HUMAN FACTORS EVALUATION OF THE STANDARD NUCLEAR UNIT POWER PLANT SYSTEM (SNUPPS)

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RECEIVED
JUN 16 1981
SNUPPS

ACKNOWLEDGEMENTS

The authors would like to gratefully thank the following people for their contributions:

- Frances Piccione
- Thomas Harding
- Al Strong
- Mark Fail
- The Graphics Department
- The Production Staff
- William Steele, Consulting Engineer

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EXECUTIVE SUMMARY

From September 1980 to February 1981, the Essex Corporation of Alexandria, Virginia performed a human engineering evaluation of the Standard Nuclear Unit Power Plant System (SNUPPS) for Nuclear Projects, Incorporated. Data were collected from two sources: the Westinghouse simulator at Zion; and the as-built control boards at the Callaway site. The evaluation employed human engineering assessment techniques developed by Essex Corporation specifically for power plant control room design reviews. These techniques were developed while writing NUREG/CR-1580 for the NRC and subsequently were refined during control room reviews for other utilities.

The objectives of the evaluation were to:

- Identify facets of the control room design that were at variance with NUREG/CR-1580
- Recommend potential backfits for each of the design facets identified
- Categorize the identified problems in terms of criticality and need for backfit
- Provide design guidance for areas that could not be evaluated due to the state of development of the control room.

Primary human engineering problems identified during this evaluation pertained to:

- ESF monitor light boards
- Mimic design, especially on the ESF control panels
- Prioritization of annunciators
- Functional grouping of controls and displays
- Visibility from the Operator's Control Console to the main control boards
- Mirror imaging of redundant channels on the ESF control board
- Demarcation and summary labels
- Abbreviation and terminology in labeling.

Although some of problems identified were not inherently critical, their cumulative effect could degrade control room operability. Essex's recommendations are to implement the suggested backfits, thereby increasing both the safety and reliability of the SNUPPS control room, and to bring the control room in line with established principles of human engineering.

1.0 INTRODUCTION

1.1 Background

On 28 March 1979 the Three Mile Island (TMI) accident occurred. One of the major contributing causes of the accident has been identified as operator error induced by the design of the cor[illegible] (NUREG/CR-1270). This fact has created concern in both government agenc[illegible]es regarding the impact of nuclear power station control room design on operator performance. In an effort to improve control room design, those concerned have turned to Human Factors Engineering (HFE).

Human factors engineering, as a discipline, seeks to reduce the chances of an operator error, thereby increasing the efficiency of a system. This is done by designing the interface between the man and machine to fit the limitations of the operator rather than expecting the man to adapt to the interface. The more complex the system interface, the greater the necessity for a sound human-engineered design. Given the complexity of a reactor interface and the consequences of an error to human safety and plant reliability, maximizing effective operator use of this interface is crucial.

Recognizing this need, Nuclear Projects, Incorporated, has contracted with the Essex Corporation to perform a human factors engineering review of the Standard Nuclear Unit Power Plant System (SNUPPS) being built at the Callaway and Wolf Creek sites. This report details the methodology and findings of this review.

1.2 Objectives

The objectives of the human factors engineering evaluation of the SNUPPS control room were to:

- Identify aspects of control room design that were at variance with human factors engineering design principles as identified in NUREG/CR-1580
- Prioritize these findings using an importance scaling that provides guidance on the criticality of the finding
- Identify potential remedies (backfits) for the more important findings

- Document the results of the evaluation in a manner that allows for immediate access to the data.

1.3 Scope

The control room at Callaway-1 was not complete at the time of the Essex review. Certain components were not installed and the design changes to be incorporated due to post TMI requirements were not finalized. Therefore, the Essex effort was limited to the Callaway-1 control boards as built and designed on November 21, 1980, and those characteristics of the Zion, Illinois, simulator that were definitely to be incorporated into the Callaway-1 control room. Information sources used for the evaluation included, but were not limited to, the following sources:

- FSARs
- Standardized Valve Nomenclature List — Rev. 0
- Procedures obtained from the simulator and SNUPPS
- System specification, Section 3 - SNUPPS BOP Functional Description
- System Specification, Section 4 - SNUPPS BOP Operator Function Summary
- Color Coding Conventions for CRT
- BOP Computer System Displays.

Other documents are identified in the body of the report.

The HFE effort included:

- Evaluation of the present control room controls and displays (Callaway-1)
- Evaluation of those controls and displays contained in the SNUPPS simulator that are relatable to the Callaway control room
- Study of three special areas — annunciator prioritization, safety state status monitoring, and control/display enhancement
- Evaluation of the operator interface with the computer system
- Documentation of results and recommendations for correcting the discrepancies.

1.4 Constraints on the Evaluation Effort

There were three difficulties in performing the SNUPPS control room evaluation. The major problem, and a potential source of inappropriate data, was the differences between the two sources of data. These sources were the Westinghouse simulator at Zion, Illinois, and the actual control boards at Callaway. While very similar, each of these reflected a higher evolution of the control room concept. Therefore, some distinct differences between component types and locations existed.

The second problem was induced by the stage of construction of the control room. Given its incompleteness, certain future components and control room environmental factors could not be addressed. These environmental factors included, but were not limited to:

- Ambient illumination
- Ambient noise
- Workspace design
- Protective equipment.

The third difficulty was encountered in acquiring information specific to the SNUPPS control room. While all PWRs respond similarly as systems, control rooms and their associated equipment vary greatly. Typically, a major source of information is the operators responsible for the reactor. The operators for the SNUPPS utilities, while very well trained and helpful, had gaps in their knowledge due to lack of experience and training on specific equipment.

These factors all contributed to the lack of a complete library of information. The management of SNUPPS made every effort to provide the necessary information but, given the short term of the contract, could not provide all information needs. The resultant evaluation is therefore based in part on assumptions made by Essex staff.

2.0 APPROACH

The human engineering evaluation of the SNUPPS control room design consisted of two basic phases: data collection and data reduction. Data collection was accomplished by methodologies that compared features of the control room design with principles of human factors engineering as delineated in NUREG/CR-1580, "Human Engineering Guide to Control Room Evaluation." Data reduction involved identifying potential errors associated with design features found to be at variance with the criteria in NUREG/CR-1580, assessing the magnitude of the effect of these errors, and assigning a priority rating based on this information.

In addition to these two phases, Essex examined the computer/man interface, performed a series of spcecial studies and a detailed examination of the ESF Status Panels, and documented the differences between the simulator at Zion and the mockup of Callaway Unit 1. The methodologies used in the evaluation are summarized below:

2.1 Data Collection

The data collection phase involved applying the following methodologies:

- Procedural walk-throughs and task analysis
- Operator questionnaires
- Comparison of the control room to generic problems
- Control room surveys
- Checklists.

Procedural Walk-Throughs and Task Analysis — The following procedures were videotaped at the SNUPPS simulator at Zion:

- E-0
- E-01
- E-02
- E-03
- E-09 leading into E-05

- GEN-0-01
- GEN-0-02
- AE-0-01.

Each procedure was taped twice, once with a full complement of operators without any interruptions and once with one operator explaining each step. The video tapes were then used to support the task analysis.

The task analysis is a technique, using procedures, that identifies what information is required for an operator task and what control actions are necessary to implement that task. Instances of poor control/display relationships, lack of necessary information and inadequate presentation of information all can be identified from this analysis.

Operator Questionnaire — Questionnaires were administered to prospective operators from the Wolf Creek and Callaway plants. The questionnaires elicited comments on various facets of control room operation (e.g., annunciator, procedures).

Comparison of the Control Room to Generic Problems — The simulator control room was examined against a list of HFE problems that consistently have been found in previously examined control rooms.

Control Room Survey — The surveys provided general information on the control room, enabling the evaluation team to become familiar with the essentials of the operator/system interface. The specific surveys used were as follows:

- Confusion survey
- Generic CR review
- Design conventions
- Research survey
- Obstructions survey.

Given the stage of control room construction, some areas normally addressed by a survey (e.g., ambient noise, ambient lighting) were not performed.

Human Factors Engineering Checklists — The checklists were used to address the control room on a panel and component level. These checklists consisted of statements

drawn from NUREG/CR-1580. Each component (control or display) was evaluated for compliance with the criteria contained in the checklist, and instances of noncompliance were noted. The checklists were administered using photos from the simulator and a photo mosaic of the Callaway 1 control boards, and spending a week at Callaway. Specific checklists used included those on:

- Rotary selector switches
- Pushbuttons
- Levers
- Counters
- Process controllers
- Simple indicators
- Legend lights
- Protection displays
- Vertical/horizontal meters
- Circular meters
- Trend recorders
- Annunciator and warning lights.

Samples of these checklists are included in Appendix G.

2.2 Data Reduction

Data reduction was done in two basic steps. The first step consisted of completing a Human Engineering Finding report (HEF). This report listed the components found to be at variance with the criteria in NUREG/CR-1580, what the variance consisted of, and what type(s) of error the variance might precipitate.

The second phase, establishing priorities for the items found to be variant, involved completing the form illustrated in Table 1. From this form a priority rating was determined for the HEF. A rating of 1 and 2 indicated a safety relation, while a rating of 3 and 4 indicated a reliability relation. A rating of five indicated that, although something was at variance with NUREG/CR-1580, it had little impact on plant safety or reliability.

TABLE 1. HEF PRIORITY SHEET

HEF NO. ________

A. Questions

1. If an error occurred, could plant safety by jeopardized or degraded?
   - Yes - enter a "1" in Question 1
   - No - enter a "0" in Question 1

2. If an error occurred, could plant reliability be reduced?
   - Yes - enter a "1" in Question 2
   - No - enter a "0" in Question 2

3. Would the plant's response to the error both
   a. Provide the operator sufficient time to correct it and
   b. Provide a positive warning (e.g. alarm) that the error has been committed?
   - Yes - enter a "0" in Question 3
   - No - enter a "1" in Question 3

B. Prioritization Formula

1	2	3		Priority	Type
1	X	1	=	1.0	Safety Related
1	X	0	=	2.0	Safety Related
0	1	1	=	3.0	Reliability Related
0	1	0	=	4.0	Reliability Related
0	0	1	=	5.0	Performance Problem

C. Priority

Question			
1	2	3	Priority

2.3 Computer/Operator Interface

Essex evaluated the interface between the operator and the computer. This interface consisted of keyboards, CRTs and the CRT display. The evaluation was based on the following documents:

- Honeywell Power Generation Planning Guide
- Bechtel Specification No. 10466-J-106, Appendix D
- SNUPPS, BOP Computer System Displays
- Bechtel Drawing CRT Display Conventions, J-06300
- Honeywell Process Video (HPV-2) Display Subsystem APVB-J-T
- Honeywell Process Video (HPV-2) Display APVA-T
- Honeywell System Specification, Section 5 — SNUPPS BOP Hardware Description 51001915
- Honeywell System Specification, Section 3 — SNUPPS BOP Functional Description 51001913
- Honeywell System Specification, Section 4 — SNUPPS BOP Operator Function Summary 51001914.

Details of this evaluation are contained in Appendix B.

2.4 Special Studies

Four special studies were conducted by Essex personnel in the course of the control room evaluation. These special studies were on the following topics:

- Annunciator Prioritization — Various methods for prioritizing annunciators and for enhancing the current SNUPPS method were discussed.
- Plant Status Monitoring — Various approaches to fulfilling the requirement for a safety parameters display system were examined and guidance was provided for assuring that displays conformed to human engineering principles.
- Control and Display Enhancement — Various methods for enhancing the current control boards and components were explored.

Details of these studies are contained in Appendix C.

2.5 ESF Status Panels

A detailed evaluation of the ESF status panels was undertaken, using the following documentation:

- FSARs
- System Description Engineered Safety Features Actuation System, 10466-J005A, Rev. 5
- Technical Specification for the Status Indicating Systems for the Standardized Nuclear Unit Power Plant System, 10466-E-094(Q), Rev. 3.

This evaluation examined the actuation logic, the inclusion or exclusion of indicators for various devices, and the placement of these indicators within the matrix. Details are contained in Appendix D.

3.0 RESULTS

Results of the HFE evaluation of the SNUPPS control room concept indicated that design problems existed. While efforts were made to incorporate useful operator aids such as computer-driven CRTs and mimics, these aids did not always conform to human factors engineering principles. This lack of conformance tends to negate the purpose of the aides, to reduce operator error. Therefore, the impact of these operator aids on improved plant safety and reliability is not very strong. The control room was found to be at variance with a number of the criteria contained in NUREG/CR-1580. Detailed results of the evaluation are presented in the following appendices:

- Appendix A — Summary of Human Engineering Findings
- Appendix B — Results of the Computer/Operator Interface Evaluation
- Appendix C — Special Studies
- Appendix C-1 — Annunciator Prioritization
- Appendix C-2 — Plant Status Monitoring
- Appendix C-3 — Control and Display Enhancement
- Appendix D — Monitor Light Boards
- Appendix E — Results of an Evaluation of the General Atomic Radiation Monitors
- Appendix F — Demarcation of the Control Boards
- Appendix G — HEER Files.

4.0 RECOMMENDATIONS

Based on the HFE evaluation, Essex has formulated the following recommendations regarding the Human Engineering Findings:

- Priority 1 and 2 findings have an impact on safety and require resolution.
- Priority 3 findings have a significant impact on plant reliability and should be resolved.
- Priority 4 findings also have an impact on plant reliability. While the impact is not as dramatic as Priority 3 findings, resolvement should be done to minimize unscheduled downtime.
- Priority 5 findings should be corrected to enhance the general control room design and to maintain consistency.

APPENDIX A

HUMAN ENGINEERING FINDING SUMMARY

The following appendix presents a summary of the human engineering findings (HEF) of the SNUPPS control room review. The summary represents the HEFs of Priority 4 and higher. They are grouped in the following categories:

- Control Room — those that are generic to all or most control panels
- Control Panel — those that are specific to each panel.

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
1	142	Annunciators: ALL but FIRST OUT	RL014 RL016 RL018 RL020 RL022 RL024 RL026	There is no prioritization of alarms; by location, color, or other schemata.	Provide a prioritization scheme using color, location or other appropriate method. (See Appendix C-1)	1
2	152	Annunciators: ALL	RL014 RL016 RL018 RL020 RL022 RL024 RL026	The character height-to-width ratio is 7.3, while the recommended height-to-width ratio is between 1:1 - 5:3	1. Re-engrave the alpha-numeric to make the characters conform to the 1:1 to 3:5 or 5:3 ratio. 2. Install new annunciator windows that utilize characters whose height-to-width ratio is between 1:1 to 5:3.	1
3	153	Annunciators: ALL	RL014 RL016 RL018 RL020 RL022 RL024 RL026	The stroke width of the characters is .04 inch. The maximum recommended viewing distance for a stroke width of .04 inch is 8 feet. At the 12 foot viewing distance, the stroke width should be 1/6 the character height, or approximately .058 inch.	1. Re-engrave the alpha-numerics so the character stroke width is equal to .058 inch, or 2. Install new windows that utilize character stroke widths of approximately .058 inch.	1
4	141	Annunciators: ALL	RL014 RL016 RL018 RL020 RL022 RL024 RL026	Annunciator windows are not keyed or coded to prevent inadvertant inter-change	Provide physical interlock or enscribe a location code on the window.	1

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
5	37	Pushbuttons: ANNUNCIATOR TEST ANNUNCIATOR ACKNOWLEDGE FIRST OUT ACKNOWLEDGE FIRST OUT RESET FIRST OUT TEST	RL015 RL019 RL025 RL005 RL003	The order of Annunciator Controls is inconsistent from one panel to another. The panels have the following order- Test, Acknowledge on RL015; Acknowledge, Test on RL019 & RL023. First out are in the following order- Acknowledge, Reset, Test on RL019; Acknowledge, Test, Reset on RL025. On RL005 the order is First Out Acknowledge, First Out Reset and Annunciator Acknowledge	Reconfigure controls so that they all are in the same order and separate the Annunciator Acknowledge from the First Out Controls. Shape coding of the handles would lessen the chances of making the error of hitting the test function when trying to acknowledge and looking at the annunciator panels at the same time.	1
6	51	Mimic Lines: ALL MIMIC LINES EXCEPT ELECTRICAL	RL001 RL017 RL018 R1019 RL020 RL023 RL024	The mimic lines are all the same size, regardless of the size of the line. This makes it very difficult to distinguish primary injection pathways from test lines, etc	Replace with mimic lines that discriminate visually by size between primary and secondary lines.	1
7	43	Mimic Lines	RL013 RL014 RL015 RL016 RL017 RL019 RL001	There are instances of mimic line flow arrows indicating the wrong direction of flow.	Examine all mimics and verify direction of flow; correct any errors.	1

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
8	52	Mimic Lines: ALL PANELS WITH MIMICS	RL001 RL013 RL014 RL015 RL016 RL017 RL018 RL019 RL020 RL023 RL024	There is an inconsistent use of color coding for the mimic lines. There are nine different colors for water and four different colors for electricity. Some colors are used for different elements (i.e., grey= electricity and water, orange=electricity and water).	Use consistent color coding throughout control room. Suggest the following: Blue=Water Red=Steam (should this be used) Green or Yellow= Electricity-use different saturations of the color to code different voltages. The higher the voltage, the darker the color.	1
9	191	Mimic: CCW ESW DIESEL GENERATORS TD AUX FW CONTROLS	RL019 RL019 RL015 RL005	The above component groups are mirror imaged. In the case of the CCW and ESW Components, the mirroring is not identical. This Creates transference of training problems.	1. Redesign to eliminate the mirror imaging, or 2. Shape code the controls and displays to provide tactual and visual feedback of the difference.	1
10	15	Demarcation Lines	All Panels	There exists a general lack of demarcation usage to visually isolate separate system components or to enhance existing relationships between components contained within the same system.	Employ demarcation lines where appropriate - brown lines would provide good contrast with panel surface. (See Appendix H)	3
11	5	Labels	All Panels	There are no functional or system summary labels employed on the control boards.	Provide system and functional group summary labeling.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
12	36	Labels: All labels colored red, yellow, white, or blue.	All Panels	The practice of color coding labels by trains creates a christmas tree effect that increases visual search times. The information, while important at times, is not needed frequently enough to be displayed in such a dramatic manner Color coding should be used to relate systems and functional groups together.	Use only one color for labels (e.g., black characters on a white background). The train can be conveyed by a colored dot located on the label.	3
13	35	Labels	All Panels	The engraved surfaces of the labels have no clear filler to prevent the buildup of dirt and grime in the etched surface over time leading to a reduction of legibility.	Fill the etched surface with a clear filler	3
14	48	J-Handle: ALL IN CONTROL ROOM WITH SPRING LOADED RETURN TO CENTER.	All Panels	The J-handle controls have a spring tension for return to center that is excessive. If the operator releases the handle when it is in an extreme position, the handle will spring back with such force that a flag and position mis-match will ensue and the possibility exists for activation of the opposite function.	Decrease the return force of the controls to eliminate the excessive return action.	1

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
15	3	Hagan Process Controller: BTRS DEMINERALIZER BYPASS CONTROL BG HC-387 RHR HX A FLOW CONTROL EJ HIL-606 RHR HX B FLOW CONTROL EJ HIL-607 CHARGING HEADER FLOW CONTROL BG HC-182	 RL002 RL0 7 RL0 7 RL001	The magnitude of the scale reading increases as the pointer moves from right-to-left rather than the conventional movement from left-to-right. The CLOSE/OPEN position convention is also violated. The OPEN position is to the left of the center, and the CLOSE position is to the right of the center.	1. Change control display movement relationships by replacing controller with a scale which increases from left-to-right as control is rotated in a clockwise direction, or 2. Replace controller with a conventional model which does not violate plant convention and population stereotype, or 3. Shape code the knobs to provide tactile feedback about the difference of the control and address through training. Use labeling (arrows) to indicate direction of motion, or 4. Rewire and relabel control so the CLOSE position is to the left of center, and the OPEN position is to the right of center.	4
16	95	Process Controllers:	All Panels	The 0 and 100 marks on process controller scales are not labeled as to which is full open and which is full closed.	Include open and closed labeling on the scale.	3

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
17	192	Process Controllers: Vertical Meters Horizontal Meters	All Panels	The display covers are subject to glare from the ambient lighting. (Data from Simulator)	1. Install glare-free cover, or 2. Use indirect lighting, diffusers, many low level light sources as opposed to a few bright sources.	3
18	143	Vertical Meters: REACTOR COOLANT PRESSURE STEAM GENERATOR PRESSURE	 RL002 RL026	During emergency procedures the operator is required to compare the two meters but they are located on panels separated by about 25 feet. This taxes short term memory.	1. Add a redundant indicator for Rx coolant pressure on R1026, or 2. Insure that this task is performed by two operators.	2

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
19	23	Vertical or Horizontal All with the exception of Vertical Meter: THRUST BEARING WEAR DETECTOR TEST Horizontal Meter: THROTTLE STEAM PRESSURE INTERMEDIATE PRESSURE	All CR RL006 RL005	The vertical and horizontal meters lack any coding to indicate the tolerance zones or set points. Therefore, the operator has to rely on memory to supply him with knowledge when a parameter is beginning to degrade.	Incorporate coding on the meter scale face (not bezel or clear cover) for those meters where tolerance zones will enhance the operator's use:	
					Those meters critical to safety (ex.: CTMT Temp, CST Level, Rx Coolant Press, etc.	1
					Those meters critical to reliability.	3
					All others.	5
20	33	Vertical and Horizontal Meters	All Panels	Displays are designed so that failure of the display or display circuit is not immediately apparent to the operator.	Meters are designed so that if the meter should fail it is not immediately apparent to the operator. Redesign so that failure of or loss of power to the meter causes the pointer to fall off scale.	3
21	112	Simple Indicators and Cutler-Hammer Pushbuttons with Integral Lights	All Panels	Single filament incandescent lamps are used without the means to test for bulb or circuit failure.	1. Incorporate lamp test or 2. Use dual filament bulbs 3. And given the estimated 21,000 lifetime of the bulbs in the Cutler-Hammer Controll, provide administrative procedures to change bulbs at a regular interval.	2
22	99	Cutler-Hammer Pushbuttons with Integral Lights	All Panels	Lamp replacement requires the use of a special tool	Insure an adequate supply of and ease of access to special tools.	1

