are inconsistent or ambiguous?

____none or comment:____

____

10. Where would additional mimics be helpful or where are they confusing?

____none or comment:____

____

11. What scales have markings incompatible with the parameter being displayed, or are difficult to interpret?

____none or comment:____

____

12. Which labels, mimics, range banding, back lighted displays or other color coded displays are difficult to see or use because of their color?

____none or comment:____

____

13. Which visual warning systems could be effectively enhanced by auditory signals?

____none or comment:____

____

14. What areas or systems in the control room lack sufficient visual warning indicators?

____none or comment:____

____

D. Auditory Displays

1. Would it improve your ability or speed at assessing plant conditions if the audio alarms were further coded by function, location, or priority of alarm?

____none or comment:________________________________

____

2. In what areas are the communication or annunciator warning systems either inaudible or too loud to allow prompt action?

____none or comment:________________________________

____

E. Controls

1. Which controls or displays do not have clear and understandable labels indicating function and direction of control activation?

____none or comment:________________________________

____

2. What controls are physically difficult to operate (turn, push, pull, etc.) under normal conditions or abnormal conditions?

____none or comment:________________________________

____

3. What controls could have a tendency to be accidentally activated, either by operators reaching for the wrong control, or by simply bumping into controls?

____none or comment:________________________________

____

4. Which controls do not offer adequate feedback that the control has been moved (clicks between positions, not

enough movement on pushbuttons, too slow of response of command such as on a display meter or a CRT, etc.)?

____none or comment:____

____

5. Which controls "over-respond" to activation (are hard to set or adjust because the "gain" on the control is too sensitive)?

____none or comment:____

____

F. Control/Display Integration

1. What controls and displays do not have a logical grouping or sequence of operation?

____none or comment:____

____

2. With your hand on a control, in what cases is its associated display/displays difficult to locate?

____none or comment:____

____

G. Operator/Computer Interface and Dialog

1. What additional operating feedback information is needed to help the operator recognize invalid data entry or output?

____none or comment:____

____

2. In what areas do you feel that the computer command language is not consistent, logical, or directly usable?

____none or comment:____

____

H. Performance Aids

1. Which procedures do not clearly outline operational practices using terminology that is consistent with actual control board coding and labeling?

   ____none or comment:________________________________

   ____

2. What tools, furniture, or equipment should be modified or added to the control room to improve the operator's performance of his/her tasks?

   ____none or comment:________________________________

   ____

I. Communications

1. Are there any areas of the control room where the communication systems are inadequate (due to ,, or speakers, inadequate separation of channels, cords too short, lack of phone jacks, etc.)?

   ____none or comment:________________________________

   ____

2. Do any communication systems need message storage capability?

   ____none or comment:________________________________

   ____

3. When does the use of plant communications systems by non-operating personnel interfere with control room use of the system?

   ____none or comment:________________________________

   ____

4. When does the communication system fail to provide adequate feedback in response to plant alarms outside of the control room?

____none or comment:______________________________

____

6.7 Mimics and Demarcation Lines

Detailed drawings of mimics and demarcation lines which have been added to the Byron Unit #2 control room boards where submitted to the Nuclear Regulatory Commission on Tuesday November 3. 1981. Guidelines to be followed for the final construction of mimics and demarcation lines are summarized below:

1. Proposed Mimic Dimensions

   Lines: 3/8" wide

   Color: Black

   Arrow: Should be engraved and filled with white plastic. The engraving is for permanence of the markings and the filling keeps the engraving from being obscured by dirt. Arrows showing direction of flow should be spaced every 5" and within 2 inches of junctions and terminations:

   Cross-overs: Where mimic lines cross but the pipes or wires represented do not have a junction, spacing between the continuous line and the discontinuous line should be between 50 and 80% of the width of the mimic line. See Figure 6.7-1.

   Symbols: Symbols used in mimics should be as near to identical with P & ID symbols as possible.

   Termination: All terminations should be labeled, whether representing the beginning or end of a flow path. The termination can be labeled with a symbol instead of a label with lettering, or even with an engraved symbol. (A tank, pump or generator symbol, for example, can mark termination.)