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
23	155	Operator Control Console	RL002 RL006	The console is too high to provide the 5th % operator with visibility over to the Main Control Consoles.	Given the impossibility of changing the console height, insure that the operator can use the CRT to obtain information that cannot be seen from the operator control console and the BOP Consoles.	2
24	4	J-Handle Rotary's:		Controls are located in an inaccessible position for operators whose height is less than 5'4"	1. Relocate controls making them accessible to the 5th percentile operator, or 2. Provide slip resistant stool.	4
		CAL-BLAND-1 BUS B PCB V45	RL014			
		13.8 KV SOURCE SELECT SW PA HS-7	RL016			
		Pushbuttons:				2
		CONTAINMENT AREA RADIATION LEVEL SH RI-2	RL020			
		CONTAINMENT AREA RADIATION LEVEL SH RI-1	RL020			
		BIT TO BORON INJ SURGE TANK ISO VALVE EM HIS-8870 A	RL018			
		BIT TO BORON INJ SURGE TANK ISO VALVE EM HIS-8870 B				

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
25	154	Labels: ALL	All Panels	Spacing between characters words and lines on engraved labels is inadequate resulting in reduced readability due due to the difficulty in separating individual characters from their backgrounds.	Revise labeling such that: 1. The minimum space between characters is one stroke width. 2. The minimum space between words is the width of one character. 3. The minimum space between lines is 1/2 the character height. 4. The stroke width is between 1:6 - 1:8 for white characters on a dark background.	2
26	29	Labels	All Panels	Impossible to differentiate the letter I from the numeral 1. Both letter and numeral are represented by a vertical slash.	Re-engrave or otherwise modify labels so the letter I can be visually distinguished from the numeral 1.	4
27	149	Vertical Meters	All Panels	The heights of the intermediate and minor graduation marks are less than 0.16 and 0.19 inch respectfully.	Modify or replace with scales whose intermediate and minor graduation marks are at least .16 and .09 inch, respectfully.	4
28	150	Vertical Meters BORON INJ SURGE TK TEMP PZR DISCHARGE TEMP METERS PZR RELIEF TANK TEMP RC LP 1, 2, 3, 4 TAVG LETDOWN HIGH PRESS RLF VLV OUTLET TEMP PRESSURIZER METERS	 RL018 RL021 RL021 RL004 RL002 RL002	The meter scales begin with an unnumbered major graduation mark.	Label the bottom graduation mark with the appropriate number.	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
29	195	Trend Recorders	All Panels	The label describing the parameter related to its pen color is located in the recorder window. This obscures part of the paper; they lack permanent attachment and can not be read with the door open.	Remove the labels from the door and place on the panel surface.	4
30	11	Chart Recorder: STEAM GENERATOR A STM/FW FLOW & LEVEL AE FR-510 STEAM GENERATOR B STM/FW FLOW & LEVEL AE FR-520 STEAM GENERATOR C STM/FW FLOW & LEVEL AE FR-530 STEAM GENERATOR D STM/FW FLOW & LEVEL AE FR-540 RHR HX INLET/OUTLET TEMPERATURE EJ TR-613 RHR HX INLET/OUTLET TEMPERATURE EJ TR-612 RCP A SEAL LEAKOFF & INJ FLOW BG FR-157 RCP B SEAL LEAKOFF & INJ FLOW BG FR-156 RCP C SEAL LEAKOFF & INJ FLOW BG FR-155 RCP D SEAL LEAKOFF & INJ FLOW BG FR-154 OVER PWR/OVER TEMP ΔT RECORDER SE TR-411	RL006 RL019 RL022	On chart recorders, the the label order of color is red-green-blue, while the actual pen order of color is blue-green-red.	Replace label with one which reads pen order of color as blue-green-red.	2

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
31	19	Pushbuttons	RL001 RL017 RL018 RL021	These pushbuttons are a reversal of plant convention and also violate population stereotypes. The functional swith positions on these pushbuttons are OPEN/CLOSE rather than CLOSE/OPEN.	1. Rewire and relabel controls so that the CLOSE pushbutton is on the left, and the OPEN pushbutton is on the right, or 2. Guard controls, or 3. Provide shape coding to inform operator of difference.	2-RL017/18 3-RL001/021
32	122	Labeling of Annunciators, Controls and Displays	All Panels	There is an inconsistent use of abbreviation in the CR. Some abbreviations have multiple meanings and some terms have different abbreviations.	Standardize the use of terminology. The labels on the panels should be consistent with the Annunciators.	3
33	200	Computer System	RL020 RL003	The CRT Displays can be effected by both keyboards. This means that an operator on the RL020 panel can disrupt and lose data on the CRT's on RL003.	1. Provide software interlocks to inhibit the operators ability to effect all CRT's from one keyboard, especially the RL020 keyboard, or 2. Use rigid administrative procedures to control.	3
34	201	Computer System CRT Color of Characters	RL003 RL020	The blue and magenta characters are difficult to read due to poor contrast with the screen background.	Modify the software to remove these colors from use.	4
35	202	Computer CRT	RL003 RL020	The color coding on the CRT displays is not consistent, one color may be used to convey different types of information.	Standardize the color coding conventions. (See Appendix G)	4

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
36	204	Computer System Printer	None	There is no printer for hard copy information located in the CR. This deprives the operator of useful information.	Locate a printer in the CR that has adequate noise shielding.	3
37	6	J-Handle Controls	RL013 RL015 RL019 RL001	The J-Handle controls located at the lower edge of the panels are subject to inadvertant activation by an operator's body.	1. Replace J-Handles with a rotary control, or 2. Install a guard rail to keep the operator's body away from the panel.	3
38	12	Indicator Lights: MN TURB TURN GEAR ENGAGED AC ZL-30B MN TURB TURN GEAR LOCKED OUT AC ZL-30K	RL025	The jacking gear indicator lights and vertical indicators associated with the chest/shell warming controls are located on remote panels (approximately 8 feet away), preventing a visually close association between the displays and their respective controls.	1. Relocate indicator lights and vertical indicators on panel adjacent to respective controls, or 2. Install redundant indicators on panel RL005 or RL006, adjacent to respective controls.	3
		Vertical Indicators: 1ST STG PRESSURE AC PI-505 1ST STG PRESSURE AC PI-506	RL024			
		Legend pushbuttons: CHEST/SHELL WARMING OFF CHEST SHELL DECREASE INCREASE	RL005			

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
39	133	Vertical & Horizontal Meters:	RL014 RL016 RL026	Vertical and Horizontal meters are located greater than 70 inches above the standing surface (between 75-84 in).	1. Lower the displays to a visually more accessible position for the 5th percentile operator (41-70 in. above the standing surface), or 2. Provide step-ladder, or 3. Install larger meters, or 4. To aid readability, shim the displays forward so the top half of the displays are propped out and downward.	4
40	205	Vertical Meters: MFW PMP TURB BRG OIL MFW PMP BRG OIL STM SEAL SYSTEM INLET PRESSURE STM SEAL SYSTEM EXHAUST VACUUM All on panel with one exception.	RL026 RL024	The size and contrast of the scale markings is inadequate for viewing from the RL005/006 benchboard.	Replace the scales with scales that incorporate darker and larger markings.	4
41	139	Multipen Trend Recorders	All Panels	Many of the 2 and 3 pen recorders have one pen that is mounted below and/or behind the scale, making trending difficult due to parallax.	Modify the meter to bring the pointer to within 0.06 inches of the scale.	4

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
42	157	Pushbuttons CCW TO RHR HX A CCW TO RHR HX B	RL017	These represent controls that require continuous pressure to operate rather than momentary. There is no way to visually distinguish this need.	1. Examine the necessity for continuous pressure and change if not necessary. 2. Label or code to provide the operator with this information	3
43	166	Pushbuttons and Simple Indicators FEEDWATER HEATER 150 VALVES FEEDWATER HEATER STEAM LINE DRAINS	RL023	Two different control display groups are used for essentially the same function. Some feedwater heater ISO valves and steam line drains have a control with integral lights for the ISO valve; others have separate indicator lights placed above the drain line indicators, causing poor control-display relationship. Different-shaped controls convey information to the operator which is not useful, thus creating visual clutter and confusion and lending itself to operator error.	Convert all the controls to the Cutler-Hammer controls with integral lights.	4
44	82	Process Controllers: ALL HAGAN FULL STATION CONTROLLERS AND HALF STATION CONTROLLERS	RL001 RL002 RL005 RL006 RL017	Process controllers have redundant and confusing labels.	Remove the labels which appear on the controller above and below the vertical scale.	3
45	83	Process Controllers: ALL HAGEN FULL STATION CONTROLLERS WITH POTENTIOMETERS	RL001 RL002 RL005 RL006 RL017	The long hand on the dial of the potentiometers covers the numbers.	Redesign circular scale with a shorter pointer that will not obscure the graduation marks, and with the numerals appearing on the outside of the indicie marks.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
46	128	Electroswitch J-Handle Controls	All Panels	The position label character height are under the minimum for the normal viewing distance of 28 inches.	Increase the label size to at least 0.10 inches	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
47	199	Computer System Numeric Keypad	RL020 RL003	The keypad is arranged in a calculator type matrix rather than a telephone type matrix.	Rearrange in a telephone style matrix.	4
48	197	Computer Keyboards Special Function Keys	RL020 RL003	The red, green and white coded keys are not grouped together or in functional sequence.	Regroup to provide color grouping and within the color grouping, order by function or alphabetically.	4
49	185	CRTs: CONTRAC CRTs	RL003 RL020	1. The two CRTs on RL020 are located between 76-91 inches above the standing surface. This location exceeds the recommended height for CRT displays, which is between 41-70 inches (and preferably 50-65 inches) above the standing surface. 2. Reading the CRT screens from far right or far left ends of control boards is impaired by distance, viewing angle, ambient lighting and glare.	Re-position RL020 CRTs with respect to distance from standing surface. Provide hoods for shielding CRTs from ambient lighting or glare. Distribute four CRTs around panels to permit accurate reading of at least one of the CRTs screen contents from any operating position within the control room. Provide training and written procedures emphasizing use of CRTs for 2-man operation within an integrated communications strategy.	4
50	203	Computer CRT Displays	RL020 RL003	The symbols on the CRT P&IDs are not identical to the symbols used for the P&ID.	Standardize the symbology or provide a legend indicating what each symbol is.	4
51	110	HAGAN FULL STATION PROCESS CONTROLLERS	All Panels	The scale numerals are placed such that the pointer obscures the numerals.	Relocate the numerals on the periphery of the scale so that the pointer does obscure the numbers.	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
52	127	Process Controllers HAGAN FULL STATION	All Panels	The vertical demand signal meter scale has 14 minor marks between the numbered marks. The maximum is nine.	Add numerals to the scale in appropriate places to minimize the number of minor, unnumbered marks.	4
53	75	Pushbuttons - Cutler Hammer with 3 or 4 Functions.	All Panels	The width of the off pushbutton is much too narrow, making it difficult to activate without activating the primary functions.	1. Replace with control that has adequately sized pushbuttons, or 2. Replace with a pushbutton where the small section is higher than the larger section.	4
54	140	Trend Recorders	All Panels	The scales on many of the trend recorders have intermediate markings the same height as the major markings.	Install new scales with intermediate marks shorter than the major marks.	4
55	78	Vertical Displays: ALL VERTICAL DISPLAYS	RL002 RL003 RL004 RL005 RL006 RL015 RL016 RL017 RL018 RL019 RL020 RL021 RL023 RL024 RL025 RL026	Functional labeling (measurement variable - PSIG, etc.) on scale face is oriented vertically, from top-to-bottom rather than horizontally from left-to-right.	Incorporate into the horizontal display label the variable that is being measured. Example: PZR RELIEF TANK PRESSURE - PSIG AB P1-469	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
56	58	Vertical Meters	RL003 RL004 RL005 RL006	Some vertical meters utilize scales which contain both positive and negative numbers. However, no positive (+) or (-) markings appear on the scale face.	Add a positive and negative sign above and below the zero position, respectively.	4
57	14	Telephone/Intercom System	CR	The telephone/intercom system is located in an area requiring the operator to stoop every time he wishes to use the system or select a channel.	1. Relocate phones, or 2. Provide channel select function above phones or horizontal benchhead, or 3. Redesign CR communication system using: a. Portable headsets b. Portable phones with channel select built in handle.	4
58	28	Labels on some of the simple indicators	RL013 RL014 RL018	Labels are located below the indicator lights. To conform with NUREG 1580 as well as with panel and plant standardization, labels should be repositioned above the indicator lights.	Relocate labels above indicator lights.	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
59	45	Process Controllers: LETDOWN HX OUTLET PRESSURE CONTROL BG PK-131 LETDOWN HX OUTLET TO LOW TEMP CONTROL	RL001	There is not a glass cover over the face of the pot on process controllers. The cover has been inadvertantly removed.	Provide a rigid transparent, glare reducing cover over the dial face.	3
60	113	Pushbutton: REGENERATIVE HX TO PZR AUXILIARY SPRAY BG HIS-8145	RL001	This control is used only when the reactor cooling pumps fail. The control is located near other similar controls and lends itself to substitution error.	1. Guard in a manner that would preclude the operator from activating this control, or 2. Shape code to provide the operator with Tactile feedback that this control is different.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
61	8	Pushbutton: RCP A SEAL WTR OUT ISOL BB HIS-8141 A RCP B SEAL WTR OUT ISOL BB HIS-8141 B RCP C SEAL WTR OUT ISOL BB HIS-8141 C RCP D SEAL WTR OUT ISOL BB HIS-8141 D Vertical Indicators: RCP A SEAL ΔP BB PI-153A RCP B SEAL ΔP BB PI-152A RCP C SEAL ΔP BB PI-151A RCP D SEAL ΔP BB PI-150A	RL001 RL021	Seal water outlet isolation values are located on panel RL001, while the leakage flow indicators are located on panel RL021.	Relocate leakage flow indicators to a more accessible location (i.e. panel RL002).	4
62	46	PRESSURIZER PRESSURE INDICATION	RL002	There is no indication of pressure between 700-1700 PSIG on the RL001 panel.	Incorporate an instrument that measures this range on the RL002 panel.	1
63	73	Labeling: IMMEDIATE BORATE FLOW BG Fl-183A	RL002	The label "IMMEDIATE BORATE FLOW" should be changed to read "EMERGENCY BORATE FLOW," as the revision conveys a clearer and more precise terminology.	Append as recommended.	1

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
64	91	Rotary Control: BTRS CONTROL SW BG HIS-27 DILUTE BORATE OFF	RL002	The OFF position is located on the right of the control instead of in the center. Also, there is no indication in terms of feedback to the operator that dilution or boration has been initiated.	Revise circuitry and relabel so the OFF position is centered between DILUTE and BORATE. Also, provide a simple indicator light that will illuminate once dilution or boration has been initiated.	3
65	26	Rotary Control: REACTOR COOLANT M/U WATER CONTROL BG HIS-26	RL002	This control has a Stop position, a Run position, and a Pull to Lock position. There is a stop provided at the Run position that lets the operator know he has activated the control. However, the operator does not know how far he must continue in the Stop position to adequately activate the control. There are no simple indicator lights associated with this control that would either indicate Running or Stop.	Provide a visual or tactual reference that the control has been activated by: 1. Engraving a line on the control face at the position identifying the exact point of component activation, or 2. Providing a detent at the stop position which provides tactual feedback that the control has been engaged, op 3. Installing a simple indicator light cueing the operator to component status.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
66	22	Counters: COMBINED M/U & BA FLOW TOTALIZER BORIC ACID COUNTER BORIC ACID TOTALIZER COMBINED REACTOR M/U & BA COUNTER	RL002	There are no units of measurement provided on the counter labels (eg.X1 or X10 GALLONS).	Add to labeling the measurement what the counter is reading in, plus add a decimal point.	3
67	20	Counters: BORIC ACID COUNTER BG FY-110B BORIC ACID TOTALIZER BG FY-110BB COMBINED REACTOR M/U & BA COUNTER BG FY-111B COMBINED M/U & BA FLOW TOTALIZER BG FY-111BB	RL002	The boric acid totalizer is located over the Combined Reactor M/U & BA counter. The Combined M/U & BA Flow Totalizer is located over the Boric Acid Counter. These counters are not related, and the totalizers locations should be revised.	Relocate the Boric Acid Totalizer over the Boric Acid Counter and the combined M/U & BA Flow totalizer over the combined M/U and BA counter.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
68	56	Counters: BORIC ACID COUNTER BG FY-110B COMBINED REACTOR M/U & BA COUNTER BG FY-111B	RL002	The red cover over the counter obscures the numbers from the view of a standing operator. To truly read the counter, the cover must be raised or the operator must bend down.	Provide the counter with a clear cover.	4
69	77	Trend Recorders: BORIC ACID BLEND FLOW RECORDER	RL002	The two scales on this trend recorder are unlabeled as to which one monitors Boric Acid Flow and which one monitors Total Makeup Flow.	Provide labeling to ensure that each scale is clearly labeled as to function or process being monitored.	4
70	34	Rotary Controls: NIS RECORDER SELECT SW SE HS-2 NIS RECORDER SELECT SW SE HS-1	RL003	The NIS Recorder Select SW 2 is positioned before the NIS Recorder Select SW1. Their position should be reversed.	Reposition NIS Select Switches so that the select switch for pen I appears first, followed by the select switch for pen 2. Also, rewrite labels to read NIS RECORDER SELECT SWITCH PEN #1 SE HS-1 and NIS RECORDER SELECT SWITCH PEN #2 SW HS-2.	3
71	24	Rotary Control: AUDIBLE COUNT RATE CONTROL-AUDIO MULTIPLIER	RL003	The position labels are partially obscured by the control. Also, the pointer is not always visible from the operators position.	1. Fill engraved surface with black pigment and relabel control positions so control collar does not obscure control position. 2. Etch a pointer into the top surface of the control Knob and fill with contrasting pigment.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
72	76	Rotary Control: ROD BANK AUTO/MANUAL SEL SW SE HS-9	RL003	On the Rod Bank Selector Switch, the control banks are positioned to be operated first and then the shutdown banks. However, the operator will control the shutdown banks before the control banks. Their positions should be reversed. Also, the associated counters should be positioned accordingly.	Charge the Rod Bank Selector Switch so the shutdown banks will appear before the control banks. Also reverse the step counter order so the shutdown bank counters are located on the top two rows and the control bank counters on the bottom two rows.	3
73	40	Pushbuttons: SOURCE RANGE BLOCK/RESET SW SE HS-5 SOURCE RANGE BLOCK/RESET SE HS-10	RL003	Both of these pushbuttons are located very close to the edge of the panel and subject to inadvertant activation and substitution. If the reset pushbutton was accidentally activated it would clear the system for start-up, and tripping the unit off line if under P-10.	1. Swap the Source Range Block/Reset with the Intermediate Range Block SWS located above, or 2. Guard the controls to prevent inadvertant activation.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
74	86	Labeling (Vertical Displays): RCLP 2T BB TI - 42IA RC LP 3T BB TI-43IA RC LP 4T BB TI-44Ia	RL004	All three labels are missing the delta symbol (Δ). Correct Example: RC LP 2ΔT BB TI-421A	Include the delta (Δ) symbol between the RCLP number and the abbreviation for temperature.	1
75	1	Simple Indicator: REACTOR TRIP BREAKER A REACTOR TRIP BREAKER B	RL004	The plant wide color convention is Red = Closed and Green = Open, These breakers are the reverse of that convention, Red = Open and Green = Closed.	Correct the color to bring in line with plant and industry standards.	2
76	151	Trend Recorder NIS RECORDER	RL004	The recorder is designed such that the top of the recorder window obscures the top of the scale.	Lower the scale to provide full visibility.	4
77	148	Trend Recorder: T REF/T AVG AUCTIONEERED	RL004	The label is located at the bottom of the Recorder, rather than above as is the plant and population stereotype.	Move the Label to the panel surface above the recorder.	4
78	87	Vertical Meter: FEEDWATER HEADER PRESSURE AE P1-508 MAIN STEAM HEADER PRESSURE AB P1-507	RL005	These vertical displays are grouped with the main steam dump controls and displays and are not a part of that subsystem.	Exchange the main steam header pressure vertical meter with the steam dump demand and use a demarcation line to indicate lack of relationship.	1