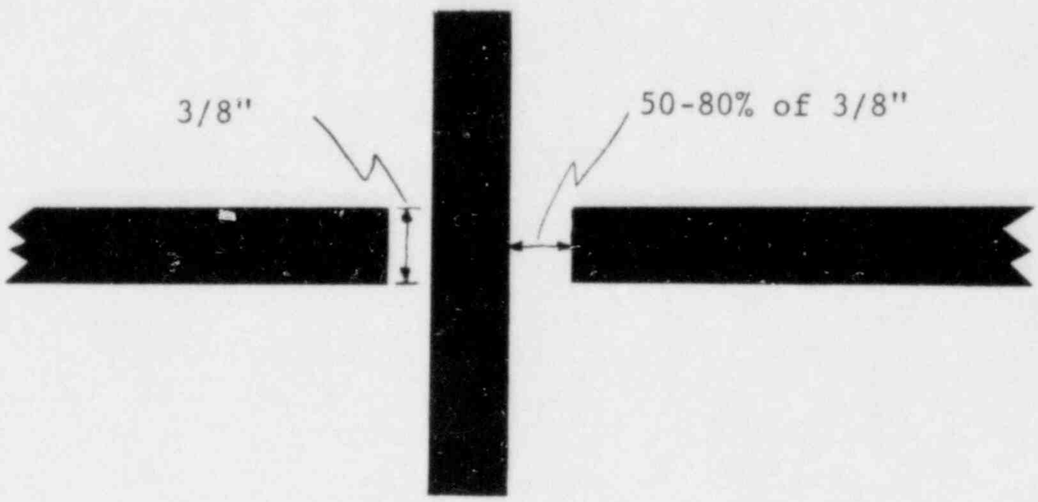


Figure 6.7-1

Proposed Mimic Dimensions

2. Demarcation Line Dimensions

System division: 3/4"wide, 1/8"-3/16" thick (the thickness is to prevent the switch module edges from obscuring the demarcation lines.)

Sub-system division: 3/8" wide, 1/8"-3/16" thick. Do not use subsystem division near mimic lines.

Color: Black

6.8 Color-Shading

The preliminary human factors engineering review revealed potential problems in the area of clear relationships between particular controls and their respective displays. One potential solution proposed is to use background color shading and lines of demarcation to group related controls and displays within particular systems and/or subsystems.

This issue is currently under investigation to determine which areas of the board require enhancement. However, previous work in this area at other CECo control rooms will be used as a general guideline. Specifically, the relationship among displays and controls at the LaSalle County Generating Station were evaluated and color shading enhancements applied to particular sections of the Feedwater, Main Generator, Zero Diesel, 1B Diesel, Fire Pump System, and HVAC vertical and benchboard panels. However, the same panels at Byron Station are not necessarily expected to be enhanced with this technique.

The same technique of evaluating and selecting particular background color shades at LaSalle County will be employed for the selection of color shading for Byron. Several shades of grey, brown and beige (off-yellow) color chips will be evaluated within the context of the Byron Station control room ambient illumination. Final color selection will depend upon proper color discrimination studies. Placement will be determined by the careful identification of panel subsystems and modules. In addition, black-taped borders surrounding color-shaded areas will be considered to enhance discriminability. Tape width will vary as a function of identified subsystems or modules.

6.9 Color Coding Approach

The following information is a summary of recommended Human Factors Engineering principles and practices to be used in the implementation of color in the control room. Visual coding improves operator performance by providing immediate discrimination of information during normal monitoring procedures and by reducing response time to critical situations.

Color-coding of functional relationships can be used to present qualitative information accurately and quickly without requiring the operator to cognitively interpret or relate such information to system or component functions. Such codes can be used to particular advantage in circumstances which require search and location of information.

The use of color in the control room may include:

- Locating documents
- Annunciator prioritization
- Cleared annunciator acknowledgement
- To relate controls with corresponding displays
- Indicator zone markings on meters and gauges
- Legends for indicators
- Selected ink colors for pen recorders
- CRT displays
- Graphic coding
- To enhance recognition of controls, displays or functional groups by color shading
- To enhance layout of multiple controls in single display

The following rules should be considered for color-coding.

1. For optimal effectiveness, color codes should represent redundant information: The color provides a perceptual alerting and which meaningfully represents information available in some other mode such as location, orientation, or scale markings.

2. The response benefits inherent in color-coding system information depend on the ready discriminability of such codes and the ease with which they can be learned. To maximize these benefits the number of colors employed should be kept to the minimum necessary to provide adequate information and should provide high contrast relative to the background area of the display.

3. There should be consistent use of meaning for each color.

4. The color whould be recognizable in various lighting conditions.

The following considerations are offered as a guide to the effective utilization of color in the control room.

1. Proposed guidelines (NUREG 0700) recommend the use of a maximum of 11 colors for purposes of coding information to be selected from the list of colors depicted in Figure 6.9.-1.

2. Surface color should be visible and recognizable under a variety of normal and emergency conditions, Figure 6.9-.2 and 6.9.-3.

Color Serial or selection number	General color name	ISCC-NBS centroid number	ISCC-NBS color-name (abbreviation)	Munsell renotation of ISCC-NBS Centroid Color
1	white	263	white	2.5PB 9.5/0.2
2	black	267	black	N 0.8/
3	yellow	82	v.Y	3.3Y 8.0/14.3
4	purple	218	s.P	6.5P 4.3/9.2
5	orange	48	v.O	4.1YR 6.5/15.0
6	light blue	180	v.l.B	2.7PB 7.9/6.0
7	red	11	v.R	5.0R 3.9/15.4
8	buff	90	gy.Y	4.4Y 7.2/3.8
9	gray	265	med. Gy	3.3GY 5.4/0.1
10	green	139	v.G	3.2G 4.9/11.1
11	purplish pink	247	s.pPk	5.6RP 6.8/9.0
12	blue	178	s.B	2.9PB 4.1/10.4
13	yellowish pink	26	s.yPk	8.4R 7.0/9.5
14	violet	207	s.V	0.2P 3.7/10.1
15	orange yellow	66	v.OY	8.6YR 7.3/15.2
16	purplish red	255	s.pR	7.3RP 4.4/11.4
17	greenish yellow	97	v.gY	9.1Y 8.2/12.0
18	reddish brown	40	s.rBr	0.3YR 3.1/9.9
19	yellow green	115	v.YG	5.4GY 6.8/11.2
20	yellowish brown	75	deep yBr	8.8YR 3.1/5.0
21	reddish orange	34	v.rO	9.8R 5.4/14.5
22	olive green	126	d.OlG	8.0GY 2.2/3.6

Table 6.9-1 Twenty-two colors of maximum contrast (from Kelly, 1965).

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

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

Figure 6.9-2 Recommended workplace reflectance levels

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

Figure 6.9-3 Surface color reflectance values

3. To maximize legibility, the color coding should contrast well with the background.

4. The use of color coding on CRT's provides a higher rate of information processing if accomplished successfully. Selected guides for color coding are given in Figure 6.9.-4.

Red—Good attention-getting color. Associated with danger.

Yellow (amber)—Good attention getting color. Associated with caution.

Green—A non-attention-getting color; easy on the eyes. Associated with satisfactory conditions.

Black—Normally used as the background color, i.e., the color of blank character spaces. Also used as the action character when reverse field coding is employed.

White—A non-attention-getting color. It should be used for standard alphanumeric text or tables where the information is contained in the characters and not the color. Might also be used for labels, coordinate axes, dividing lines, demarcation brackets, etc.

Cyan (light blue)—(Same as white)-Might be used in conjunction with white to provide some amount of noncritical discrimination (e.g., use cyan for tabular column headings and demarcation lines; use white for alphanumeric data).

Blue (dark)—Poor contrast with dark background. Not recommended for attention-getting purposes or for information-bearing data. Use for labels and other advisory type messages.

Magenta—A harsh color to the eye. Should be used sparingly, and for attention-getting purposes.

Orange—Good attention-getting color. Care must be taken that hue is selected to be readily differentiable from red, yellow, and white.

Figure 6.9-4 General characteristics of colors used in CRT displays.

6.10 Auditory Coding Approach

The Byron Station Control Room auditory annunciator warning system is currently partially operable.

The guidelines to be followed include those published in Section 6 of NUREG 0700 and accepted human factors and psychoacoustic conventions. However, a conceptual auditory warning system has been developed and is currently undergoing review at the Byron Station. Characteristics of the system include:

1. Priority coding using waveform (physical acoustic structure); and

2. System coding using frequency, period, and location.

The following alarm coding scheme is being considered during this design phase. (The effectiveness of this approach will be evaluated in the control room using operator signal detection and classification performance data and physical measurements:

1. 1PM01J #3 ("ping") F_1 = 800Hz, F_2 = 1300Hz, period = 1 sec.

2. 1PM02J, 03J, and 04J, #4 ("warble") F_1 = 800Hz, F_2 = 1400Hz, period = 1 sec.

3. 1PM06J - #1 ("wow") F_1 = 950Hz, F_2 = 1450Hz, period = 1 sec.

4. 1PM05J - #2 ("yelp") F_1 = 1000Hz, F_2 = 1600Hz, period = 1 sec.

5. OPM03J - #8 ("long beep") A(max) = 10dB(A) above ambient, F = 700 Hz, period = 1.5 sec (50% duty cycle)

6. OPM02J - #9 ("short beep") A(max) = 10dB(A) above ambient, F = 850Hz, period = .75 sec (50% duty cycle)

7. OPM01J - #12 ("gong"), A(max) = 10dB(A) above ambient, F = 1000Hz, period = 1 sec.

8. Rad Monitor Alarm #5 ("low warble") F_1 = 700 F_2 = 1200, period = 1 sec.

The bandwidth of all center frequencies should be between ± 100 and ± 200 Hz. (roll-off to be determined).