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
79	169	Pushbutton : TD AUX FW PUMP TRIP/RESET FC H1S-332	RL005	This critical control is located in a position that lends itself to inadvertant activation, especially given the fact that operators tend to lean over the panel to access controls and r displays on the back vertical boards.	Guard the controls to prevent inadvertent actuation.	2
80	158	Pushbuttons TD AUX FW PUMP TRIP/RESET	RL005	The pushbutton has an integral label that reads Trip, which is confusing given the Trip/Reset label.	Determine which function the control provides, trip or reset, and label pushbutton accordingly.	2
81	132	J-Handle: STEAM DUMP SELECT SW AB US-500Z	RL005	The STEAM DUMP SELECT SW AB US-500Z on panel RL005 selects the mode for the STEAM HEADER PRESSURE CONTROL. The select switch is not located adjacent to the process controller, resulting in a poor sequentional association between associated controls.	1. The Steam Header Pressure Control should be switched with the two vertical displays on Panel RL005 - Main Steam Header Press and the Steam Dump Demand, or 2. Use Demarcation lines to indicate the relationship.	3
82	97	Pushbutton: MFW TURBINE A LOCKOUT TRIP/TEST MFW TURBINE B LOCKOUT TRIP/TEST	RL005	Only one of the pushbuttons on this control is used and is labeled LOCKOUT. However, the pushbutton is really used to test the Lockout trip and should be labeled TEST not lockout.	Replace pushbutton labeled LOCKOUT with a pushbutton labeled TEST.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
83	177	Pushbuttons: MFW PUMP TURBINE A TRIP RESET FC H1S-18 MFW PUMP TURBINE A OVERSPD TEST/RESET FC H1S-19 MFW PUMP TURBINE B TRIP/RESET MFW PUMP TURBINE B OVERSPD TEST/RESET FC H1S-119	RL005	The turbine trip and overspeed controls are placed adjacent to each other. The controls are extremely similar in appearance and could be easily confused.	The trip portion of the MFW PUMP TURBINE A/B TRIP RESET Controls should be red to provide a method for the operators to distinguish between the two controls.	3
84	10	Legend Light Pushbuttons: MAIN TURBINE EHC PANEL AC XX-1	RL005	It is difficult if not impossible to distinguish the legend pushbuttons from the legend lights on the MAIN TRUBINE EHC PANEL	Visually isolate legend pushbuttons from legend lights by: 1. Adding demarcation lines, or 2. Altering legend plate design: a) tactually b) visually-use demarcation on legend plate.	3
85	54	Circular Meters: MFW PUMP TURBINE SPEED FC SI-33 MFW PUMP TURBINE B SPEED FC SI-133	RL005	Numbers are placed on the same side as the pointer causing the pointer to obscure the value.	Redesign the meter face so that the scale values are not obscured by the pointer.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
86	32	Vertical Meters: CV SIGNAL PRIMARY STANDBY IV SIGNAL PRIMARY STANDBY	RL005	Pointers are on the same side of the scale as the numbers, obscuring numerals, and making indicator reading difficult	1) Replace vertical indicators with displays which have numbers placed outside graduation marks to avoid having numbers covered by the pointers, or 2) Adjust pointers so there is a gap no greater than 1/16 of an inch between the tip of the pointer and the numbers on the scale face.	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
87	17	Rotary Controls: STM GEN A LVL SEL SW AE LS/519C STM GEN B LVL SEL SW AE LS/529C STM GEN C LVL SEL SW AE LS/539C STM GEN D LVL SEL SW AE LS/549C	RL006	These controls are not directly below their associated trend recordes, but directly below an Aux Feedwater vertical indicator, predisposing them to inadvertent association with the vertical indicators.	Use demarcation lines to help make visual association clearer.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
88	80	Simple Indicators: STM GEN A STM DUMP TO ATMOS VLV POS STM GEN A STM DUMP CTRL AT SHUTDN PNL STM GEN B STM DUMP TO ATMOS VLV POS STM GEN B STM DUMP CTRL AT SHUTDN PNL STM GEN [illegible] STM DUMP TO ATMOS VLV POS STM GEN C STM DUMP CTRL AT SHUTDN PNL STM GEN D STM DUMP TO ATMOS VLV POS STM GEN D STM DUMP CTRL AT SHUTDN PNL	RL006	The STM GEN A DUMP CTRL AT SHUTDN PNL LABEL is placed in such a manner that it can be associated with simple indicators that it does not apply to. Only the white light goes with the second label. The green and red lights go with the first label.	Center the first label over the green and red indicator lights and the second label over the white indicator light.	2
89	42	Trend Recorders: -STEAM GENERATOR A STM/FW FLOW + LEVEL AF FR-510 -STEAM GENERATOR B STM/FW FLOW + LEVEL AF FR-520 -STEAM GENERATOR C STM/FW FLOW + LEVEL AF FR-530 -STEAM GENERATOR D STM/FW FLOW + LEVEL AF FR-540	RL006	These trend recorders measure STM/FW flow, and level. There are two scales 0-100 and 0-5. The 0-5 scale measures STM/FW flow and the 0-100 scale measures level. Scales are not labeled as such.	Incorporate labeling to delineate which scale measures what varible.	2

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
90	96	Legend Light: TEST INTERLOCK LOSS OF PWR PRESS SIGNAL	RL006	The label script is barely readable due to inadequate engraving depth and lack of contrasting color for the script.	Engrave deeper and fill with a contrasting pigment.	3
91	196	Legend Light: STEAM DUMP VALVE POSITION LIGHTS	RL006	The closed indicators are located above the open indicators. This violates population and plant convention.	Reverse the light location so that open is above the close.	4
92	41	Vertical Display: VARMETER MA J1-4	RL006	This scale is inappropriate to measure vars. The way it is now the zero is at the bottom of the scale and the only way the operator can tell if it is leading or lagging is by raising or lowering the AC Auto Voltage Regulator BKR and watching to see if the pointer lowers or raises. It would be appropriate to have the zero in the middle so you could monitor a lagging or leading by the pointer above zero or below.	Peplace current scale with more appropriate scale.	3
93	114	Rotary Control: MAIN GEN VOLTMETER PHASE SELECT SWITCH	RL006	The handle on this control obstructs both the position labels and the pointer due to its size.	1. Replace handle with smaller handle. 2. Extend pointer and relocate position labels to the periphery.	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
94	106	Horizontal Meters: CIRC WTR PMP A/FDR BKR 152 PB 12103 SERV WTR PMP A/FDR BKR 152 PB 12104 CIRC WTR PMP B/FDR BKR 152 PB 12203 SERV WTR PMP B/FDR BKR 152 PB 12204 CIRC WTR PMP C/FDR BKR 152 PB 12203 SERV WTR PMP C/FDR BKR 152 PB 12303 INTAKE PUMP A/FDR BKR 152 PB 11704 INTAKE PUMP B/FDR BKR 152 PB 11705 INTAKE PUMP C/FDR BKR 152 PB 21802	RL013	The horizontal indicators are missing identification labels.	Provide appropriate labeling above the prospective meters.	4

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
95	156	Horizontal Meter: COOLING TOWERS BASIN LEVEL CT1 BASIN LEVEL CT2	RL014	The scale is indexed in feet above sea level rather than actual basin level.	Change instrument to read in actual basin level.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
96	105	Legend Lights DEMINERALIZER TRAIN A DEMINERALIZER TRAIN B	RL014	The Legend Plates are not keyed or coded to prevent inadvertant interchange during bulb replacement.	Etch a code on each Legend Plate that significies position.	3
97	111	Labels: ESF XFMR XNB01 UNIT 2 XFMR XPB 218 AND MISCELLANEOUS TRANSFORM-ERS	RL014	The two labels are located side-by-side. This arrangement of labe's is confusing and results in uncertainty as to what the indicator represents. It appears to refer to unit 2.	Simplify labeling to reduce ambiguity.	3
98	174	Process Controller: BLOWDOWN VALVE #2/ CONDUCTIVITY RATIO/AUTO-MAN CONTROLLER BLOWDOWN VALVE #1/ CONDUCTIVITY RATIO/AUTO-MAN CONTROLLER Horizontal Meter: COOLING TOWERS BLOWDOWN FLOW CT 1 BLOWDOWN FLOW CT 2	RL014	The process controllers are ordered #2, #1 from left to right. The horizontal meter is ordered CT1, CT2 from Top to Bottom. This violates the standard control-display sequence. The sequence should be 1,2, left to right and 1,2 Top to Bottom.	Reverse the position of the process controllers or reverse the cooling tower order of the horizontal indicators.	3
99	105	Process Controllers: PLANT BYPASS VALVE/MANUAL CONTROLLER WATER TREAT PLANT/INLET VALVE/AUTO-MAN FLOW CONT	RL014	The association between the controller and its related display is not readily apparent. The cooling tower horizontal meter associated with the plant Bypass Valve is located to the right of the controller, while the Water Treat Plant Inlet Flow meter associated with the Inlet Valve is located to the left of the controller.	1. Relocate the horizontal indicators below their associated control, or 2. Functionally group related controller and indicator through the use of demarcation lines.	3

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SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
100	30	J-Handle Controls: CAL-BLAND-1 BUS B PCB V45 TIE-43 TIE PCB V43 START UP XFMR 1 BUS A PCB V41 CAL-BLAND-2 BUS A PCB V51	RL014	The characters used in identifying control position (TRIP CLOSE) are larger than the characters used in identifying the control	Relabel control position with a smaller front.	4
101	27	Simple Indicator Lights: SFGD XFMR B/BUS B SWITCHER/V25 CAL-BLAND-1/BUS B PCB/V45 GEN 1/BUS B PCB/V55 START UP XFMR 2/BUS B PCB/V75 CAL-MTGY-2/BUS B PCB/V85	RL014	Indicator lights are mounted rather high for the 5th percentile operator, exceeding the recommended location of 70 inches above the standing surface.	For Accessing Bulbs: 1. Move indicators to point within reach of 5th percentile operator, or 2. Provide a slip - resistant step stool.	4
102	131	Process Controllers: BLOWDOWN VALVE #2/ CONDUCTIVITY RATIO/AUTO MAN CONTROLLER BLOWDOWN VALVE #1/ CONDUCTIVITY RATIO/AUTO MAN CONTROLLER PLANT BYPASS VALVE/MANUAL CONTROLLER WATER TREAT PLANT/INLET VALVE AUTO-MAN FLOW CONT	RL014	The horizontal meters on the process controllers lack: 1. Numbered indicies and 2. Indication of function or process being monitored by the meter.	Add numerics to scale	4

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
103	55	HORIZONTAL METERS: ALL	RL014	Pointer is positioned at the top of horizontal scales making it difficult to see from normal operating position.	Reposition pointers so they're located below meters at the bottom of the scale.	4
104	190	HORIZONTAL METERS: DIESEL GENERATOR NE01 D.C. AMPS DIESEL GENERATOR NE02 FIELD AMPS	RL015	There is a discrepancy in meter labeling between one of the meters for the Diesel Generator NE01 and the Diesel Generator NE02 train. Similarly positioned meters within the two trains are labeled differently. This discrepancy should be investigated, and the meter which is incorrectly labeled should be relabeled.	Investigate disparity and either relabel the D.C. Amp meter in train A as Field Amps, or relabel the Field Amps meter in train B as D.C. Amps.	1
105	70	J- HANDLES: 4.16 KV BUS NB02 BREAKER 152 NB0109 NB H1S-3 4.16 kv BUS NB02 BREAKER 152 NB0212 NB H1S-5	RL015	These alternate breakers are not differentiated from their adjacent normal breakers, and as such, are vulnerable to accidental activation.	Protect against inadvertent activation by: -shielding the control with a transparent plexiglass cover guard -providing the control with an interlock so that extra movement (i.e., pull to activate) is required to engage the control.	2

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
106	67	J-Handle: -DG NEO1 SYNC Transfer SW NE HS-27 -DG NEO2 SYNC XFER SW NE HS-28 -4.16 KV BUS NBO1 BLR 152NBO109 SYNC NB HS-7 -4.16 KV BUS NBO1 BKR 152NBO112 SYNC NB HS-6 -4.16 KV BUS NBO2 BKR 152NBO209 SYNC NB HS-8 -4.16 KV BUS NBO2 BKR 152NBO212 SYNC NB HS-9	RLO15	These controls are designed with the numeral "1" occupying the central position between OFF and ON. The numeral "1" does not convey any meaningful information to the operators.	Resolve the confusion as to what the number "1" stands for and either: 1. Relabel the central position to convey more meaningful information to the operators, or 2. Remove the confusing numeral if it's determined that it doesn't belong there.	4
107	16	Horizontal Meters: DIESEL GENERATOR NEO1 KILOWATTS KILOVARS HERTZ D.C. AMPS AMPS KILOVOLTS DIESEL GENERATOR NEO2 KILOWATTS KILOVARS HERTZ FIELD AMPS AMPS KOLOVOLTS	RLO15	The meters are arranged in a matrix that lends itself to confusion. The only method for differentiating meters is by the labels on the meter scales The labeling on the scale face is not very visible.	Provide labeling adjacent to each meter that identifies it.	2

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
108	59	J-HANDLE: 4.16 KV PB03-PB04 TIE BKR 152 PB0401 PB H1S-5	RL015	This breaker is located in the lower left hand corner on panel RL015. Its ammeter is located in the lower right hand corner. The distance between the two is about 4 feet but is connected by a mimic line.	1. Relocate breaker to the lower right hand corner beneath its corresponding ammeter (which reads 4.16 KV PB03-PB04 BUS TIE AMPS PB 11-2). 2. Code the control and the display by color or some other distinctive visual code.	4
109	167	J-HANDLE: 4.16 KV BUS NB02 BREAKER 152NB0212 NB H1S-5 4.16 KV BUS NB01 BREAKER 152NB0112 NB H1S-2	RL015	The breakers come from ESF XFMR XNB01 but the labeling on panel RL015 at the beginning of the breaker mimic is vague as to the origin of the mimic.	Change the "OFFSITE POWER" label which is located at the beginning of the breaker mimic on Panel RL015 to read "FROM ESF XFMR XNB01."	3

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
110	60	J-Handles: 480 V XPG19-LC PG19 BREAKER 52 PG1901 PG H1S-16 480 V XPG20-LC PG20 BREAKER 52PG2001 PG H1S-18	RL016	The intentional or accidental tripping of these two breakers would result in a reactor trip. Given the criticality of the results of an inadvertant trip and the similarity of these controls with adjacent controls, they should be guarded.	1. Affix a cautionary label to the control explaining the consequences of tripping the breakers, or 2. Protect breakers against inadvertant actuation by: a) Recessing, shielding or otherwise surrounding the control by a physical barrier. b) Incorporating an interlock into the control so that extra movement (e.g. pull to engage) is required to trip the breaker. c) Shape coding the control handles.	3
111	65	J-Handle Labels: XMR01 to XNB01 BREAKER 252 PA0201 NB H1S-1	RL016	The label is wrong and should be rewritten to read XMR01 to XNB02 BREAKER 252PA0201	Relabel control as suggested	3

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
112	63	Mimic Line	RL016	There should be a section of gray mimic line connecting the 480 V XPG20-LCPG20 BREAKER 52PG2001 PG HIS-18 J-Handle Control to the 480 V LC PG19-PG20 TIE BKR 52PG1416 PG HIS-17 J-Handle Control.	Install missing mimic line	3
113	66	Mimic Line	RL016	Mimic Line is missing between the 13.8 KVPA02-XPB04 Breaker 252PA0208 PB HIS-2 J-Handle control and the 13.8 KV BUS to XFMR XPB04 AMPS PB 11-2 vertical indicator.	Install the missing mimic line.	3
114	69	Transformer Mimic for J-Handle Breaker Control: 480V XPG25-LC PG25 BREAKER 52 PG2501 PG HIS-24	RL016	The transformer mimic is upside down. The gray 480 V mimic should be on the bottom, and the black 13.8 KV mimic should be on the top.	Reverse transformer mimic as suggested.	3
115	183	Main Control Board: ESF CONTROL PANEL	RL017 RL018	The ESF Control panel has significant problems in mirror imaging. The RHR mimic is mirrored between A train and B train but the vertical meters are not. The CTMT spray mimics are mirror imaged. The SI mimic is not mirrored. The accumulator mimics look like they are mirrored but aren't. No other components on RL018 are mimiced. This mirroring creates performance problems alone, but the incomplete mirror imaging magnifies the problem.	1. The panel should be redesigned as the problems are to great to be truly corrected. 2. The problems can be lessened a little by complete mirroring of RL017, the use of functional demarcation lines, or background coloring.	1

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
116	178	Mimic Line Termination Labels: ACCUM MIMIC: - TO ACCUMULATOR A,B,C,D SI MIMIC: - FROM SAFETY INJ PUMP A - TO REFUELING WATER STORAGE TANK RHR MIMIC: - TO SAFETY INJECTION TEST LINE - TO ACCUMULATOR INJ DISCHARGE - TO SAFETY INJECTION PUMPS	 RL018 RL017	The Line termination labels for these mimics provide the operator with inaccurate information. In some cases the label says where the line is going when it should say where the line is coming from, and vice versa. In some instances the labels are wrong.	The mimics should be reviewed to determine more appropriate labels. Suggestions are: To accumulators = Accumulator To Safety Injection Test Line= To Accum Inj discharge Loop 3 To Accum Injection Discharge= To Accum Inj Discharge Loop 1. To refueling water storage tank = remove as is not really necessary From Safety Inj Pump A - to the destination To Safety Inj Pumps - From the source.	1
117	94	Pushbutton: BN HIS 88128 CIRCUIT/LAMP TEST BN HIS 8812BA BN HIS 88122A CIRCUIT/LAMP TEST BN HIS 8812AA	RL017	The two pushbuttons on each control are not labeled making it difficult to identify which pushbutton is for lamp test and which pushbutton is for circuit test. Also, there is some confusion as to what this control is used for.	Resolve disparity concerning pushbutton function and provide clear, unambiguous control labeling by: 1. Engraving control function in each pushbutton, or 2. Providing functional labeling above and below the appropriate pushbutton, respectively.	1

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
118	102	Simple Indicator Lights: -SI RETURN TO RWSR ISO VLV POSITION BN ZL-8813 -SI ACCUM INJECTION ISOLATION VLV POS EM ZL-8835A -SI PUMP B HOT LEG ISO VLV POSITION EN ZL-8802BA -RHR TO ACCUM INJ LOOP 3C4 VLV POS EJ ZL-8809BA -RHR/SI HOT LEG RECIRC VLV POS EJ ZL-8840A -SI PUMP HOT LEG ISO VLV POSITION FM ZL-8802AA -RHR TO ACCUM INJ LOOP 1&2 VLV POS EJ-ZL 8809AA EJ-ZL 88091	RL017	These indicator lights are located to the right of their associated controls rather than above them. Also, the identification labels are located below rather than above the lights.	1. Relocate indicator lights above their respective controls and affix identification labels above indicator lights, or 2. Use demarcation lines to make relationship apparent.	1
		ACCUMULATOR TANK B OUTLET VLV POSITION EP ZL-8809BA ACCUMULATOR TANK D OUTLET VLV POSITION EP ZL-8808DA ACCUMULATOR TANK A OUTLET VLV POSITION EP ZL-8808AA ACCUMULATOR TANK C OUTLET VLV POSITION EP ZL-8808CA	RLO 18			

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
118	2	Legend Light Matrix ESF system status Indication SA-166-Y and SA-066-Y	RL018	These redundant displays have significant problems. The major problems are: 1. Lack of identical layout between matricies 2. Inconsistent use of abbreviation 3. Inconsistent logic used in the NSSS monitoring system Details are in Appendix D-1	Correct the problems identified as suggested in Appendix D-1 or other suitable method.	1
120	184	Mimic-Accumulators	RL018	These mimics have lines that terminate without a label indicating destination.	Review the P&ID's to determine destination of all lines and label accordingly.	1
121	72	J-Handle: CONTAINMENT ISOLATION PHASE B SBHS-47	RL018	The control label has Phase B isolation when it is really Phase A.	Relabel with Phase A	1

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
122	50	Pushbutton Guards: CONTROL BUILDING VENT ISOLATION B FUEL BUILDING VENT ISOLATION B CONTAINMENT PURGE ISOLATION B AUX FEEDWATER ACTUATION B TO AUX FW PUMP ACTUATE CONTROL BUILDING VENT ISOLATION A FUEL BUILDING VENT ISOLATION A CONTAINMENT PURGE ISOLATION A AUX FEEDWATER ACTUATION A	RL018	The Guarding Mechanism for these controls consists of a plastic cover that is removed to operate. These covers are not permanently attached and will be easily lost.	1. Redesign the Guard so that it stays permanently attached and can't be lost, or 2. Remove the cover and insure that the Guard is of adequate depth to preclude inadvertent activation.	2
123	189	Vertical Indicators: CTMT ATMOS PRESSURE GN PI-935 CTMT ATMOS PRESSURE GN PI-937 CTMT ATMOS PRESSURE GN PI-934 CTMT ATMOS PRESSURE GN PI-936	RL018	Containment pressure is measured in PSIA on the above meters. For all other indicators, pressure is measured in PSIG.	Replace the PSIA meters with PSIG meters.	1

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
124	100	Trend Recorders: RHR HX Inlet/Outlet RHR Pump 2 Temperature EJ TR-613 RHR HX 2 RHR HX Inlet/Outlet RHR Pump 1 TEMPERATURE EJ YR-612 RHR HX 1	RL018	Inconsistent labeling between trend recorders on RL018 and their respective controls on RL017. Numbers (1&2) are used for component identification within trains on trend recorder, and letters (A&B) are used for component identification within trains on their respective controls. Nomenclature should be consistent between hardware. There should be a check valve logo on the mimic line leading to the reactor coolant system which serves to separate the "BORON INJ TANK EM HIS-8801B" and "BORON INJ TANK EM HIS-8801A" from the "SIS TEST LINE ISO VALVE EM HIS-8843" and "SIS TEST LINE ISO VALVE EM HIS-8882".	Standardize labeling of components within trains changing: a) numerals to letters; or b) letters to numerals so that a consistency is maintained.	1

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
125	71	J-Handle: BORON INJ RECIRC PUMP B EM-NIS-2 BORON INJ RECIRC PUMP A EM-NIS-1	RL018	These controls are located about 66 inches off the floor. This exceeds the maximum allowed for emergency controls of 57 inches.	Lower the controls on the board to within 57 inches.	2
126	145	Process Controller N_2 SUPPLY CTMT ATMOS ISO VLV EP #C-943	RL018	This controller is identified as a isolation valve when it is really a vent valve	Relabel label to read Vent Valve	3
127	119	Process Controller: N_2 SUPPLY CTMT ATMOS ISO VLV EP HL-943	RL018	This process controller relates to two separate mimic loops but visual connection is poor, due to a mimic line that terminates without a label specifying where it goes.	Install a label that specifies that the control interfaces with accumulators A and C. Example: TO ACCUM A and C	3

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
128	68	Trend Recorders: RHR HX INLET/ OUTLET TEMP EJ TR-613 RHR HX INLET/OUTLET TEMP EJ TR-612	RL018	For the trend recorders on panel RL018, the pointer totally obscures the shortest graduation marks on the face of the scale.	Adjust pointer so that it extends to, but does not obscure the shortest scale graduation marks.	3
		RCP A SEAL LEAKOFF & INJ/FLOW BG FR-157 RCP B SEAL LEAKOFF & INJ/FLOW BG FR-158 RCP C SEAL LEAKOFF & INJ/FLOW BG FR-159 RCP D SEAL LEAKOFF & INJ/FLOW BG FR-160	RL022	For the recorders identified on panel RL022, the pointer totally obscures all graduation marks along with the numerals.		