In most cases, signal amplitude should remain within a S/N ratio of at least 20dB, measured within a single octave band. Each signal should be adjusted to an equal detectability level measured from the normal operating area. The physical waveform structure of each tone is presented in Figures 6.10-1a and 6.10-1b.

BETATONE III SOUNDS
(Constant Amplitude)

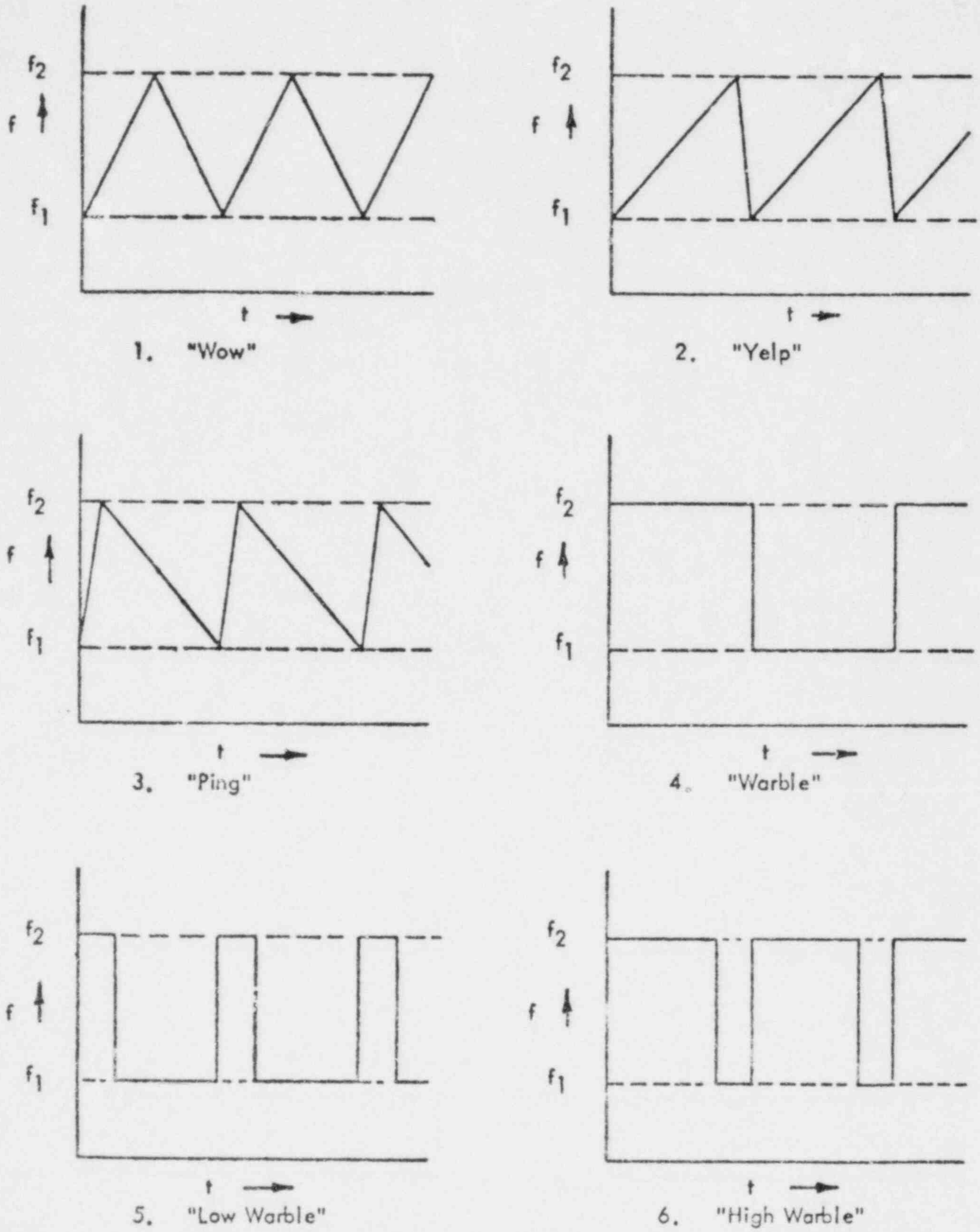
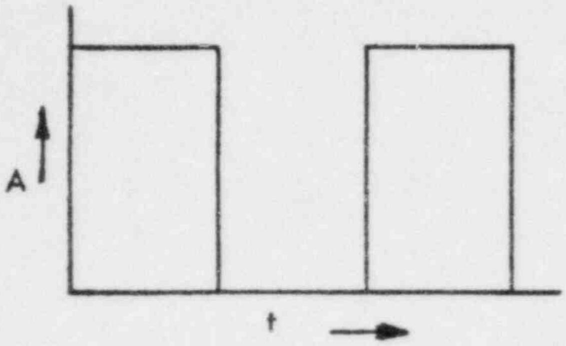
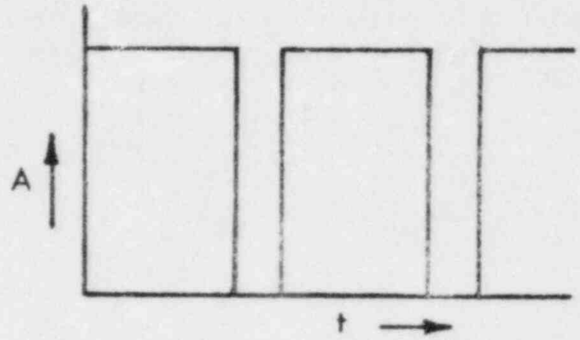