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
129	124	Pushbutton: ACCUMULATOR TANK FILL LINE ISO VALVE EM HIS-8888	RL018	This pushbutton is associated with all accum tanks but is located such that it can be inferred that it applies only to B&D trains.	1) Provide a yellow and red identification label to serve as a visual cue to remind operators that this control effects both trains, or 2) Extend a red mimic line from the pushbutton to the label which reads "TO ACCUMULATOR TANKS," or 3) Append above label to read TO ACCUMULATOR TANKS B&D A&C	4
130	186	Simple Indicators: CCW PUMP B RESET EG 2L-21 CCW PUMP D RESET EG 2L-23 CCW PUMP A RESET EG 2L-22 CCW PUMP C RESET EG 2L-24	RL019	The arrangement of indicators is not consistent from application to application. The above indicator lights are placed to the right or left of their associated control rather than above it.	1) Relocate the indicator lights above their respective controls or move lights closer, or 2) Use Demarcation Lines for visual association, or 3) Address through training.	2

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
131	173	Mimic Lines: Intersection at labels for following: CCW TO RCS ISOLATION VALVE EG HIS-71 ESW A/SERVICE WATER CROSS CONNECT VALVE EF HIS-25 ESW TRAIN B RAD MONITOR ISO VLV EF HIS-88 ESW A TO CCW HX A EF HIS-51	RL019	The mimic line intersects the above labels, implying a connection when there is none.	1. Shorten the label plates to allow clear space for the Mimic Line. 2. Inscribe the Mimic Line on the Label.	2
132	107	Permissives/blocked/ partial trip status panel	RL022	The legend labels on the indicators are 0.125 inches high, much too small for reading from the operators console.	1. Increase label size 2. Investigate use of a magnifying screen.	1
133	90	Vertical Display (Labeling): PZR RELIEF TANK - LEVEL - PRESSURE - TEMPERATURE REACTOR COOLANT LOOP FLOW	RL021 RL022	The labeling is on one line with the flow, etc., on a second line. This tends to create the impression that only one of a string of three is flow, rather than all of them being flow.	The "PZR RELIEF TANK" lettering should be larger than the level, etc. lettering. The "REACTOR COOLANT LOOP" lettering should appear on a separate label that is centered above the 4 flow indicators with the word "FLOW" centered above each indicator or, FLOW should be moved up to the same line as reactor coolant loop.	4

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
134	93	Pushbutton: RC DRAIN TANK HX DISCHARGE ISO HB HIS-7176	RL021	The standard abbreviation for normal is NORM. However, on this particular pushbutton the word is spelled out in its entirety and divided. NOR MAL	Replace the "NORMAL" pushbutton with a pushbutton labeled "NORM."	4

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
135	9	Legend Lights: PERMISSIVE/BLOCKED PARTIAL TRIP STATUS SA-0682	RL022	1. Legend plates are not keyed or coded to prevent accidental interchange during maintenance. The matrix is particularly vulnerable during bulb removal since plates are not locked into position. A slight displacement of the grid from vertical during removal will result in a radical alteration to the indicator order. 2. The Display is extremely difficult to use as designed now. See Appendix D for details.	1. Code legend plates for visual reference as to correct position. 2. See Apprendix D for recommendations.	1
136	44	LED Display: DR PI	RL022	To have an adequate view of all rod position indicators, the operator must leave his position at RL003 and move to RL005.	1. Angle the right side of the display towards the operator's position at RL001&2 to make all the rod positions visible, if seismically possible, or 2. Address through administrative procedures and training.	1

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
137	147	Trend Recorders: RCP A,B,C,D, SEAL LEAKOFF AND INDICATOR	RL022	1. The bottom scale on the recorder obscures the top of the paper. 2. The Pointer on the bottom scale is behind the scale.	Raise the bottom scale and adjust the pointer to be placed in front of the scale.	4
138	193	J-Handle: RHR PUMP ROOM SUMP PUMP B LF HIS-5 RHR PUMP ROOM SUMP PUMP A LF HIS-6 RHR PUMP ROOM SUMP PUMP D LF HIS-19 RHR PUMP ROOM SUMP PUMP C LF HIS-20	RL023	The Controls are arranged in the following order: B A D C This violates population sterotype and is not organized in a proper sequence for smooth operation.	Rearrange the controls in the following order: A B C D or arrange the CTMT Sump Pump Controls A-D from left to right. The RHR Pump Room Sump Controls can then be placed A-D from left to right underneath the CTMT Sump Controls.	4

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
139	38	Simple Indicator Lights: AIR COMPRESSOR C KA QL-1 AIR COMPRESSOR B KA QL-2 AIR COMPRESSOR A KA QL-1	RL024	The Air Compressor C Indicator Lights are located over the Air Compressor A Reset Control. The Air Compressor A Indicator Lights are located to the right of Air Compressor B Lights.	Move the Air Compressor C Indicator Lights to the place where the Air Compressor A Indicator Lights are now and vice versa.	4
140	117	Vertical Meters: Simple Indicators: MAIN STM RHTRs	RL024 RL024	1. The vertical meters are off-set to the left of their associated controls by about 6 to 12". 2. The simple indicators are offset to the left and arranged in a 2x2 matrix rather than being located under their associated vertical meters. 3. The vertical meters are labeled in an inconsistent manner.	The following controls and displays should be moved to the left (where RHTR A displays and MN STM to MSR indicators are now;) -vertical meters AC P1-505 and AC P1-506 -J-Handle AC PS-505Z The RHTR vertical meters should be shifted to the right and the main STM to MSR indicators should be placed under the appropriate vertical meter. The labeling for the vertical meters should be standardized.	4

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
141	116	Pushbuttons: MN STM/FW ISO VLV ACCUM CHARGE TEST AB HS-66 MN STM/FW ISO VLV ACCUM CHARGE TEST AB HS-68 MN STM/FW ISO VLV EXERCISE ACTUATE AB HS-70 MN STM/FW ISO VLV EXERCISE ACTUATE AB HS-73	RLO25	Controls are functionally and sequentially related but are not grouped together. They are placed next to "sensitive" pushbuttons used only in a shut-down or emergency situation, and can be associated with the MAIN STM loops or STM generators when they control valves across all the steam loops.	1. They should be grouped together and demarked to preclude any association with a specific steam loop, or 2. Use demarcation lines to separate out of Steam Generator Groups.	4
142	130	J-Handle and simple indicators for main turbine lift pumps	RLO25	The labeling between the J-Handles and their associated indicators does not imply the the relationship. The main turbine Oil Lift Pump Lights Label does not imply which bearing it is associated with.	Relabel to make the relationship clear. Example: MN TURBINE OIL LIFT PUMP 1 FOR BEARING 3.	3

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
143	170	J-Handle MAIN TURBINE TURNING GEAR MOTOR AC HIS-30C/PG13RAF2	RL025	J-Handle control setting values do not increase with a clockwise rotation; The sequence is from Stop, Run (Fast Speed), to Run (Slow Speed)	Rewire and relabel control so that the sequence of activation from left to right is STOP, RUN (Slow Speed), RUN (Fast Speed).	4
144	187	J-Handle MN TURBINE LIFT PUMP BEARING 3 4 5 6 7 8 10	RL025	"AUTO" label on control setting is a decal and therefore subject to easy removal.	Permanently affix "AUTO" label to control by engraving or etching label into control surface and filling with a black pigment.	4

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
145	88	Trend Recorders: STEAM GENERATOR A & B WIDE RANGE LEVEL AE LR-501 STEAM GENERATOR C & D WIDE RANGE LEVEL AE LR-503 STEAM GENERATOR A & B PRESSURE AB PR-514 STEAM GENERATOR PRESSURE AB PR-555	RL026	The labeling for the 2 pointers on each recorder inconsistently refers to train A&B as 1&2 respectively. Examples: SG LP 1 W-RNG LVL (%) SG LP 2 W-RNG LVL (%)	Change the labeling on the Trend Recorder face to SG A, SG B, SG C, S` D.	2
146	39	Trend Recorders: STEAM GENERATORS A & B WIDE RANGE LEVEL STEAM GENERATORS C & D WIDE RANGE LEVEL STEAM GENERATORS A & B PRESSURE STEAM GENERATORS C & D PRESSURE Vertical Displays: STEAM GENERATOR A, B, C, D, LEVEL STEAM GENERATOR A, B, C, D, PRESSURE	RL026	These displays must be read while operating a control on the RL006 panel. The viewing distance is approximately 10 feet. The character height is .25 inches. For effective reading from that distance the characters should be 0.65 inches. The problem is further compounded by combining two steam generator wide range levels on one trend recorder. This makes reading the second steam generator (B and D) difficult as the pointer is placed below and recessed behind the scale.	1. Increase the size of the scale characters to 0.65 inches. 2. Move the RL006 console closer to the RL026 console. 3. Incorporate steam generator wide range level and pressure indicators into the RL006 panel.	2

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
147	194	Trend Recorders: STEAM GENERATOR A & B WIDE RANGE LEVEL STEAM GENERATOR C & D WIDE RANGE LEVEL STEAM GENERATOR A & B PRESSURE STEAM GENERATOR C & D PRESSURE	RL026	These are grouped so that all the STM Generator A Trend information is not grouped with the other STM Generator A information, etc., You have STM Generator A level in with STM Generator C Displays etc.	Combine each separate STM Generator Level and Pressure on the same recorder and group with the appropriate Controls and Displays.	4

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
148	115	Vertical Meters: MFW PUMP TURB A TURB BRG OIL PRESS FC PI-64A MFW PUMP TURB B TURB BRG OIL PRESS FC PI-164A MFW PUMP TURB A PUMP BRG OIL PRESS FC PI-68A MFW PUMP TURB B PUMP BRG OIL PRESS FC PI-168A	RL026	The vertical meters are arranged in the following sequence: Turb A Turb BRG Oil, Turb B Turb BRG Oil, Turb A Pump BRG Oil, Turb B Pump BRG Oil; The associated controls for Pump A are in a vertical column below the TURB BRG Oil Press Meters and the Controls for Turb B are below the Pump BRG Oil Press, creating a poor functional grouping of Turb A displays with controls, and Turb B displays with controls.	Group the Turb A meters above the Turb A Controls and the Turb B Meters above the Turb B Controls.	3

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HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
149	47	J-Handle: SYNC CHECK RELAY BYPASS MA HS-7	RLO27	J-Handle control violates direction-of-movement stereotypes.	Relabel and rewire the control to convert it to the following direction of activation, Function — Control Action on — right, clockwise off — left; counterclockwise raise — right, clockwise lower — left; counter-clockwise	3
150	123	Rotary Control: SYNC CHECK RELAY BYPASS MA HS-7	RLO27	The handle is removable in either ON or OFF position. This creates a confusing situation where the operator cannot visually verify the switch position	Redesign so that the handle can be removed only in the OFF position.	3

HUMAN ENGINEERING FINDING SUMMARY

SUMMARY NUMBER	HEF NUMBER	ITEM DESCRIPTION	LOCATION	FINDING	RECOMMENDED BACKFIT	PRIORITY
151	182	Trend Recorder: MAIN TURBINE ECC/SPEED VLV POS	RL028	The glass Cover is distorted and not transparent making readinc through difficult.	Replace the Glass with a clear glass.	3
152	181	Impact Recorders: MAIN TURBINE VIBR.TION AC YR-141 MAIN TURBINE TEMP & EXPAN AC UR-140	RL028	1) The recorded data is printed on top of other data, making it totally illegible. 2) The graph lines are light blue rather than black, lending toward problem of poor legibility and contrast. 3) The scaling on the graph paper does not correspond to the horizontal scale on the impact recorder.	1) Adjust recorder so printed data does not obscure previously recorded data. 2) Replace graph paper with paper that has black grid lines. 3) Provide graph paper with scaling that corresponds to the horizontal scale on the impact recorder.	4

APPENDIX B

EVALUATION OF COMPUTER SYSTEM MAN/MACHINE INTERFACE

1.0 BACKGROUND

The SNUPPS computer system contains equipment located in the computer room, turbine building, electrical penetration-separation groups, and the control room. The Balance of Plant (BOP) System communicates, via data links, with the Nuclear Steam Supply System (NSSS) and with an off-site computer. The BOP system provides the primary computerized plant interface for the operator and supports process data acquisition, alarming, logging, point maintenance functions, and appropriate data links with the NSSS and off-site computer facilities.

A variety of sensors, contact inputs/outputs, analog outputs and counters are supported by the BOP system. Processing capabilities include:

- Validity checking of sensors, equipment
- Linearization
- Zero clamp
- Calibration correction
- Conversion of internal units to engineering units
- Process alarm testing (contact cutout, process limits, significant limits, deadband)
- Point/alarm status establishment
- Process or validity alarm initiation
- Value status establishment.

The SNUPPS BOP system comprises two TDC 4500 computers. Either computer may (at any given time) assume the function of the on-line BOP computer. Concurrently, the other computer will assume the backup BOP computer function. The two BOP computers, the NSSS computer are utilized to meet the computational requirements of SNUPPS. To efficiently convey the required data between the various computers, three dissimilar data links are used:

- Asynchronous serial link between NSSS and on-line BOP
- Asynchronous parallel link between backup and on-line BOP
- Synchronous serial link between on-line BOP and off-site computer.

These communication links allow passage of various types of data to the printer or to color television monitors, for review by the CR operator. Alphanumeric characters, punctuation marks, format symbols, and graphic symbols are used to represent the plant process information, including:

- Data base initialization
- Value/status and calibration for analog and calculated addressable points
- Alarms
- Digital point changes
- Nuclear performance calculations
- Data link disable/failure
- Peripheral device status.

Information can be entered on the display monitor by either the computer or the keyboards. The displays can have almost unlimited format and content. Textual and numeric information can be displayed as well as schematic representations of the process or control system. Using a keyboard, the operator and the computer can exchange information quickly and effectively. The operator may request information from the computer, transmit information to the computer.

Specialized computer functions and CRT outputs for any of the four CRTs are initiated by the operator through either of the two keyboards. Some printer outputs are automatically generated, whereas others are on a "demand" basis and are keyboard-initiated. These hard copy outputs are generated on the operator's printer, which is not located in the control room itself.

This evaluation summarizes the human factors aspects of the Honeywell Process Video (HPV-2) Display Subsystem components which the control room operator uses either to input commands or data to or receive (output) data from the computerized data system. These components include the four CRTs, two keyboards, and the display formats that are generated as part of this subsystem. The Terminet printer used to obtain hardcopy of various computer outputs is not located in the control room itself; therefore, the human factors review of its operation and capabilities will be relatively brief.

2.0 RESULTS

2.1 Keyboards

Two Aydin Model 5115 keyboards are provided. One of these is positioned for standing operation below the two rack-mounted CRTs on the RL020 panel; the other, suitable for seated operation, is positioned below and in front of the desk-mounted CRTs (on the RL003 panel). Both CR keyboards are functionally and physically identical, enhancing operator performance using either one.

Standard keys are the alphanumeric keys, punctuation keys, cursor control keys, color switch keys, edit function keys, transmit data keys, and a 10-numeral key pad. In addition, a 45-key function code panel is flanked on either side by large ENABLE keys. The operator can transmit a function code to the computer by pressing the desired function key. The computer software recognizes the function code as specifying that a predetermined system function is requested by the operator.

Each keyboard is vertically divided into three areas, each of which holds two horizontal groups of keys. Each of the six key groups is clearly and easily distinguishable from the others. The key labels are visible and legible, both from a seated and a standing position. The keys are easy to operate and give distinct tactile feedback when activated.

The upper third of the keyboard contains a 45-key function keyboard (three rows with 15 keys each) flanked by two large ENABLE keys and a group of four channel selector keys. The function keys are color coded by function:

- Grey — ENABLE keys
- Red — operator functions
- Cyan — log functions
- Green — point function
- Blue — menu list functions
- Yellow — maintenance function
- Magenta — display summary function
- White — engineer functions or unlabeled (unused) keys.

The color coding is an excellent concept and would be immensely valuable if carried to its logical conclusion, i.e., grouping all keys of the same color together, thereby combining color and position coding to reinforce the operator's memory for key functions. At present, the magenta keys are all physically adjacent, as are the cyan, the blue, and the yellow keys; the green and red keys are somewhat randomly distributed.

The keys, color, and functional group are listed in Figures 1-3, in order from left to right, beginning with the topmost row.

Appendix A in the SNUPPS BOP Operator Function Summary lists each function key with its selectable software options, required operator input data, and error messages.

The four-channel select keys are white with black labels and numbered in logical sequence (1-4) from left to right. These keys allow the operator to designate which of the four CRTs will serve as the output device for data being entered at the keyboard or retrieved from the computer. Software functions also are available to permit the operator to designate the output device.

The middle third of the keyboard contains a bank of color-coded edit function keys and a set of five cursor control keys. Except for the DC POWER button (which illuminates when pressed to activate the keyboard), the edit function keys are used, not by the control room operator, but by technical personnel, for quick and easy modification of displayed information and screen display formats.

The cursor keys are grey with white labels and provide the capability to move the cursor up, down, left, right, and to the home position. Pressing two of the keys at the same time will move the cursor at a 45° angle in the direction of the two keys. The home key moves the cursor to the first character position on the first line of the display.

The lower third of the keyboard contains a display data keyboard and a number pad, both containing grey keys with white labels. The display data keys allow for the transmission of a total of 128 display symbols. Of these 128 symbols, 64 are alphanumeric and punctuation characters, 4 are tab, cursor, and selective characters, and 60 are special graphic symbols. The keys are positioned in a standard QWERTY arrangement, with SHIFT LEFT and SHIFT RIGHT keys provided to activate either of two uppercase characters for each key. (Lowercase character is standard QWERTY capital letter or digit.)

The number pad is arranged in calculator fashion, with numerals 7, 8, and 9 at the top, rather than in the recommended telephone-set fashion (numerals 1, 2, and 3 at the top).

FIGURE 1

First (Top) Row of Keys

Key	Color	Functional Group
Blank	White	None
Blank	White	None
Post event review	Red	Operator
Trend pen select	Magenta	Display summary
Pen summary	Magenta	Display summary
Decimal point display	Magenta	Display summary
Summary display	Magenta	Display summary
Bar chart	Cyan	Log
Group display	Cyan	Log
Operator log	Cyan	Log
Operator log summary	Cyan	Log
Demand Log	Cyan	Log
Repeat log	Cyan	Log
Point summaries	Green	Point

FIGURE 2

Second (Middle) Row of Keys

Key	Color	Functional Group
X/Y plot	White	Engineer
Build point log	White	Engineer
Build page	White	Engineer
Video trend	Red	Operator
Print region	Red	Operator
Major equipment log	Red	Operator
Four blank keys	White	None
NSSS demand	Blue	Menu list
System index display	Blue	Menu list
Alarm review	Red	Operator
Alarm CRT select	Red	Operator
Alarm acknowledge	Red	Operator

FIGURE 3

Third (Bottom) Row of Keys

Key	Color	Functional Group
Blank	White	None
Point display	Green	Point
Point print	Green	Point
Point trend	Green	Point
Insert value	Yellow	Maintenance
Delete point	Yellow	Maintenance
Alarm ignore	Yellow	Maintenance
Point restore	Yellow	Maintenance
Restore peripheral	Yellow	Maintenance
Restore process I/O controller	Yellow	Maintenance
Device test	Yellow	Maintenance
Point calibration	Yellow	Maintenance
Change time/date	Red	Operator
Blank key	White	None
Repeat	Red	Operator

Operator keyboard functions and activities are discussed in detail in the SNUPPS BOP Operator Function Summary (Pub # 51001914).

2.2 Display Screens

Two 25" CONRAC Model 5111 CRT screens are rack-mounted side by side in a fixed position on the RL020 panel, with no provisions for adjusting the screen orientation about either the horizontal or vertical axis. The bottom edges of the screens are approximately six feet from the floor, producing some difficulty in reading characters near the top or bottom of the screen when standing at the rack-mounted keyboard. For accurate reading of the screen contents of these CRTs, the best position is in a standing posture directly in front of the Operator Control Console (OCC), between the OCC and the RL020 panel (thus blocking the view of an operator seated at the OCC, in front of the two 19" desk-mounted CRT screens in the OCC). As one moves either to the right or to the left of the rack-mounted CRTs to operate controls on the RL011, RL026 or RL028 panels, accurate reading of the screen contents is impaired. This is aggravated by glare, ambient lighting, and the lack of easily accessible controls to adjust contrast, brightness, or color.

Two 19" CONRAC Model 5111 CRTs are mounted in a fixed position side by side on the extreme right end of the OCC (panel RL003). The screen contents of these CRTs are easily read by an operator in either a standing or seated position directly behind the OCC. As one progresses to the extreme left end of the OCC (panel RL001), screen formats are increasingly hard to read.

Seven colors (magenta, blue, white, green, red, yellow, and cyan) are used for display characters. All colors are distinguishable from a distance of two feet or less, although characters in magenta or blue are more difficult to see or read at greater distances.

One operator can control the output to all BOP CRTs from either keyboard allowing for one-man operation. However, an operator standing at the rack-mounted keyboard cannot read the contents of the desk-mounted CRTs, and an operator positioned at the desk-mounted keyboard cannot easily read the screen contents of the rack-mounted CRTs.

When two operators are using the keyboards simultaneously, the potential exists for one operator's requested CRT displays to be erased, inadvertently or otherwise, by the

other operator. As yet, no integrated communications strategy and operating procedures have been developed or documented for operator use of the computer system devices in the control room.

The CRTs use a scanning rate of 50 frames per second, with 357 scan lines per field, at a horizontal scan rate of 17,850 lines per second, in a noninterlaced field scan mode. The 48 display lines used 336 of the 357 scan lines. The remaining 21 lines are used at the upper and lower display edges and in the vertical fly-back. Preset controls for contrast, brightness, and color are enclosed within the chassis and are not accessible to the plant operator.

Each display is formed by a matrix of 80 character positions on each of 48 display lines, to produce a total of 3,840 standard size character slots. Large size character slots are made up of two character positions by two display lines to form a matrix of 40 by 24, for a total of 960 large size character slots.

Each standard size character position on the display consists of a matrix of 7 vertical scan lines by 7 horizontal bit positions. Alphanumeric characters are displayed within the character position on a 5 by 5 matrix, while graphic characters are displayed in the full 7 by 7 character position matrix.

Each large size character position on the display consists of a matrix of 14 scan lines by 14 bit positions, with the display character being displayed within a matrix of 9 scan lines by 7 bit positions.

A blinking underline marker called the cursor is always present on the screen. The cursor indicates either the position at which the next entered character will be displayed, or the location from which a character will be read for a transmit operation. The cursor may be controlled by the operator from the keyboard and can be moved to any position on the screen witnout changing any of the displayed data.

Color signals are carried to the CRT on three cables, one each for red, green, and blue outputs. The seven available colors (white, yellow, magenta, cyan, red, green, and blue) are derived by switching the three outputs on or off, in combination, to produce the desired color. The use of pure blue for character display rarely produces a satisfactory character appearance because when the CRT is adjusted to produce a pure white, the

brightness and contrast of the blue video is so low that the character may not easily be seen.

All characters are upright (not slanted), and there is no problem in distinguishing the letters "O" and "I" from the numerals "0" and "1." The following character dimensions are utilized for 19" and 25" CRT screen displays of standard size characters:

	19" (48.26 cm) Display	25" (63.5 cm) Display
Position/Graphic		
Height	.20" (.50 cm)	.27" (.69 cm)
Width	.18" (.46 cm)	.24" (.61 cm)
Alphanumeric		
Height	.15" (.38 cm)	.20" (.50 cm)
Width	.13" (.33 cm)	.17" (.43 cm)

For large size characters, the following dimensions are used:

	19" (48.26 cm) Display	25" (63.5 cm) Display
Position		
Height	.40" (1 cm)	.54" (1.38 cm)
Width	.36" (.92 cm)	.48" (.86 cm)
Alphanumeric		
Height	.27" (.69 cm)	.36" (.91 cm)
Width	.18" (.46 cm)	.24" (.61 cm)

There are 60 graphic characters available for use in building shape coded symbols (e.g., pipes, shapes, lines, tanks). Twenty-three of the characters are made of 1 dot wide strokes, 19 of 3 dot wide strokes, and 18 symbols of general use (e.g., arrows, hollow square, solid square).

2.3 Display Formats

The Honeywell SEER, VIEW, and RTMOS permit real-time definition and maintenance of screen display formats. Plant process data can be displayed within the predefined formats on the CRT screens.

These software modules provide a set of powerful and flexible tools for developing CRT displays. A wide variety of features is available:

- Single or multiple pages
- Standard or user-defined title or text blocks on every page

- Alphanumeric text
- Graphic, point value/quality, or point description/engineering value data
- Conditional attributes (e.g., open/closed, on/off) represented according to analog alarm status, digital point status, analog/digital conversion (levels, flow, etc.)
- Attributes such as color, blink status, intensity, video status, character size, orientation, and data refresh rate, that can be associated with any display item for enhancement of critical information
- Eight-color coding scheme: magenta, blue, white, green, red, yellow, cyan, orange
- One hundred twenty-eight characters including graphic and punctuation symbols, mathematics, engineering, and power symbols, and Greek letters
- Predefined displays for group, page, point, alarm, video trend, bar graph, and summary displays
- Graphic symbols for use in constructing displayed process lines, pumps, valves, breakers, and other devices or equipment
- Bar chart display for up to 10 operator-designated sets of points and scale limits per display page
- Vertical video trend display for up to four uniquely colored, operator-selected points and trend limits, base, and interval with optional shading
- Point summary displays, including summaries of out-of-scan analog/digital values; analog, digital, and composed points in alarm; analog/digital values that have been manually inserted in the data base; field association comparison; point/status internal addresses; point status/value and limits data
- Trend summary displays for decimal points, analog trend pen points, or operator log points
- Point maintenance functions allowing the operator to substitute temporary values for inputs, calculated values, or constants (thereby suspending normal scan); to remove analog input, composed value, contact input, or composed contact from alarming; or to restore points to scan or alarm.

The operator's keyboards are used for operator requests to the computer. Console operation is in conversational mode and uses the conversation area of the screen for operator input and computer responses. In this mode, the computer asks for one item of

data at a time, accepts the input, and validates it before proceeding to the next item. Invalid operator input causes an error response. When a Point ID is needed for a request, the computer displays the point's descriptive name after the operator has entered the Point ID. If no console input is received within a fixed time period, or if the operator enters an abort request, the request is aborted and the conversation area returned to its former status. A function request in process may be restarted or aborted in favor of another function by pressing the desired function button.

Selected functions, such as the NSSS Operator Console Requests, are initiated via menu lists that display the available functions or parameters for each menu. Included on the display line for each function are the parameters or range of parameters required to initiate the function and an identifier for the operator to use in selecting the desired function. When the desired function is selected, the function line and its associated parameters are highlighted to aid the operator's scanning activities.

Video operations are generally divided into two parts: the initial honoring of the request, at which time the entire data required is displayed; and a cyclic updating of values. If the operator is making a request, the updating will skip cycles for that screen only until the format is stable. Video demand functions preempt the current demand screen without the operator having to cancel previous requests.

Page-forward and -backward capabilities are provided to permit operator review of data for a function extending over multiple screen images or "pages." A page is defined as that group of items that can fit in the area of the screen used by the function selected.

Color coding for computer/operator interaction is as follows:

- Computer questions — yellow
- Operator responses — green
- Error messages — cyan
- Acknowledge/verification messages — green.

Color coding for demand displays is as follows:

- Points in normal status — green
- Analog points in alarm — yellow
- Digital points in alarm — red

- Out-of-service/failure messages — cyan
- Message types (headers, etc.) — white.

Screen display formats for some 25 plant subsystems have been developed. Ten of the subsystems have multi-page display formats; the other subsystems have single-page screen displays. These displays are accessible by pressing the Plant System index function key and then entering the page number.

These display formats portray key elements of schematic P&ID representations for the individual subsystems, with point and parameter values, status, and tolerance limits. Labels clearly identify subsystem interfaces, Point IDs, and parameter values appropriate to the respective subsystems.

On all screen formats, the following data fields occupy a standard position:

- Time (HH:MM:SS) — upper left corner
- Date (MM/DD/YY) — upper right corner
- Subsystem Title — top center line
- Subsystem Code — centered below Subsystem Title
- Engineering Units — bottom line
- Operator Precautionary Messages — bottom center of screen.

The cursor is clearly distinguishable from all other characters and blinks continuously. Cursor positioning movements by the operator are minimized by software features and keyboard TAB, REVERSE TAB, and PAGE keys. As data are entered on the keyboard, they are displayed on the screen.

The system provides extensive flexibility to the operator in controlling the amount and complexity of information displayed by choosing specific display frames (although specific subsystem display formats are predetermined during display construction), or by using the specialized function keys to request associated information displays for bar charts, video trends, points, logs, alarms, and so forth, for operator-designated parameters.

Standard symbols have been developed to represent the location, configuration, and status of 11 devices (valves, dampers, transformers) and 18 pieces of equipment (pumps, fans, steam generators, heat exchangers, turbines, tanks, and so forth) in the subsystem

display formats. Some of these symbols are identical to those used in the SNUPPS P&IDs, while others are similar, and several do not appear on the P&ID symbol legends at all. The symbols are all sufficiently unique to facilitate rapid operator identification of the respective device or component and its status.

For electrical breakers only, color coding is used to indicate closed (red)/locked out (green) status. For process lines and in-line equipment in the subsystem screen formats, the following color coding conventions are observed:

- Cyan — flowing liquid fluid
- Magenta
  - pressurized steam
  - energized electrical systems
- White — operating ventilation air
- Blue — pressurized hydrogen and nitrogen containing lines and enclosures
- Green
  - nonflowing liquid fluid
  - nonpressurized steam or gas
  - deenergized electrical systems
- Yellow
  - active process line with undefinable actual status due to lack of computer-based information
  - equipment outline such as tanks, heaters, etc., when no other behavior is specified.

Alphanumeric information on the subsystem screen formats is color-coded as follows:

- White
  - date and time
  - parameter values within normal limits
- Red — parameter values in alarm condition
- Black on yellow background — static, nonvariable data (titles, equipment labels, engineering units, parameter identifiers prefixing parameter values, last revision date, other notes).

The use of the varied color coding conventions tends to place a burden on the operator's memory and contributes to stimulus overload in emergency situations, rather than facilitating search and scanning behavior. The computer software has capabilities

for associating altered color, blink status, or video status with alarm conditions in device status (open/closed, on/off, digital point status, analog alarm status, or analog/digital conversion of levels, flows, etc.). Utilizing more of these capabilities rather than relying so heavily on color coding techniques would enhance operator performance.

The operator's videos are partitioned into two 24-line regions and a full screen 48-line region. The upper 24-line region is primarily intended for operator communications. When not in use, however, the operator communication area may be used to present point or group displays, point trends, bar charts, summaries and half page schematics. The same displays are also applicable to the bottom 24-line region. The full screen region permits display of full page schematics.

The Alarm Video is divided into two regions. The top region is for primary alarms, while the bottom is for secondary alarms. Additionally, the lower 24 lines of the Alarm Video may be used for operator communications when the video is not being used to display alarms.

The following are considered to be primary alarms:

- Analog sensor failure
- Analog sensor reading unreasonable
- Process limit exceeded
- Significant limit exceeded
- Contact group validity failure
- Abnormal equipment status as detected by a digital change of state
- Peripheral failure
- PIU Failure
- Highway Failure
- PIU Board Failure
- NSSS function acknowledgements (advisory message)
- Backup computer failure.

A maximum of nine primary alarms may be displayed on one page at a time. These primary alarms are displayed in double size characters, on the top 24 lines of the screen.

The following are considered to be secondary alarms:

- Analog validity
- Analog sensor reading unreasonable
- Abnormal equipment status
- Digital group validity
- Peripheral failures
- PIU failure
- Highway failures
- PIU board failure
- Returned to normal
- NSSS function acknowledgements (advisory message)
- Post event review advisory message.

A maximum of nine secondary alarms may be displayed on one page at one time. These secondary alarms are displayed, using small size characters, on the bottom 24 lines of the screen.

The alarm display, whether for primary or secondary alarms, contains the following data:

- Time of alarm
- Point/alarm status
- Point ID
- Point name
- Point value (or status if contact)
- Value status
- Engineering units (if not contact)
- Violated limit (if not contact)

Formats for alarms and other operator messages have been developed that include certain data fields appearing in standardized positions within the message. These data fields include:

- Time — HH:MM (messages) or HH:MM:SS (alarms)
- Message type — one of 32 6-character symbols specifying reason for message
- Point/alarm status — one of 32 4-character symbols documenting point status

- Point ID — 9-character symbol identifying process variable
- Point name — alphanumeric descriptor identifying process variable
- Point value, increment or limit — numeric data preceded by 2-character alpha code indicating increment or limit
- Value status — 1-character alpha code mnemonic indicating quality of value
- Engineering units — one of 128 6-character codes defining meaning of value
- Alphanumeric message — general information
- Computer cycle time or (optionally) millisecond time
- Equipment status — one of 128 6-character symbols indicating equipment status
- Contact status — 0 (open) or 1 (closed) state of digital equipment contact.

The various symbols utilized to represent the data fields conform to population stereotypes, use mnemonic codes or abbreviations, and conform to HFE recommendations for lengths of character strings.

A variety of video display capabilities are provided to assist the operator in monitoring plant data:

- Group displays — for displaying values of more than one point at a time
- Point displays — for displaying value of any point
- Page displays — for displaying alphanumeric pages (including point values and status)
- Alarm review — for displaying alarms in sequence of occurrence (most recent alarms are displayed first)
- Primary alarms — process limits, digital status, data link failure
- Secondary alarms — analog validity, digital validity, peripheral failures, process I/O failures
- Summary displays — point summaries
- Video trends — allows operator to select up to four points for trending on video at one time (each trend is assigned a unique color)
- Bar charts — operator selects points and point limits to be displayed
- NSSS function acknowledgements

- Operator advisory messages.

2.4 Hard Copy Capability

No hard copy device is planned to be immediately accessible by the operator in the control room. However, an extensive output capability is provided on the operator's printer. If the operator's printer were located in the control room and were provided with adequate acoustic shielding, the printed outputs would enhance the operator's monitoring and diagnostic performance. These printed outputs are briefly summarized below.

A number of periodic logs of point values and status are produced on the operator's printer. These logs include the following:

- Plant alarms
- Operator messages
- NSSS function acknowledgements
- Summaries
- Sequence of Events.

3.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the human factors aspects of the Honeywell Process Video Display Subsystem components used by the control room operator for inputting data to or receiving (outputting) data from the SNUPPS computerized data system.

In general, the equipment is accessible, well designed, and easy to operate; the software provides an intensive and flexible set of capabilities for designing output display formats used to present a variety of types of information to the operator. The system may be comfortably utilized by a single operator, although two-man operation is also feasible. Those aspects of equipment or display format that should be modified to enhance operator performance are highlighted in the paragraphs below. It would also be desirable to include written guidelines for using the computer system under a comprehensive or integrated communications strategy.

3.1 Keyboards

The numeric key pad is arranged in calculator style (numerals 7, 8, and 9 at the top) rather than in the recommended telephone-set style (numerals 1, 2, and 3 at the top).

The 45-key function keyboard contains various color coded function keys. The green (point function) keys, the red (operator function) keys, and the white (engineer function or unlabeled) keys are not grouped by color, but are somewhat randomly distributed. Grouping of all keys of one color has been followed for the magenta, cyan, blue and yellow keys; this grouping procedure should be extended to include the green, red, and white keys.

The 45-key function keyboard contains yellow (maintenance function) and white (engineering or unlabeled function) keys that appear not to be intended for use by CR operators. A software or mechanical lock-out should be provided for these keys if they are not intended for CR operator use.

The four channel-select keys on each keyboard allow an operator at either keyboard to designate any of the four CRTs as output devices. While this flexibility is

advantageous, during 2-man operation one operator might inadvertently or purposely designate as an output device a CRT currently displaying data of value to the other operator, thus erasing such data. It is suggested that software functions be developed which retain output flexibility but which require one operator to take a moment to verify that the designated CRT screen does not contain data valuable to the other operator.

An operator positioned at the rack-mounted keyboard cannot see the OCC-mounted CRTs. Training and written procedures should emphasize that an operator positioned at the rack-mounted keyboard should not designate either of the two OCC-mounted CRTs as output devices for his own viewing.

3.2 Display Screens

Specifications for the control room CRTs indicate that brightness, color, and contrast are preset at the factory and that easily accessible controls are not provided. It is recommended that controls for brightness, color and contrast be made available not to casual observers but to CR operating personnel. Such controls would ensure that screen contents are maximally visible and legible, despite any "drift" that might occur over time.

The rack-mounted CRTs are positioned so that lower screen edges are approximately six feet above the standing surface, impairing character legibility at the lower and upper edges of the screens. Visual displays mounted on vertical panels should be placed perpendicular to the operator's line of sight if possible, preferably between 41 and 70 inches above the standing surface. Displays to be read precisely and frequently should be placed in an area 50 to 65 inches above the standing surface.

For both sets of CRTs, reading of screen contents is increasingly difficult as an operator moves to operate controls on the RL 011, RL 026, RL 028, or RL 001 panels (i.e., the far right or far left end of the boards). This condition is aggravated by ambient lighting, glare, and the lack of easily accessible controls for adjusting contrast, brightness or color.

An obvious comment concerning the CRTs is that an operator positioned somewhere between the RL 011 and RL 028 panels may be able to read RL 020 CRT contents but cannot read the contents of the RL 003 CRTs. An operator positioned somewhere

between the RL 001 and RL 003 panels can always see any of the four CRTs, but probably cannot read the contents of the RL 020 CRTs, and even the detailed contents of the RL 003 CRTs may not be legible.

3.3 Display Formats

Standard symbols have been developed to represent the location, configuration and status of 11 devices (valves, dampers, transformers) and 18 pieces of equipment (pumps, fans, steam generators, heat exchangers, turbines, tanks, etc.) in the 25 plant subsystem display formats. Some of these symbols are identical to those used in the SNUPPS P & IDs; others are similar, and several do not appear in the P & ID symbol legends at all. While the symbols are all sufficiently unique to permit rapid operator identification of a device or component and its status, overall operator performance would be enhanced by using display format symbols as similar as possible to those used on the SNUPPS P & IDs. Any symbology chosen should be used consistently throughout the CR operating procedures, written materials or visual display formats.

Display format color coding conventions vary according to the type of information displayed. Different color codes are used for the three major categories of displayed information. These categories are:

- Computer/operator conversations
- Demand displays
- Plant subsystem displays.

Within the plant subsystem displays, color coding is used in different ways to depict three types of information:

- Electrical breaker status
- Process lives and in-line equipment
- Alphanumeric information.

The use of the varied color conventions tends to place a burden on the operator's memory and contribute to stimulus overload in emergency situations, rather than facilitating visual search and scanning behavior. The computer software has extensive capabilities for associating altered color, blink status, or video status with alarm

conditions in device status. Utilizing one or more of these capabilities instead of relying so heavily on color coding techniques would enhance operator performance. Using one coding technique (such as video status, blink or a particular color) to indicate only one status, level or condition (such as on/off or alarm status) would improve operator performance. Whatever coding techniques are selected for indicating critical information should be used consistently throughout the system to represent one type of condition. For example, if reverse video is used to indicate analog alarm status, then it should never be used to indicate digital values within normal limits.

When choosing colors for CRT display formats, magenta and blue should be avoided. Using pure blue for character display rarely produces a satisfactory appearance due to the CRT's engineering characteristics. When the CRT is adjusted to produce a pure white, the brightness and contrast of the blue video are so low that the character is not easily visible. Magenta characters may be visible but legibility is reduced. This condition is aggravated due to ambient lighting, glare, and lack of controls to adjust brightness, color or contrast.

3.4 Hard Copy Capability

Although extensive output capability is planned on the operator's printer, timely use of these outputs by CR personnel, particularly under emergency conditions, is unlikely. Current planning does not include a hard copy device located in the CR and immediately accessible by CR operators. Providing an operator's printer with adequate acoustic shielding in the control room itself would enhance the operator's monitoring and diagnostic performance.

APPENDIX C

SPECIAL STUDIES

C-1 ANALYSIS OF ANNUNCIATOR PRIORITIZATION CONCEPTS
C-2 PLANT STATUS MONITORING
C-3 CONTROL AND DISPLAY ENHANCEMENT

APPENDIX C-1

ANALYSIS OF ANNUNCIATOR PRIORITIZATION CONCEPTS

1.0 OBJECTIVE: to identify and evaluate alternate concepts for SNUPPS annunciator prioritization.

2.0 METHOD: the approach to this study began with an analysis of requirements associated with annunciators, proceeded through an evaluation of alternate design concepts, and ended with a description of the selected option.

3.0 RESULTS

3.1 Requirements Analysis

An annunciator system must:

- Immediately attract the attention of a busy or bored operator
- Advise the operator of the location and nature of the problem
- Advise the operator as to the priority of the problem
- Not interfere with the operator's continued attention to other duties
- Not alarm spuriously
- Not fail.

Operator functions associated with the annunciator system are:

- Detect a problem
- Identify the problem
- Determine that the problem warrants immediate attention
- Determine that the problem indication is valid
- Identify the system involved
- Diagnose the problem – isolate the cause
- Decide on a course of action
- Take action
- Verify the action.

Function	System Requirement	Conditions Affecting Operator Performance
• Detect a problem	• indication is attention-getting but not startling • unambiguously indicate a system level problem • display a problem indication at all possible operator locations • second problem on same indicator rings through	• operator location with respect to the indicator • confusion of units where two units share one room • masking of auditory signal and density • number of annunciators • spatial distribution of annunciators
• Identify the problem	• indicator labeling/markings must be immediately readable by an operator at any location • labeling/markings must unambiguously indicate the cause of the problem • auditory signal should unambiguously identify the room and the panel	• contrast of labeling and background • brightness distribution of the window • glare from overhead lighting • size of labeling • number of illuminated annunciators
• Determine that the problem warrants immediate attention	• problems should be prioritized from "immediate response required" to "deferred action OK" • priority should not vary with operational mode	• ongoing activity – workload • clarity of decision rules • discriminability of different signals
• Determine that the indication is valid	• when an annunciator activates, it should indicate that a problem is detected • annunciator location should facilitate check reading of displays	• false alarm rate – nuisance alarms • arrangement of annunciators and associated displays • clarity of decision rules
• Identify the system wished (desired)	• annunciator location should facilitate problem identification	• annunciator location with respect to system panel

Function	System Requirement	Conditions Affecting Operator Performance
• Diagnose the problem and isolate the cause	• annunciator position facilitates identification of affected component, subsystem, train and system • annunciator label should identify the system, component, condition and nature of the problem • annunciator location should facilitate reading appropriate displays • annunciator coding should clearly indicate the first-out condition causing a reactor trip • first-out indicators should be readable at any location in the room	• number of annunciators simultaneously activated for the same problem • annunciator location • first-out indicator array location
• Decide on course of action	• annunciator labeling must indicate nature of the problem • procedures should include decision criteria • annunciators include permissives indicating legal and illegal actions	• clarity of decision rules
• Take action	• activate controls • monitor displays	• control/display arrangements
• Verify the action	• annunciator activation should include an indication of problem cleared • problem-cleared indication unmistakably different from new problem indication • positive action for operator to remove cleared annunciator	

3.2 Design Options

Based on these requirements, a number of annunciator system characteristics were identified. Alternate design approaches for each characteristic were developed. Advantages and disadvantages of each design option are discussed below.