Figure 6.10-1a

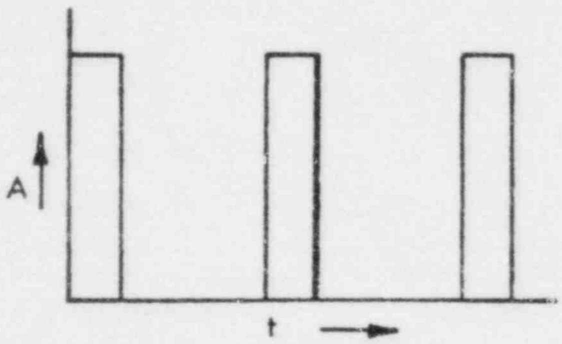
BETATONE III SOUNDS
(Constant Frequency)



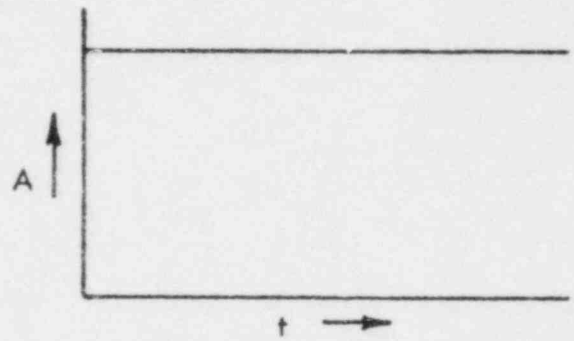
7. "Beep"



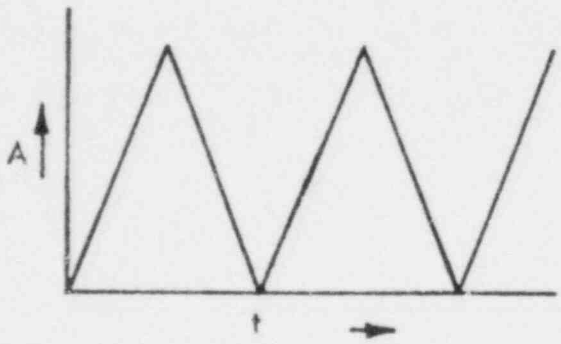
8. "Long Beep"



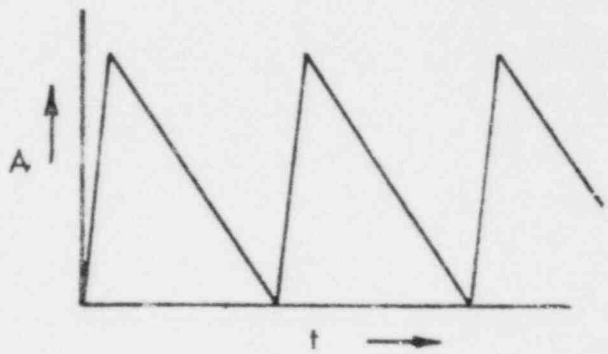
9. "Short Beep"



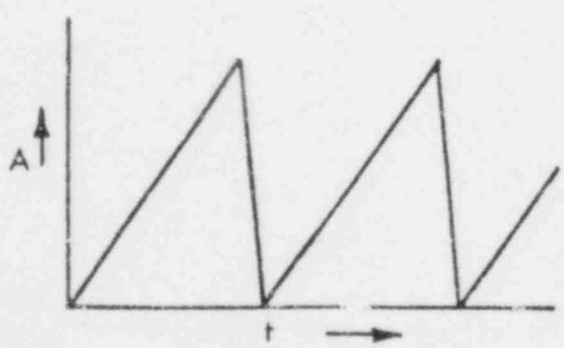
10. "Steady"