Characteristic: Priority Coding

Option 1 Color and Location

Description: coding immediate response annunciators — red and placed at the top of an array; 2nd order annunciators — amber or yellow and located on second line; 3rd order (deferred action okay) — white and located on third and/or fourth line; permissives — blue and located on fifth and sixth line

Advantages

- unambiguously indicates order of priority
- allows operator to respond rapidly when he needs to, and to attend to other pressing problems for lower priority display activations

Disadvantages

- unsymmetrical array — many more third-level annunciators than first- or fourth-level
- contrast of black label on red panel could degrade readability
- reduces options for indicator grouping within an array

Option 2 Color, Location and Coded Auditory Signal

Description: same as Option 1, except that the auditory signal accompanying light activation is coded (by frequency or type of tone) to indicate priority

Advantages

- operator doesn't even need to visually acquire the annunciator to establish the priority level

Disadvantages

- requires memorization of auditory signals
- operator must differentiate signals for a 2-unit room
- signals must be clearly discriminable — shouldn't lead to judgment of a third-order priority when in fact it is an immediate-response priority
- signals can be masked by voice communication, ambient noise, other signals

Option 3 Color Coding Alone

Description: color code described in Option 1 above

Advantages

- allows more flexibility in grouping indicators
- enables rapid determination of priority

Disadvantages

- slower reaction time than Option 1
- aging can change spectral composition of window – making a white window appear yellow
- places a burden on operators who confuse color easily

Option 4 Location Alone

Description: window all white and located as in Option 1

Advantages

- no color problems

Disadvantages

- potentially misreading a second-order problem as a third-order

Option 5 Flash vs. No Flash or Different Rate

Description: with either color, location, or color and location coding, problems of the first and second order flash, problems of the third order don't flash or flash at a different rate

Advantages

- rapid judgment that immediate action is not required

Disadvantages

- confusing a newly lit, nonflashing window with one already acknowledged
- requires memory for different rates
- discriminability of different rates

Characteristic: Panel Identification

Option 1 Central Master Warning Array

Description: at a central location, a matrix of lights indicates location of relevant panel

Advantages

- facilitates rapid selection of panel

Disadvantages

- central location may not be optimal depending on operator location
- still need to acquire panel to determine priority

Option 2 Color Coded Central Master Warning Array

Description: same as Option 1, except that lights indicating panels are color coded to indicate problem priority

Advantages

- immediate centrally located indication of problem priority
- no panel scanning required until priority is established
- can be seen from any point in the control room

Disadvantages

- color problems – operator vision and window aging
- treatment of panels not in the control room

Option 3 Local Indicators

Description: a light over each panel and array of annunciators which illuminates to indicate that the problem is at this panel

Advantages

- operator needn't scan each array

Disadvantages

- operator does need to scan the panels
- does not indicate priority until the individual window is acquired

Option 4 Local Indicators – Color Coded

Description: same as Option 3, except that three color coded lights indicate priority at each panel

Advantages

- determination of priority sooner than in Option 3
- focuses attention on the afffected panel

Disadvantages

- christmas tree effect – too many lights

Option 5 Coded Auditory Signal

Description: with any of Options 1 through 4, an auditory signal differentiated by intensity or frequency to indicate panel number

Advantages

- reduces time to acquire the panel

Disadvantages

- requires memory
- discrimination of signals
- masking of signals
- problem of two units in one room

Characteristic: Annunciator Relationship to Associated Panel

Option 1 Color Coding

Description: annunciators or annunciator borders are color coded to match colors of associated display backgrounds

Advantages

- facilitates correlation of annunciator and display

Disadvantages

- interferes with other color coding options
- could result in a visually noisy panel

Option 2 Mirrored Location

Description: annunciator located in an array to correspond to display location on the panel

Advantages

- simplifies association of window with display

Disadvantages

- if several displays scattered over the panel are associated with a window — how best to arrange the window in the matrix

Option 3 Integrated Annunciators/Displays

Description: as an annunciator illuminates, a jewel light illuminates next to the associated display(s)

Advantages

- immediate and accurate correlation

Disadvantages

- difficult to implement for an existing board

Option 4 Annunciator Mimic

Description: a mimic diagram depicts the spatial relationships of annunciators

Advantages

- easier to see relationships

Disadvantages

- too busy
- not evident that the approach is even feasible, much less manageable

Option 5 Hierarchical Arrangement

Description: indicators for system, subsystem, train, component and element in hierarchical order

Advantages

- readily identify component

Disadvantages

- too much information
- interferes with other position coding options

Option 6 Label/Symbol Link

Description: annunciators and related displays linked by labels, symbols or connecting lines

Advantages

- facilitates correlation

Disadvantages

- connecting lines could be confusing
- symbols may require memory

Characteristic: Grouping of Windows Within an Array

Option 1 Grouping by Similarity

Description: in this arrangement, windows are oriented vertically when elements are the same and parameters differ, and horizontally when elements differ and parameters are the same

Advantages

- easy to relate annunciators to elements or parameters

Disadvantages

- interferes with other position coding options
- arrays tend to be asymmetrical in that numbers of items vary

Option 2 Grouping by Priority Alone

Description: windows prioritized vertically by order of priority, arranged horizontally by importance within each order

Advantages

- additional priority indication

Disadvantages

- not clear whether or not the horizontal ordering makes sense

Option 3 Grouping by Priority and Similarity

Description: windows arranged vertically by priority and horizontally by similarity

Advantages

- reduces confusion

Disadvantages

- need to demarcate similarity groups

3.3 Selection of Most Effective Option

Given the present SNUPPS design, the most viable option is to use color and location. The alarms could be divided into four levels:

- Level One (First Order) — First-out and those alarms that could lead to potential plant, environment or personnel safety hazard. These should be red. The first-outs should remain where they are, but their section of the window matrices should be demarked and labeled. The other Level One annunciators should be located on the top row.
- Level Two (Second Order) — Those alarms requiring immediate action to prevent equipment damage or a reactor or turbine trip. These should be amber or yellow and located on the second row.
- Level Three (Third Order) — Those alarms that indicate out-of-tolerance conditions or are advisory. These should be white and located on the third and fourth rows.
- Level Four (Fourth Order) — Those alarms that are general information or permissives. These should be light blue and located on the last two rows.

4.0 REQUIREMENTS FOR ADDITIONAL RESEARCH

Additional research is required to:

1) Select auditory signal characteristics
2) Select color contrast ratios – labels and backgrounds
3) Select methods of indicating
   - new problem detected
   - problem acknowledged

- problem cleared in the system
- second problem det cted

4) Criteria for false alarm rates

5) Criteria for number of displays illuminated simultaneously

6) Criteria for selection of parameters for annunciation

7) Criteria for grouping of indicators within an array

8) Methods for correlating indicators with displays

9) Criteria for locating individual indicators within an array

APPENDIX C-2

PLANT STATUS MONITORING (SPDS)

1.0 SPDS PROBLEM DEFINITION

The concept of a plant safety panel designed to present an integrated display of operating data related only to fundamental plant safety, is one of several NRC requirements resulting from the accident at Three Mile Island. The Safety Parameter Display System, as it is more commonly recognized, is envisioned by the NRC as an operator aid designed to assist control room personnel in evaluating the safety status of the plant. The primary objective of the system is to present a continuous indication of plant parameters to key personnel, in the hope of preventing unsafe plant conditions. Recognizing that this information must be presented in the most efficient manner possible, the NRC, through NUREG 0696, stipulates the need to incorporate human factors engineering (HFE) principles into the various aspects of SPDS design.

Volumes of research have been published on the subject of memory, although little, if any, of this research deals specifically with the unique demands placed upon the nuclear reactor operator. We do not have to delve very deeply into the literature before realizing that the storage capacity for a defined amount of information will be the same regardless of where the information originated; whether the task involves monitoring displays in a nuclear power plant or in an airplane cockpit, the demands imposed upon short-term memory during stressful emergencies will evoke similar response patterns. During a plant transient, hundreds of displays simultaneously compete for the operator's attention. Hence, the incessant beckoning of these displays will overload the cognitive faculties of even the most intelligent and qualified operators.

To aid the operator in assessing plant status, the parameters deemed most relevant for plant safety should be identified and presented in a dedicated area which is visually accessible from the primary operating position. Once the informational requirements have been identified and the panel location selected, a specific display medium must be chosen. According to a recent utility survey conducted by EPRI, 88 percent of the utilities plan to support SPDS functional requirements with a common, computerized data system. This implies the need for a display interface to facilitate the transfer of information between the computer and the user. The most efficient display presently used to satisfy this pivotal function is the CRT display.

The key to mitigating an emergency which may arise within the plant is speed and accuracy. Although the CRT display may seem to be a panacea, a plethora of potential problems plague this particular interface. Recent research indicates that 35 percent of an operator's time is spent scanning displays. This task represents the single greatest factor accounting for operator time. Since the goal of human factors engineering is to maximize efficiency and minimize operator error, special attention should be given to the way in which information is presented. An effective user interface is essential to facilitate the information transfer between the CRT screen and the human operator. Sound HFE recommendations rooted in empirically derived psychological principles must be made regarding the acquisition, organization, enhancement, and transfer of displayed data.

During the past several months, Essex has actively researched the SPDS concept proposed by other utilities. The remainder of this section contains discussion of the various design strategies we have reviewed. Included will be an analysis of the advantages and drawbacks inherent in each of the proposed methodologies, a recommendation for a minimum SPDS parameter set, an example SPDS display format and a note on human engineering evaluation of the display design.

2.0 SPDS DISPLAY FORMATS

Several approaches to the SPDS were presented at the recent EPRI-sponsored Conference on Computerized Operator Support Systems. A generic categorization of display formats discussed is given in Table 1, described below. Definitions and examples of the formats precede the table. Some of these formats are vendor/organization-specific at present. A particular organization's approach may include one or more of the formats, usually not on the same display page. In the SPDS application, dedicated pushbuttons are commonly used to access different display pages.

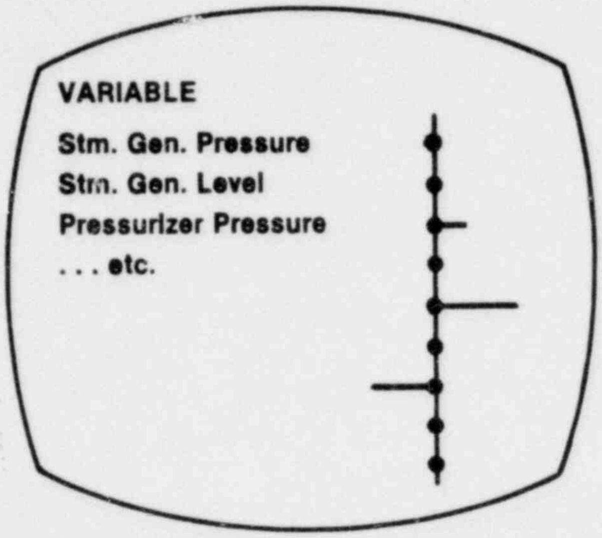
Features which can be used with the different formats are being considered or incorporated. These features include split screen, color coding, graphics, blinking, size coding, and various other display coding and enhancement techniques to facilitate data organization and rapid problem detection and diagnosis by the operator. Some SPDS concepts incorporate an alphanumeric or graphical fault diagnosis prompt which results from a computer weighting of variables which affect parameters that have exceeded set limits. For example, this prompt might display histogram bars of varying heights, where the height of each bar represents the probability of a certain fault.

The matrices in Tables 1 and 2 provide a rating of the different generic formats, based upon a subjective human factors evaluation. In Table 1, each display format is rated according to whether it possesses (relative to the other formats) the performance features listed at the top of the matrix. For simplicity, a yes/no rating was used. The features are worded so that a filled cell indicates a desirable feature and an empty cell indicates the (relative) lack of that desirable feature. Table 2 lists the same display formats and features as Table 1, but a numerical ranking is used. The ranking procedure used is as follows. For each feature listed at the top of the matrix, each of the seven display formats was assigned a rank of 1-7 (e.g., in column #3, "Monitoring and Detection," the Reference Line and Histogram display format was judged generally best, and thus was assigned a rank of 1 on that feature). Where a tie occurred, the tied formats were each assigned the average of the ranks they would otherwise have received (e.g., the three occurrences of a rank of 2 in column #2, "Diagnosis," resulted from averaging the ranks 1, 2, and 3). Before a rank was entered into its cell, it was first multiplied by the weighting factor for the feature being considered. In the examples already given, in each case, the weighting factor was 1; thus, the value of the rank did not change. In the last two columns, where the weighting factor was .5, the features listed therein were

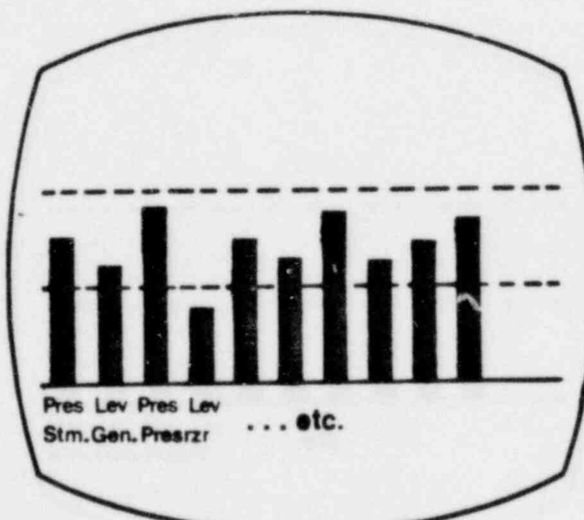
subjectively considered less critical than where the weighting factor was 1. Of course, different weightings can be used to reflect different criticality judgments, and totals different than those given would reflect those weightings. The lower the total and overall rank, the better the format is judged to be.

SPDS GENERIC FORMATS

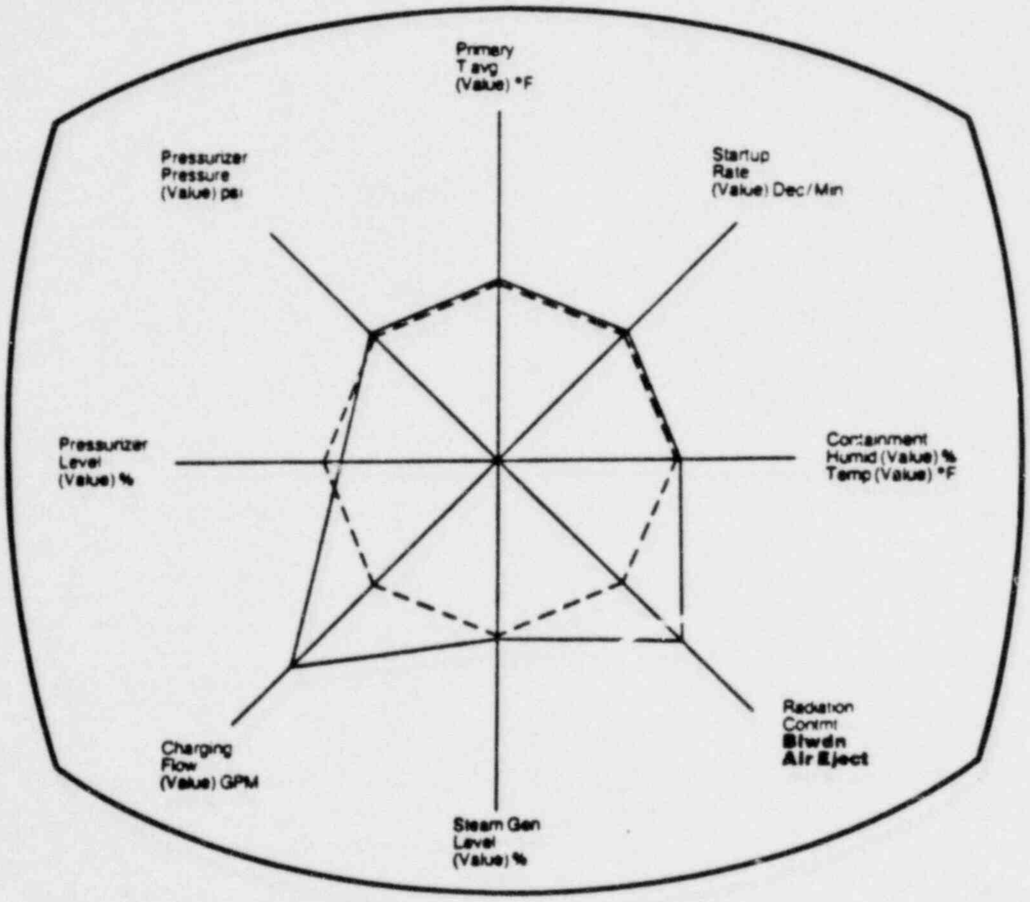
1. Reference Line & Histogram — This is a display of a single line on the screen. Points along the line represent variables at a criterion value. Variable labels reside at the side of the display. When a variable falls below or rises above the criterion value, the display takes the appearance of a histogram with bars on either side (i.e., below or above the criterion value).



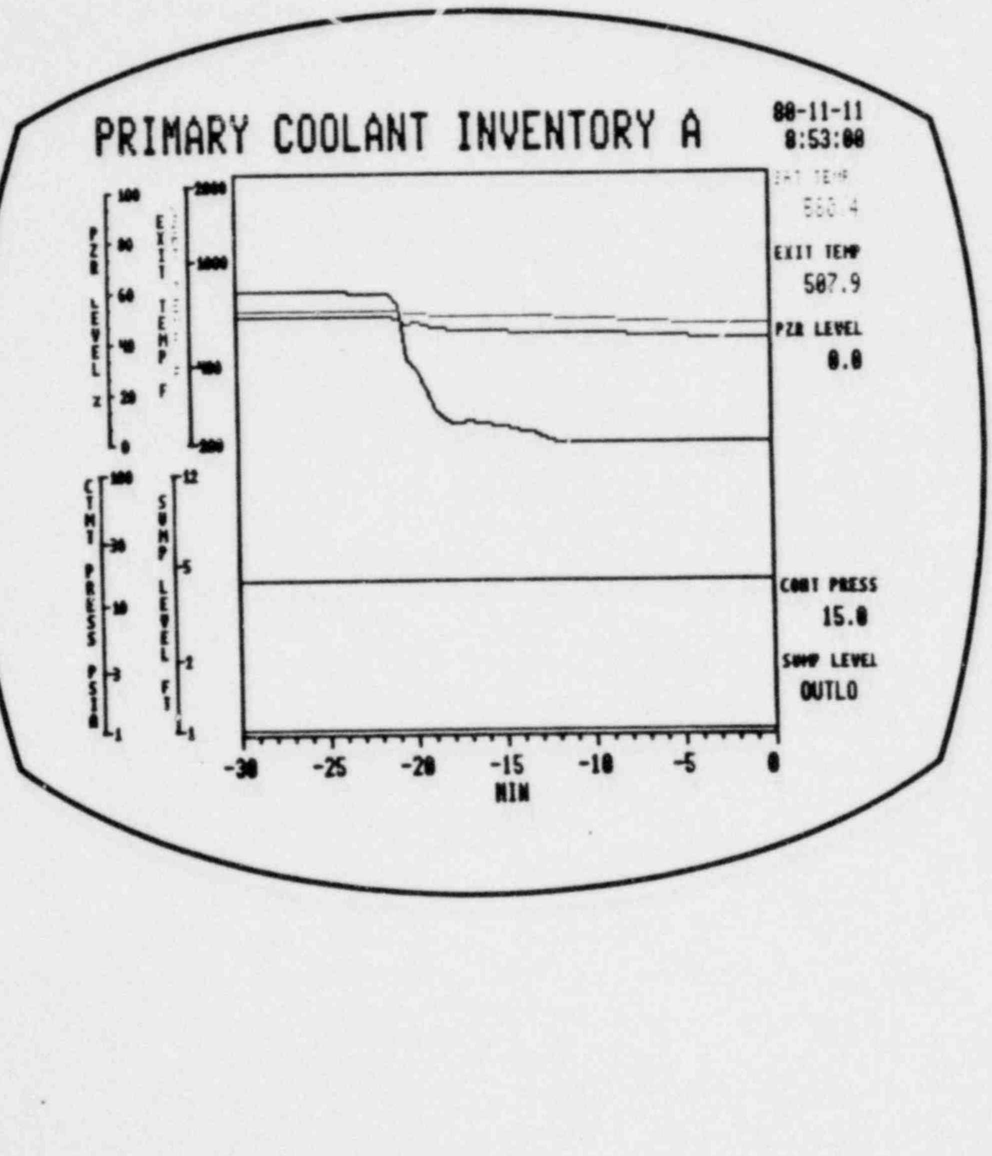
2. Histogram & Reference Lines — This is a display of a histogram where the bars represent the values of labeled variables. Superimposed on the display are two parallel dashed lines defining the acceptable upper and lower limits of the position of the top of each histogram bar.



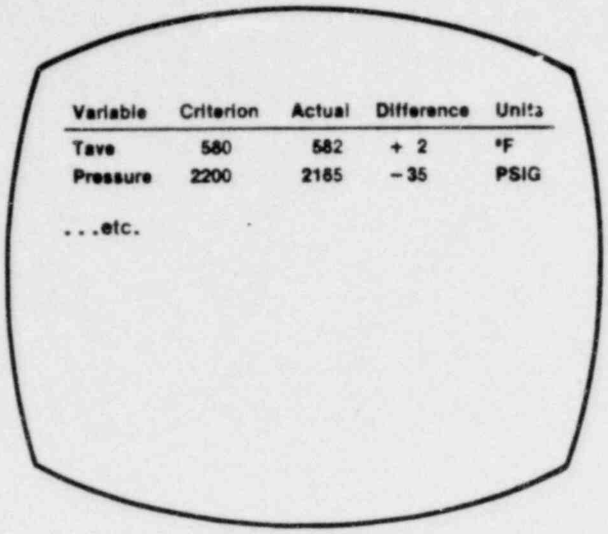
3. Octagon & Reference — This is an octagonal figure in which each of the 8 points of the figure represents the value of a given parameter. Actually, two octagons are used, with the actual parameter values (solid line) superimposed over a reference octagon (dashed line).



4. **NSAC Safety Panel — This is a function oriented display with several pages. Each page is dedicated to monitoring a particular function (e.g., reactivity control, sufficient coolant inventory, containment integrity, etc.). Graphical representations of important variables contributing to the particular function are on each page.**



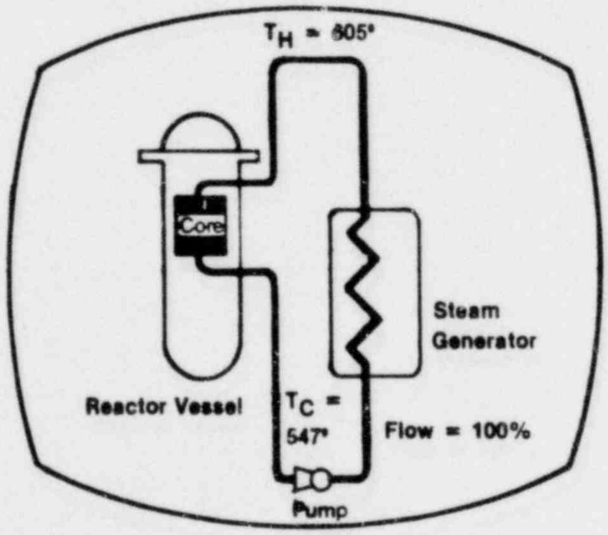
5. **Tabled Reference & Actual Values — This display lists parameters, their criterion and actual value & the discrepancy between them.**



Variable	Criterion	Actual	Difference	Units
Tave	580	582	+ 2	°F
Pressure	2200	2165	− 35	PSIG

. . .etc.

6. **Piping & Instrumentation Diagram — This is a two dimensional sketch or abstraction of the physical system components.**



7. **Hardwire — This refers to a consolidated grouping of hardwired displays; not computer driven CRT displays.**

TABLE 1
DISPLAY FORMAT FEATURES

DISPLAY FORMAT	Comprehensiveness	Diagnosis	Monitoring & Detection	Reference Pt.	Simplicity	Time History	Exact Values	Future Expansion
1. Reference Line & Histogram	X	X	X	X	X			X
2. Histogram & Reference Lines	X	X	X	X	X			X
3. Octagon & Reference			X	X	X			X
4. NSAC Safety Panel		X				X	X	
5. Tabled Reference & Actual Values	X	X		X			X	?
6. Piping & Instrumentation Diagram		X					X	X
7. Hardwire	X	X				?	X	

TABLE 2
DISPLAY FORMAT FEATURE RANKINGS*

FEATURE & WEIGHTING FACTOR

	1	1	1	1	1	1	.5	.5		
DISPLAY FORMAT	Comprehensiveness	Diagnosis	Monitoring & Detection	Reference Pt.	Simplicity	Time History	Exact Values	Future Expansion	Total	Rank
1. Reference Line & Histogram	2	2	1	2	2	5	3	1.5	18.5	1
2. Histogram & Reference Lines	2	2	2	2	2	5	3	1.5	19.5	2
3. Octagon & Reference	4	7	3	2	2	5	3	1.5	27.5	3
4. NSAC Safety Panel	7	2	5	5	5	1	2	1.5	28.5	4
5. Tabled Reference & Actual Values	2	5	5	4	5	5	.5	3	29.5	5
6. Piping & Instrumentation Diagram	4	4	5	7	5	5	1.5	1.5	33	6
7. Hardwire	4	6	7	6	7	2	1	3.5	36.5	7

*The number in each cell = (column weighting factor) X (display format rank on that feature). See text for more details.

3.0 SPDS PARAMETER SET

Listed below is the minimum PWR SPDS parameter set recommended by Essex subject matter experts.

Radiation Monitors

- Area
- Main Vent
- RCS
- Steam Generator
- Containment

Steam Generator

- Level
- Pressure
- (Feedflow - Steam Flow)

Containment

- Temperature
- Pressure
- Hydrogen Level

Pressurizer

- Level
- Pressure

Reactor Coolant System

- ΔT
- Core Exit Temperature
- RCS Pressure

Rod Bottom Indication

Power Range Indication

4.0 SPDS DISPLAY FORMAT — EXAMPLE

Figure 1 presents a proposed computer-driven single page SPDS display as submitted to Essex by a utility for human factors input. A 19" color graphics CRT is the planned mode of display. Figure 2 presents Essex's revision of the display format. While elaboration of the details and dynamics of each display is not presented here, an examination of the two figures will reveal a regrouping and reformatting of information to simplify the display. These changes were made with the goals of reducing detection time for abnormal conditions and improving operator information extraction. Other recommendation areas included coding methodologies, coding consistency (within the display and between the display and the control room), display resolution, and parameters to be monitored. Further evolution of the display is expected as the SPDS parameter set undergoes final revision and as hardware input is received. For more details on this display, contact Essex Corporation.

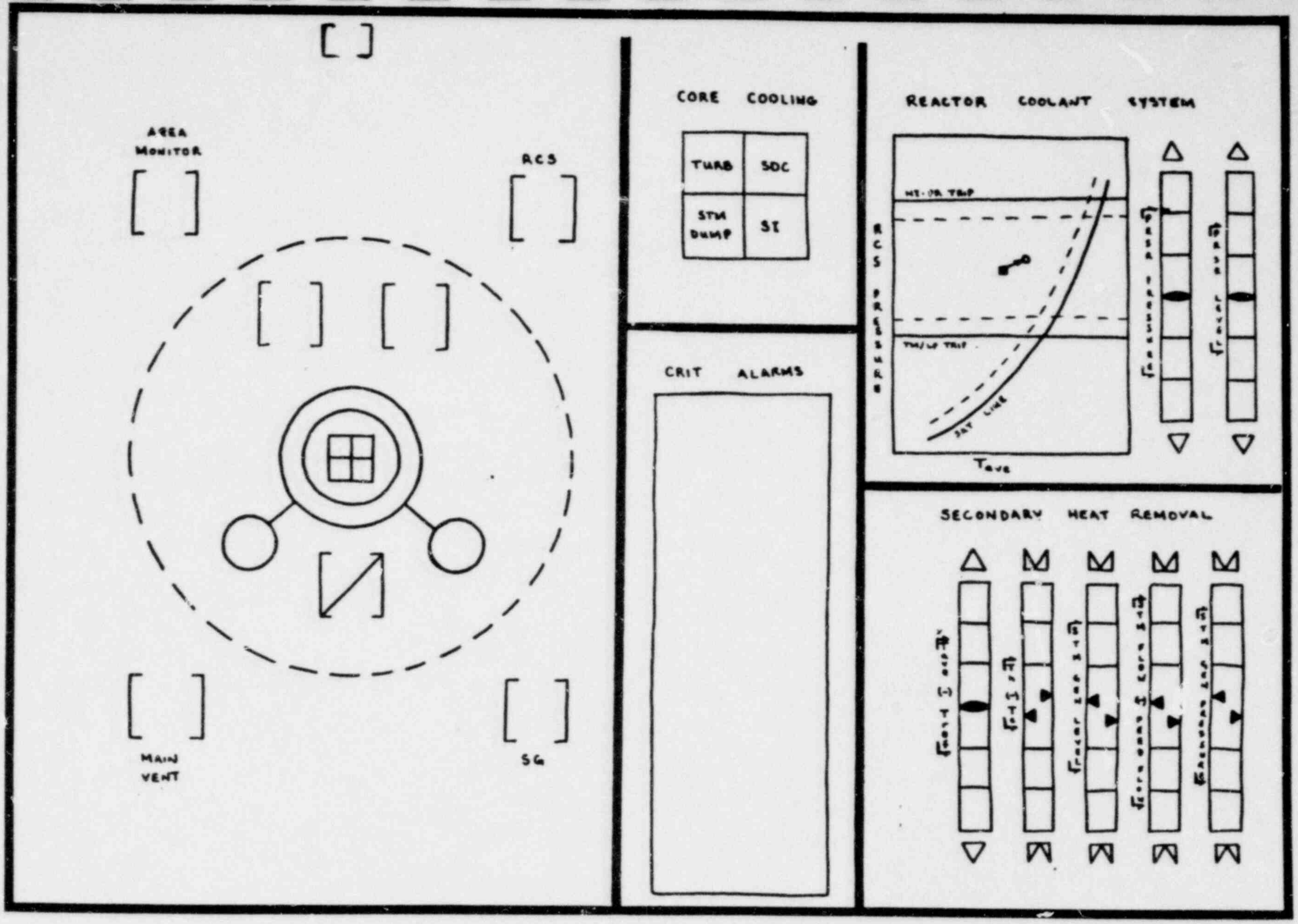


FIGURE 1. A UTILITY'S SPDS INPUT TO ESSEX (SEE FIGURE 2).

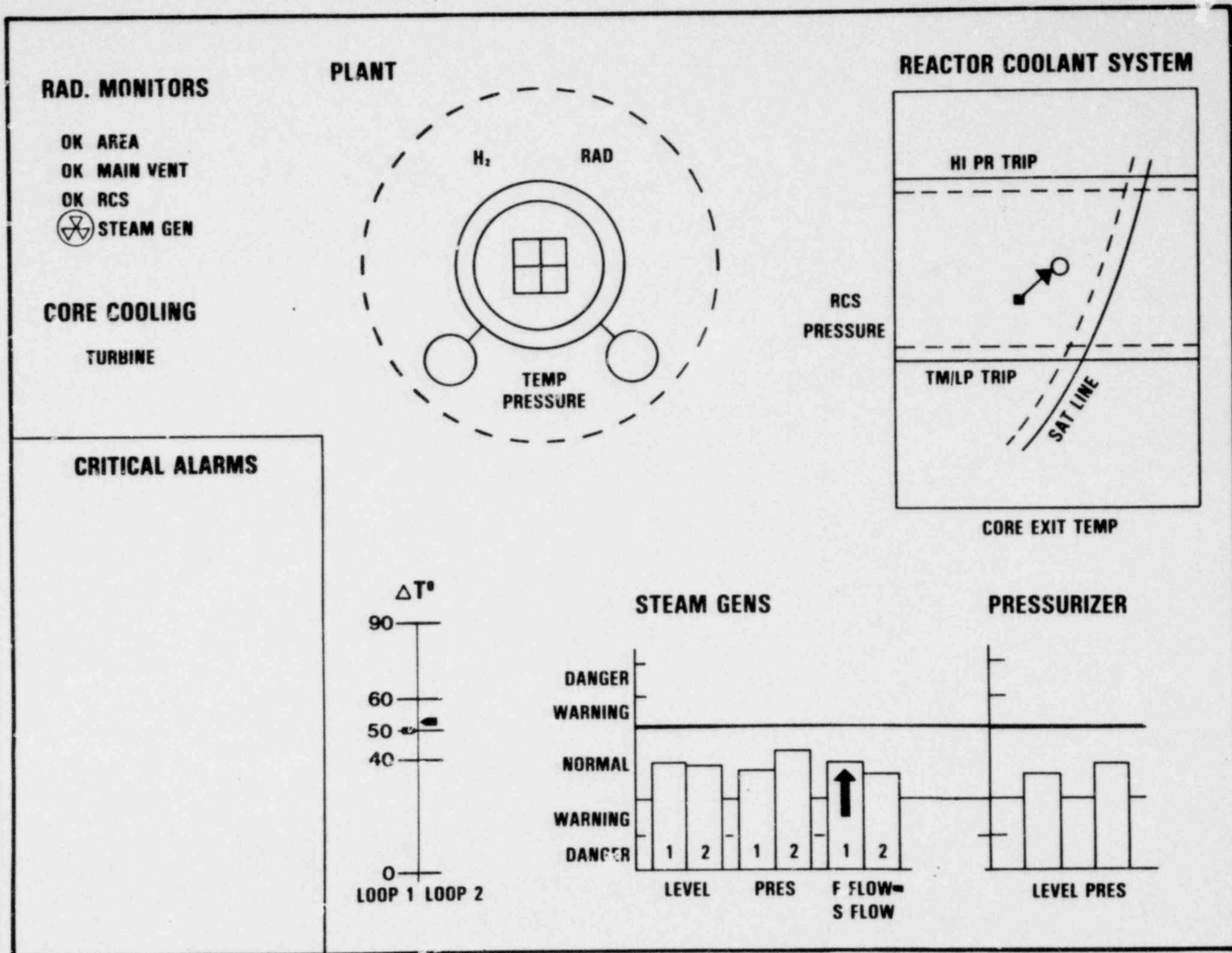


FIGURE 2. ESSEX REVISION OF SPDS DISPLAY.

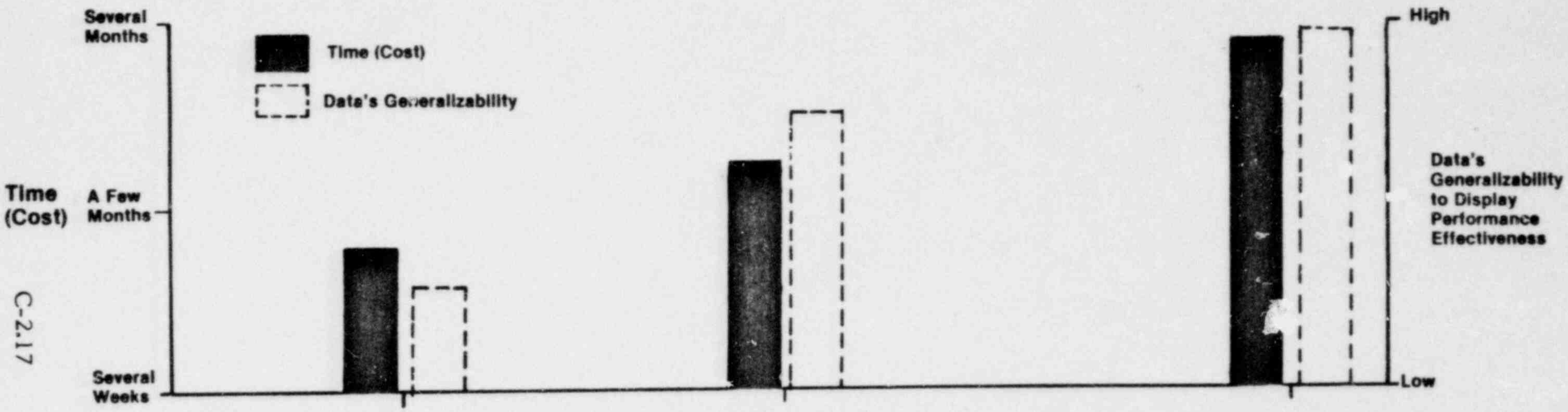
5.0 A NOTE ON SPDS DISPLAY DESIGN EVALUATION

The ultimate measure of the effectiveness of an SPDS display design, in a given context, will be its contribution to user performance during normal and abnormal operating conditions. But deficiencies should be corrected before implementation if at all possible. Afterwards, awareness of design deficiencies may come as a result of a disaster and may be costly to remedy. Thus, we must consider approaches to a human factors evaluation of the SPDS display design before it is implemented. Common evaluation approaches are depicted in Figure 3 in a relationship to time and cost and the degree to which the resulting data would generalize to performance effectiveness. While the figure is a general and somewhat arbitrary statement, it is hoped that it will serve a useful purpose in considering trade-offs involving display effectiveness, evaluation time and cost, and the SPDS implementation schedule.

As is illustrated on the left side of Figure 3, an answer to the question about display effectiveness can be found by eliciting ratings of displays from appropriate groups (e.g., human factors specialists or proposed system users). While the results will provide opinion ratings, they may not necessarily reflect what actual user performance would be like on a given display. A process that would produce performance measures is shown on the right side of the figure. This quasi-experimental approach involves utilizing a simulator to evaluate different dynamic display concepts using "real-world" scenarios. The performance measures recorded could very closely relate to those that might be used to judge real-world operational performance. Some example performance measures are given in the figure. If realistic scenarios were utilized in this type of study, the results should generalize very well to the real world. This type of study is labeled "quasi-experimental" to reflect the fact that in applied settings, constraints often prohibit exercising complete experimental control over extraneous variables. The advantages of performing research under conditions closely matching those to which the results will be generalized are thought to mitigate the quasi-experimental nature of such applied work.

Just as the performance data generated by the quasi-experimental approach is expected to better relate to operational performance than that generated by the first approach described, so too are cost and study time expected to be greater. The latter approach would require that displays be programmed, scenarios selected, on-site data collected within simulator schedule constraints, etc. Of course, other design evaluation

approaches can be imagined. Another approach is depicted between the two that have already been described in the figure. It is somewhat intermediate in complexity, cost and generalizability to operational performance. Many other approaches are possible.



Example approach:	Ratings by Human Factors Experts and/or system users.	Experiment using static representations of proposed dynamic displays. Vary content, format, coding, etc.	Quasi-Experiment using practiced users, concurrent task loading and proposed dynamic displays in simulator scenarios. Vary content, format, coding, etc. Compare control panel with SPDS.
Example data:	Subjective: Ratings, comments and suggestions.	Objective: Time to detect problem, time to identify problem, time to diagnose, accuracy of identification/diagnosis, etc. Subjective: user comments and suggestions.	Could record the same types of data as listed for the experiment using static display(s). Since the quasi-experiment would run at real time, the results should more accurately generalize to an operational setting than would those from the experiment using static displays.

FIGURE 3. SOME EXAMPLE APPROACHES TO SPDS DISPLAY DESIGN EVALUATION

APPENDIX C-3

CONTROL & DISPLAY ENHANCEMENTS

1.0 INTRODUCTION

This appendix addresses SNUPPS control and display design features which may be enhanced (in terms of operator reliability and acceptance of design) by a variety of means. These enhancements have not necessarily been driven by specific human engineering discrepancy reports, but do relate to existing problems. Both general and specific recommendations are provided.

The specific types of control/display enhancements addressed in this appendix are:

- Integration of Display Parameters, based on operational and task requirements (for example, comparisons of steam flow and feedwater flow to and from steam generators)
- Integration of Controls, based on use (for example, combining control functions that are always used concurrently)
- Means to Reduce Problems of Mirror Imaging, in accordance with specific incidences of mirror imaging in the SNUPPS control room
- Potential Use of Green Board, or related design practices in the SNUPPS control room, to filter and summarize information for the operator.

Other considerations (control/display enhancements) are addressed as part of the above. Control rearrangements are dealt with, in part, under mirror imaging and control integrations.

Specifically not addressed as part of this appendix are (1) miniaturization, and (2) means to highlight critical information on video monitors. Miniaturization has not been addressed since the its purposes are to: lessen the physical dimensions of the entire control space; reduce visual search; and reduce control room traffic. Given that the SNUPPS control room is already well into the construction phase, the potential gains of miniaturization cannot now be realized. In addition, some tendency towards miniaturization is evident at SNUPPS in the use of smaller breaker controls and valve controllers. Means to highlight information on video monitors is addressed in Appendix D, "Evaluation of Computer System Man/Machine Interface".

The following discussions deal with specific areas of control display enhancement.

2.0 DISPLAY PARAMETERS WHICH COULD BE INTEGRATED OR JUXTAPOSED

Since displayed values in nuclear power plants frequently must be directly compared to one another, displays should be designed and positioned to facilitate this direct comparison without need for short-term memory or higher levels of information processing. The following is an example of such a design:

Layout of the OTΔT and OPΔT set point trend recorder and loopwise hot/cold leg recorders (RL022) can be rearranged to better present the information, based on operational requirements.

Movement of OTΔT and OPΔT is recommended since:

1. When relocated, they are more visible from the related displays on panel RL002
2. They relate more closely to the loop hot/cold leg recorders in terms of power
3. Visual search and acquisition time will be reduced, since the difference between hot and cold leg temps is an indication of power and ΔT.

Movement of loop hot/cold leg recorders is recommended since:

1. Rx coolant displays on this plane are well arranged vertically for each loop, <u>except</u> for hot/cold leg temp recorders, which are presented in the order 2, 4, 1, 3
2. Display selection errors will be reduced

Current layout is shown on Figure 1. A potential rearrangement is demonstrated in Figure 2.

One issue regarding information integration on displays deals with providing system tolerances on scale surfaces. This information currently is provided in tech specs, PLS documents, and so forth. This requires recall tasks or referencing on the part of the operator. The following diagrams (Figures 3 & 4) demonstrate two ways this information can be presented directly to operators.

In addition, for parameters in which set points "float" with other system variables (e.g., over power), dual pointer scales may be employed rather than multiple display units. Those parameters listed in reference to Figure 5 are also appropriate here. Set point information can also be engraved directly onto annunciator tiles.