11. "Wail"



12. "Gong"



13. "Tweet"

Figure 6.10-1b

6.11 List of Abbreviations

APPENDIX
APPROVED STATION ABBREVIATIONS

AB	Boric Acid Processing
AC	Acid Feed & Handling (except Boric Acid)
ACCUM	Accumulator
ACB	Air Circuit Breaker
ACT	Actuator
AF	Auxiliary Feedwater
AN	Annunciator
AOV	Air Operated Valve
AP	Auxiliary Power 480V and Above
AR	Area Radiation Monitoring
AS	Auxiliary Steam
ASST	Assembly
AUX	Auxiliary
AVG	Average
BAG	Administrative Guidelines
BAP	Administrative Procedures
BAR	Annunciator Response Procedures
BAT	Boric Acid Storage Tank
BATT	Battery
BCG	Chemical Guidelines
BCP	Chemical Control Procedures
BD	Blowdown
BEAR	Bearing

BEP	Emergency Procedures
BFP	Fuel Handling Procedures
BG	Bottled Gas
BGP	General Operating Procedures
BHP	Maintenance Electrical Procedures
BHS	Maintenance Electrical Surveillance Procedures
BIP	Instrument Procedures
BIS	Instrument Surveillance Procedures
BIST	Bistable
BIT	Boron Injection Tank
BKG	Office Guidelines
BKR	Breaker
BKWH	Backwash
BLDG	Building
BMG	Maintenance Guidelines
BMP	Maintenance Procedures
BLR	Boiler
BOA	Abnormal Procedures
BOG	Operating Guidelines
BOP	System Operating Procedures
BOS	Operating Surveillance Procedures
BR	Boron Thermal Regeneration
BRCH	Breaching
BRG	Radiation Protection Guidelines
BRP	Radiation Protection Procedures
BSG	Security Guidelines

BSP	Security Procedures
BTG	Training Guidelines
BVG	Technical Guidelines
BVP	Technical Procedures
BVS	Technical Surveillance Procedures
BWG	Stores Guidelines
BYP	Bypass
BZP	Byron Emergency Plan Implementation Procedure
CAB	Cabinet
CAV	Cavity
CB	Condensate Booster
CC	Component Cooling
CD	Condensate
CDSR	Condenser
CENT	Centrifical
CF	Chemical Feed & Handling
CHEM	Chemical
CHG	Charging
CHLR	Chiller
CKT	Circuit
COND	Conductivity
CLG	Cooling
CLR	Cooler
CNMT	Containment
CO2	Carbon Dioxide
CO	Carbon Monoxide
COST	Clean Oil Storage Tank

COL	Column
COLL	Collection
COMP	Compressor
CONT	Control
CONN	Connection
CPTR	Computer
CQ	Communication (Code Call, Public Address, Telephone, Evacuation Alarm, Station Security, etc.)
CR	Cold Reheat Steam
CRDM	Control Rod Drive Mechanism
CS	Containment Spray
CSD	Cold Shutdown
CST	Condensate Storage
CUB	Cubicle
CV	Chemical and Volume Control System
CW	Circulating Water
CX	Computer and Power Supply
DA	Deaerator Tank
DC	Battery and DC Distribution
DEH	Digital Electrical Hydraulic
DELTA T	THOT - TCLD
DEMIN	Demineralizer
DET	Detector
DG	Diesel Generator
DISTIL	Distiliate
DM	Drains, Misc. Bldgs. (Crib House, Pumphouse) floor and roof including Sump Pumps - Non-Radioactive
DP	Differential Pressure

DO	Diesel Fuel Oil
DOT	Dirty Oil Tank
DRN	Drain
DRV	Driven
DSCH	Discharge
DV	Feedwater Heater Misc. Drains and Vents
DWST	Downstream
EA	Emergency Air
ECCS	Emergency Core Cooling System
EDUC	Eductor
EF	Engineered Safety features, Logic Testing & Actuation
EFF	Effluent
EH	Turbine EHC
EL	Elevation
ELEC	Electric
EM	Environs Monitoring (including Strong Motion-Seismic Instrumentation)
EMER	Emergency
ENG	Engine
EPN	Equipment Part Number
EQUAL	Equalizing
ES	Extraction Steam
ESF	Engineered Safety Feature
EVAP	Evaporator
EW	Welder Outlets
EXH	Exhaust
FAI	Failed As Is

FC	Fuel Pool (Pit) Cooling & Cleanup
FCLD	Failed Closed
FCV	Flow Control Valve
FH	Reactor Fuel Handling & Transfer Systems
FLT	Filter
FO	Fuel Oil
FOPN	Failed Open
FP	Fire Protection and Detection (excluding CO_2 Systems)
FT	Flow Transmitter
FU	Fuse
FW	Main Feedwater
FWTP	Filter Water Transfer Pump
FWST	Filtered Water Storage Tank
GC	Generator Stator Cooling (including Excitation Cubicle Cooling)
GD	Grounding and Cathodic Protection
GEN	Generator
GENS	Generator Supervisory
GS	Turbine Gland Seal Steam
GSC	Gland Steam Condenser
GW	Radioactive Waste Gas (excluding Off-Gas)
H2	Hydrogen (in general)
HC	Hoists, Cranes, Elevators & Manlifts (except Fuel Handling and Transfer System)
HD	Feedwater Drains-Turbine Cycle
HDR	Header
HI	High
HOV	Hydraulic Operated Valve

HR	Hot Reheat Steam
HSD	Hot Shutdown
HST	Hot Standby
HT	Heat Tracing (excluding those associated with specific systems)
HTG	Heating
HTR	Heater
HVAC	Heating, Ventilation and Air Conditioning
HWT	Hot Water Tank
HX	Heat Exchangers
HYD	Hydraulic
HY	Hydrogen System
HTPO	Hypochlorite, Sodium
HUT	Hold-Up Tank
IA	Instrument Air Supply
IC	Incore Flux Mapping
ICNMT	Inside Containment
IMB	Inside Missile Barrier
IND	Indicator
INF	Influent
INJ	Injection
INSP	Inspection
INST	Instrument
IP	Instrument and Control Power (including Inverters, MG Sets)
IS	Industrial Security (including Gate Operators and Gate TV)
ISOL	Isolation
IT	Incore Thermocouple System
JUNC	Junction

LA	Lightning Arrestor
LBB	Local Breaker Backup
LCS	Level Control Switch
LCV	Level Control Valve
LD	Load Dispatcher
LL	Lighting
LM	Loose Parts Monitoring
LO	Low
LOCA	Loss of Coolant Accident
LP	Local Panel
LT	Level Transmitter
LTD	Line Tension Disconnect
LTDWN	Letdown
LV	Auxiliary Power, Low Voltage 120/208V, Transformers, Distribution
MAN	Manual
MAX	Maximum
MCC	Motor Control Center
MIN	Minimum
MISC	Miscellaneous
MB	Mixed Bad
M/G	Motor-Generator
MOD	Modification or Motor Oper. Disconnects (determined by context)
MODER	Moderator
MON	Monitor
MOV	Motor Operated Valve
MP	Main Power (Generator, Exciter, Main Transformers, Bus Duct)

MS	Main Steam
MSIV	Main Steam Isolation Valve
MSTR	Moisture
MSR	Moisture Separator Reheater
MTR	Motor
N2	Nitrogen (in general)
NO	Number
NPSH	Net Positive Suction Head
NR	Neutron Monitoring (out of core)
NAR	Narrow Range
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NT	Nitrogen System
O2	Oxygen (gas or liquid)
OCB	Oil Circuit Breaker
OCNMT	Outside Containment
OD	Equipment and Floor Oil Drain Disposal (including sump pumps)
OG	Off-Gas (including Hydrogen Recombiner)
OH	Caustic Handling
OMB	Outside Missile Barrier
OT	Bearing Oil Transfer and Purification (for Turbine Generator Turbine & Devices)
PA	Auxiliary Control Equipment Room & Computer Room Panels & Cabinets (Equipment Arrangement)
PC	Primary Containment Isolation
PCV	Pressure Control Valve
PD	Positive Displacement
PEN	Penetration

PI	Control Rod Position Indication
PIND	Pressure Indicator
PL	Local Instrument Panels (Equipment Arrangement)
PM	Main Control Room Panels (Equipment Arrangement)
PNEU	Pneumatic
POP	Power Operation
PP	Pump
PR	Process Radiation Monitoring
PRES	Pressure
PRI	Primary
PROT	Protection
PRT	Pressurizer Relief Tank
PRV	Pressure Regulating Valve
PS	Process Sampling Primary & Secondary System (including Chiller Equipment)
PT	Pressure Transmitter
PUR	Purifier
PW	Primary Water
PWST	Primary Water Storage Tank
PZR	Pressurizer
RB	Reactor Building
RCP	Reactor Coolant Pump
RC	Reactor Coolant (not including Pressurizer System)
RCFC	Reactor Containment Fan Cooler
RCVR	Receiver
RD	Control Rod Drive (full length & part length)
RDT	Reheater Drain Tank

RE	Reactor Building and Containment Equipment Drains to Rad-Waste (including Reactor Coolant Drain Tank & Pumps)
RECIR	Recirculation
REFRIG	Refrigeration
REFU	Refueling
REG	Regulator
REGEN	Regeneration
RES	Reservoir
REV	Revision
RF	Containment Floor Drains to Radwaste (including Sump Pumps)
RH	Residual Heat Removal (RHR)
RHTR	Reheater
RLF	Relief
RM	Remote Manual
RP	Reactor Protection
RPI	Rod Position Indicator
RSH	River Screen House
RTD	Resistance Temperature Device
RV	Reactor Vessel
RWST	Refueling Water Storage Tank
RWT	Rinse Water Tank
RX	Reactor
RY	Reactor Coolant Pressurizer System
SA	Service Air
SC	Strong Cation
SAMP	Sample
SB	Service Building

SD	Steam Generator Blowdown System
SEC	Secondary
SCTN	Section
SEP	Separator
SFGD	Safeguard
S/G	Steam Generator
SH	Station Heating (excluding ducted air systems)
SHDN	Shutdown
SID	Safety Injunction
SNUB	Snubbers
SOV	Solenoid Operated Valves
SS	System Security (automatic dispatch)
SPSO	System Power Supply Office
ST	Sewage Treatment
STA	Station
STM	Steam
SJAE	Steam Jet Air Ejector
STO	Storage
STRN	Strainer
SU	Startup
SUCT	Sunction
SW	Screen Wash
SWIT	Switch
SWGR	Switchgear
SWYD	Switchyard
SX	Essential Service Water

SY	Switchyard
SYS	System
TAVE	(TCLD + THOT) /2
TCLD	Cold Leg Temperature
THOT	Hot Leg Temperature
TB	Turbine Building
TC	Thermocouple
TCV	Temperature Control Valve
TD	Turbine Drains and Vents
TE	Turbine Building Equipment Drains
TEMP	Temperature
TERT	Tertiary
TF	Turbine Building Floor Drains
TFR	Transformer
TG	Turbine Generator Auxiliaries and Misc. Devices (Turning Gear, etc.)
THRT	Throttle
TI	Temperature Indicator
TK	Tank
TO	Turbine Oil (Bearing Oil & Seal Oil Systems furnished with Turbine Generator)
TR	Waste Water Treatment
TS	Turbine Supervisory
TT	Temperature Transmitter
TURB	Turbine
TW	Treated Water (including Clarifier & filtered water)
TWR	Tower

UO	Unit Common
U1	Unit One
U2	Unit Two
UPST	Upstream
VA	Auxiliary Building HVAC
VAP	Vaporizer
VAC	Vacuum
VAR	Variable
VC	Control Room HVAC System
VCT	Volume Control Tank
VD	Diesel Generator Room Ventilation
VE	Misc. Electrical Equipment Room Vent.
VF	Containment Building and Auxiliary Building Filtered Vents
VH	Pump House Ventilation
VI	Radwaste and Remote Shutdown Control Room HVAC
VJ	Machine Shop Ventilation
VK	Switchyard Relay House HVAC
VL	Laboratory HVAC
VLV	Valve
VN	Containment Building and Auxiliary Building Non-Filtered Vents
VOL	Volume
VP	Primary Containment Ventilation
VQ	Primary Containment Purge
VR	Volume Reduction
VS	Service Building HVAC
VT	Turbine Building Ventilation

VV	Miscellaneous Ventilation (including Gate House, Receiving Building, Bottled Gas Enclosure, and Waste Water Treatment Building)
VW	Radwaste Facility Ventilation
VX	Switchgear Heat Removal
WC	Weak Cation
WD	Raw Water & Potable Water
WE	Fuel Handling Building Equipment Drains
WF	Aux. Bldg. Floor Drain Radwaste Reprocessing and Disposal
WG	Gland Water
WM	Make-Up Demineralizer (including Effluent & Flushing)
WO	Plant Chilled Water
WR	Wide Range
WS	Non-Essential Service Water
WTR	Water
WW	Well Water
WX	Solid (Wet and Dry) Radwaste Reprocessing and Disposal
WY	Laundry Equip. and Floor Drains Radwaste Reprocessing and Disposal
WZ	Chemical Radwaste Reprocessing and Disposal
XFER	Transfer
XTIE	Cross-Tie

6.12 Reference Photographs

Photographic mosaics of the Byron Generating Station Unit #2 control boards were submitted to the Nuclear Regulatory Commission on Tuesday, November 3, 1981.

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