FIGURE 1
LAYOUT OF HOT/COLD LEG TEMPS AND OVERPOWER SET POINT RECORDERS

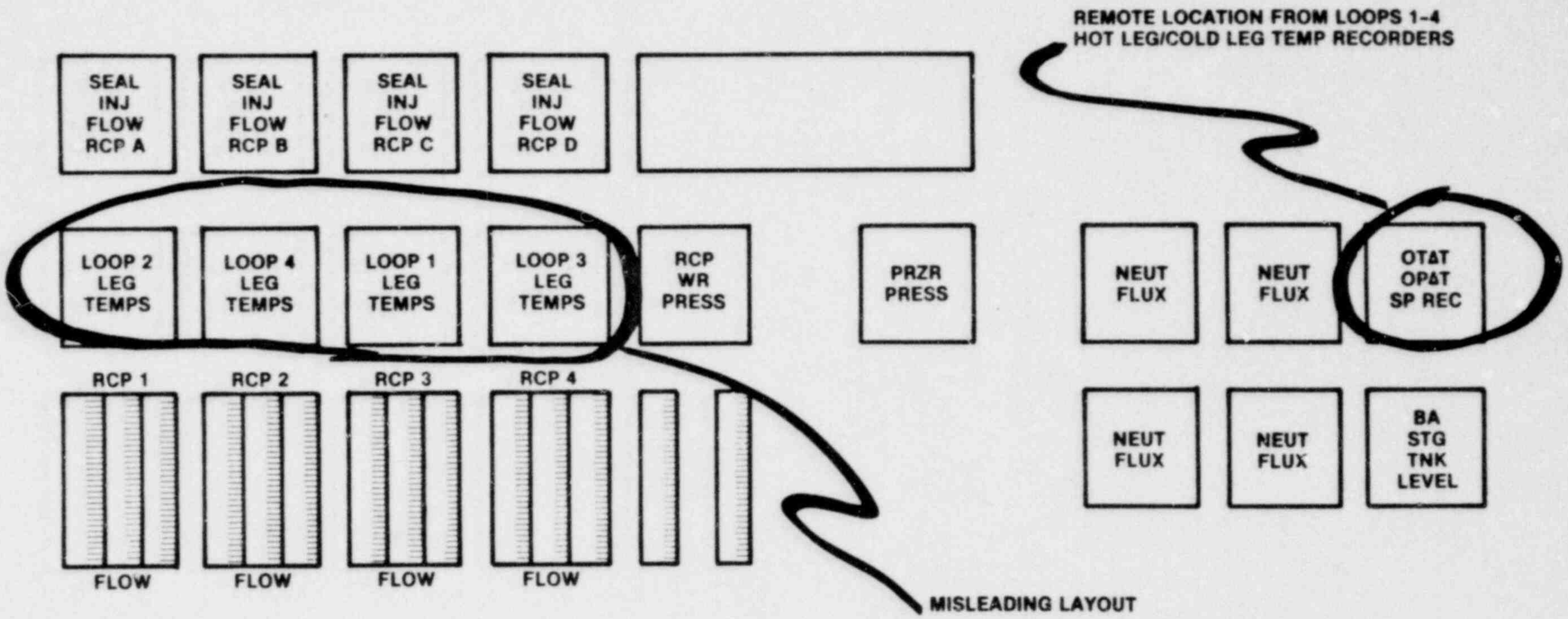
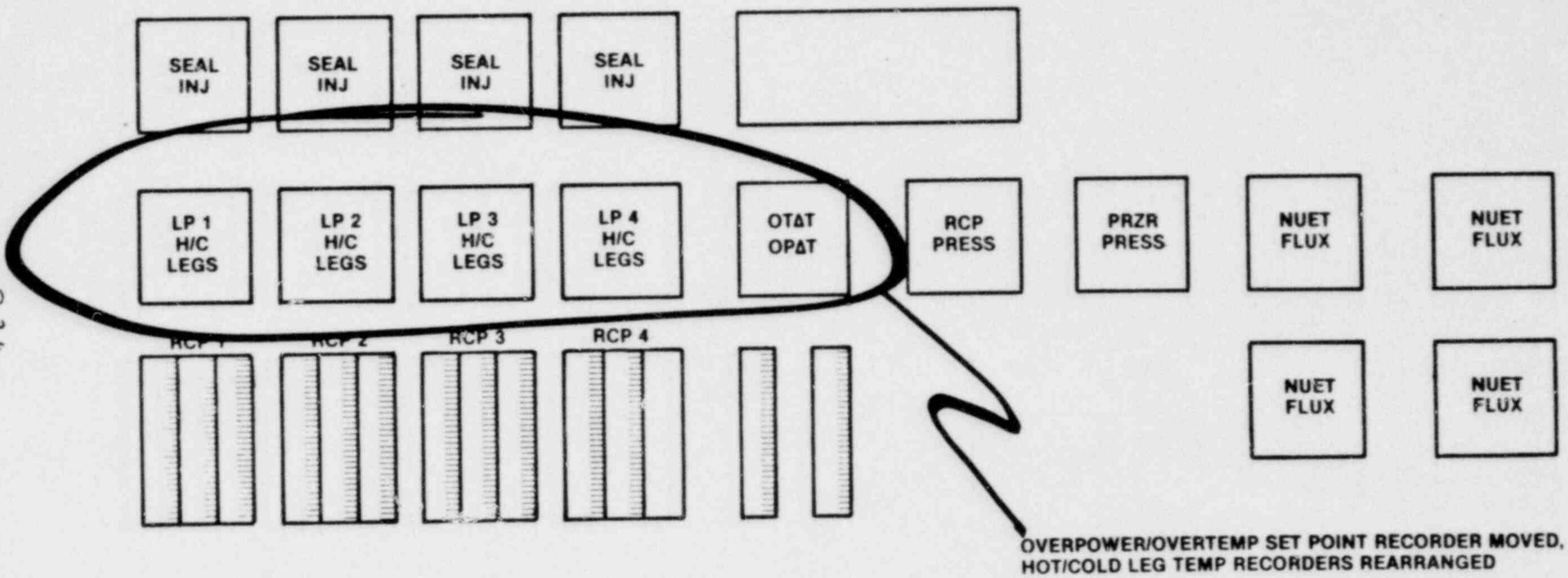


FIGURE 2
RECORDER REARRANGEMENTS



BA STORAGE TANK LEVEL MOVED TO CVCS AREA

SET POINT INFORMATION CAN BE PLACED DIRECTLY ON DISPLAYS:

RWST LEVEL

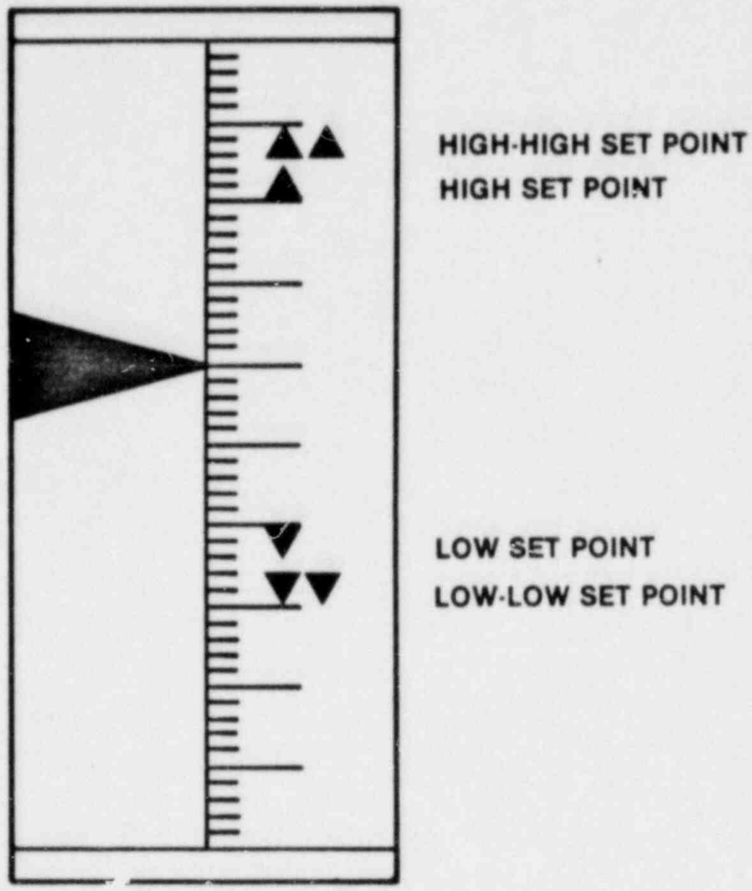
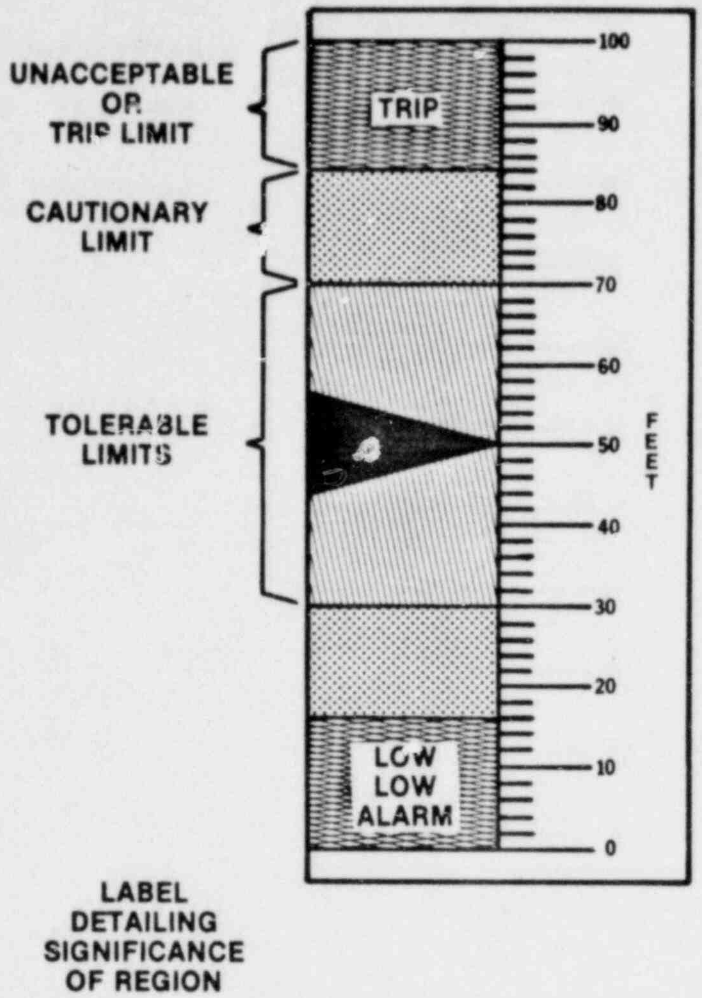


FIGURE 3



NOTE 1: WHEN INTOLERABLE LIMIT INDICATES A TRIP SET POINT, REGION IS RED. IF SIGNIFICANCE IS AN ALARM ONLY, REGION IS YELLOW

NOTE 2: POINTER MUST OFFER HIGH CONTRAST WITH ALL COLORS USED. (RED POINTERS OVER RED BACKGROUND FIELDS IS NOT ACCEPTABLE).

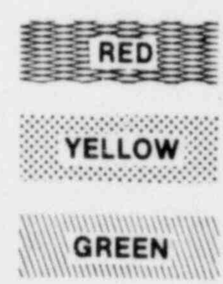
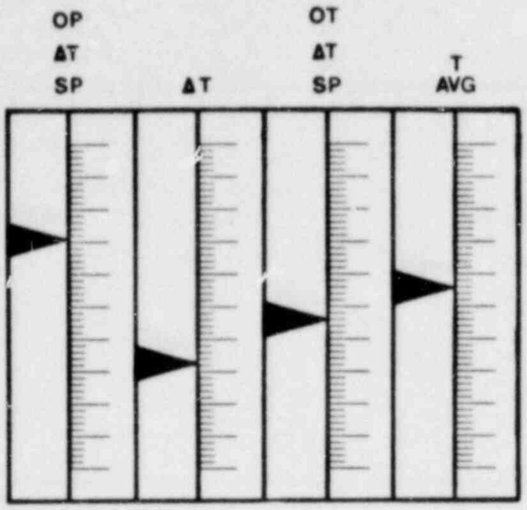
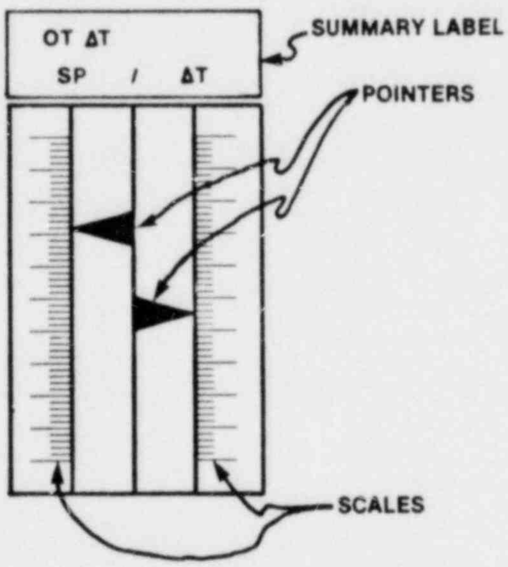


FIGURE 4

COMPARED PARAMETERS, e.g., LOOP ΔT AND OPΔT, ETC., CURRENTLY DESIGNED:



COULD BE REDESIGNED:



OTHER DISPLAYS INCLUDE STEAM FLOW/FEED FLOW; PRESSURIZER PRESSURE AND T-AVG; LOOP HOT AND COLD LEG TEMPERATURES; MAKEUP AND LETDOWN; STEAM GENERATOR LEVEL AND SET POINT; FIRST AND SECOND STAGE REHEATER STEAM FLOWS; AND RANGE DETECTORS

FIGURE 5

3.0 CONTROL INTEGRATIONS

A fundamental principle of human factors engineering design is simplicity of operation. Simplifying operational tasks reduces performance times and training requirements, increases reliability and provides other benefits (fatigue reduction, enhanced vigilance, etc.). One way to simplify a variety of tasks is to reduce or limit the number of components on the control boards. In the SNUPPS (and other) nuclear control rooms, this is not always possible due to separation requirements, redundancy of systems and so forth.

Essex has, however, identified instances where approximately 30 controls can be eliminated from the control room by integrating controls into single units. However, since all test, calibration and normal operating procedures were not analyzed, some of these switch integrations may not be feasible. SNUPPS personnel must examine each instance to make appropriate redesign decisions. Following are 12 instances where Essex believes that control functions may be integrated.

1. ESW A return from
   LCW Hx A
   EF HIS 59

   and

   ESW A TO CC HxA
   EF HIS 51

   Can be integrated into an HxA isolation control:

   ESW SPLY AND DISCHG
   FOR CCW Hx A ISOL
   - EF HIS 59
   - EF HIS 51

2. ESWB RETURN FROM
   CCW Hx A
   EF HIS 60

   and

   ESW B TO CCW Hx B
   EF HIS 52

Can also be integrated to:

ESW B SPLY AND DISCHG
FOR CCW HxB ISOL
EF HIS 60
EF HIS 52

3. HYDROGEN ANALYZER A
DISCHARGE ISOLATION
GS HIS 17

and

HYDROGEN ANALYZER A
DISCHARGE ISOLATION
GS HIS 18

Can be integrated:

H_2 ANALYZER A
DISCHARGE ISOL
GS HIS 17
GS HIS 18

4. HYDROGEN ANALYZER B
DISCHARGE ISOLATION
GS HIS 8

and

HYRDOGEN ANALYZER B
DISCHARGE ISOLATION
GS HIS 9

Can be combined as:

HYDROGEN ANALYZER
DISCHG ISOL
GS HIS 8
GS HIS 9

5. HYDROGEN ANALYZER B
INLET ISOLATION

GS HIS 3

<u>and</u>

HYDROGEN ANALYZER B
INLET ISOLATION
GS HIS 4

<u>and</u>

HYDROGEN ANALYZER B
INLET ISOLATION
GS HIS 5

Can be integrated as:

H_2 ANALYZER
INLET ISO
GS HIS 3
GS HIS 4
GS HIS 5

6. HYDROGEN ANALYZER A
INLET ISOLATION
GS HIS 12

<u>and</u>

GS HIS 13

<u>and</u>

GS HIS 14

Combined to:

H_2 ANALYZER A
INLET ISOL
GS HIS 12
GS HIS 13
GS HIS 14

7. MN turbine lift pump controls (seven of them) can all be integrated into a single control

8. MN FW PUMP TURB A STEAM DRAINS (seven controls) can be integrated into a single control

9. MN FN PUMP TURB B STEAM DRAINS (seven controls) can be integrated into a single control

10. CONTAINMENT COOLER DRAIN VALVES (four controls) can be integrated into a single control

11. 1st STAGE REHEATER
STEAM SUPPLY
AC-HIS-189

and

1st STAGE REHEATER
STEAM SUPPLY
AC-HIS-32

Can be combined

12. MN STEAM DRAIN TRAP
BYPASS VALVES (five controls):
AB HIS 23
AB HIS 50
AB HIS 51
AB HIS 52
AB HIS 53

Can be combined

Many other potential combinations were examined but ruled out by virtue of train separation requirements and observation of operational requirements.

4.0 MIRROR IMAGE LAYOUTS

Many instances of mirror imaging exist at the SNUPPS control room, including:

- AUX FW PUMPS
- COMPONENT COOLING WATER
- ESSENTIAL SERVICE WATER
- ENGINEERED SAFEGUARDS
- ELECTRICAL DISTRIBUTION

From a human factors perspective, mirror imaging is a highly undesirable design practice, for the following reasons:

- Visual search times increase
- Control and display substitutions (selecting incorrect controls and displays) increase
- Confusion increases due to increased memory and information processing requirements
- Task execution times increase
- Operational sequences and task networks become more complex.

Further, mirror image designs at the SNUPPS plant are not complete mirrors. That is, one-to-one mirrored components do not correspond in function (e.g., reference ECCS system (A) "SI PUMP B DISCH HOT LEG ISO VLV," and (B) "SI PUMP A RETURN TO RWST ISO VALVE"). Furthermore, on many layouts, the center portion of the design is not mirrored; rather only the extremities are mirror imaged. Within a mimic, for example, only the extremes (left and right) are mirrored (safeguards, for example). In addition, mimics lack positional consistency, that is, a one-to-one correspondence does not always exist. Finally, mirror imaging is unreliable in that only portions of redundant systems are mirrored. For example, accumulator controls appear very definitely to be mirrored, but are not. Given these design practices at SNUPPS, the problems with mirror images noted before are very much magnified.

The best way to address mirror imaging problems is to avoid or eliminate them in control spaces. Where this cannot be done, error rates and operational effects for each incidence must be examined to identify backfits.

Potential methods to reduce the effects of mirror image design are:

- Procedural changes
- Increased training

- Panel cosmetic changes
- Panel redesign.

Each is discussed below.

Procedural Backfits. It is indeed possible to specify poor HFE designs, in notes and cautions, as part of procedure design. This approach is inadequate for addressing problems of mirror imaging, however, since:

- Much of what takes place in CRs (in terms of control and display use) is not procedurally bound but rather is directed by training and experience
- During application of E-Os, ROs work the boards while the SRO directs activities from procedures. Therefore, cautionary information is not presented directly to the operator working the boards. Further, immediate operator actions are learned (memorized) behaviors, not directed by E-Os.
- Procedures are already large documents, somewhat complex and inclined to induce error. Contributing to their complexity and unreadability is to be avoided.
- Procedures are essentially (forced) aids to memory, means to "check-list" CR activities, and sources of complex information. They are not intended to illustrate poor design, thereby obscuring the information they were meant to present.

Therefore, procedures fail to address the problems of mirror imaging because: 1) the information may not reliably be imparted to operators; 2) if imparted, most errors induced by mirror imaging will not be alleviated; and 3) presenting additional notes and cautions will tend to obscure other procedural information.

Training. ROs and SROs receive essentially two types of training, conceptual (cognitive-information processing, model development) and perceptual-behavioral. Mirror imaging problems can be discussed in relation to both, but more directly to perceptual-behavioral training (conceptual in terms of incidentally learned rules, e.g., "to find the other component — go down 3 displays, then right 2, and begin search"). Operator behavior training is performed on the SNUPPS simulator and represents little more than training on using complex stimulus-response networks, partially mediated by conceptual learning (mediational responses) and procedure design. In mirror image designs, the stimulus requires a discrimination reversal (from one side or the other of the mirror), which complicates the discrimination and is apt to cause errors (perhaps due to response persistance, inadequate search, a breakdown of response mediation, and so forth).

Training assessments on simulators in power plants are based heavily (almost exclusively) on analysis of outcomes, that is, whether simulated accidents and situations were successfully mitigated by operator activity. This means that each operator develops his own strategy for dealing with the difficult design. Little control can be applied to this type of learning.

At the SNUPPS plants, the mirror image designs are so unreliable and change so much from application to application that operator rule development is very much complicated, is dependent upon long-term memory retrievals, and requires high levels of information processing. Uniform rules ("Remember, this side is exactly the opposite of the other") simply do not apply. Other rules probably will be developed (e.g., "Don't trust this console"). These other rules may not be totally unreliable during low stress periods, but will be highly unreliable where time, operator attention, recall and processing are limited.

Problems with addressing mirror imaging at SNUPPS via training programs, therefore, are:

- Mirror layouts at SNUPPS are so different in design and so unreliable in terms of component positioning that strategies for accurate component localization would be highly complex. Learning objectives would be difficult to identify. Adequacy of training would be difficult to assess.
- Much of any learned strategies would be lost under high stress and time-constrained periods, since strategies would require access to long-term memory, extensive sensory input, and extensive information processing, all of which often fail (except sensory input) during high stress periods.

Panel Redesign and Cosmetic Changes. Panel redesign and/or cosmetic changes represent the most promising means to resolve mirror imaging problems. Following are discussions of each incidence of mirror imaging with recommendations for each.

A) Aux FW Pumps. This layout (see Figure 6) appears to be a mirror image design but is not for the motor driven pumps; for the turbine driven aux feed pump, only the loop 2 and 3 steam supply valves and ESW supply valves are mirrored. The following recommendations regarding these problems are ranked in order of preference.

1. Completely redesign the layout of the AUX FEED system in a manner that does not create the illusion of mirror imaging (see example in Figure 7).
2. Rearrange components in AUX FEED to eliminate all incidences of mirror imaging, and move PUMP B breaker control to the left, so as to be positioned

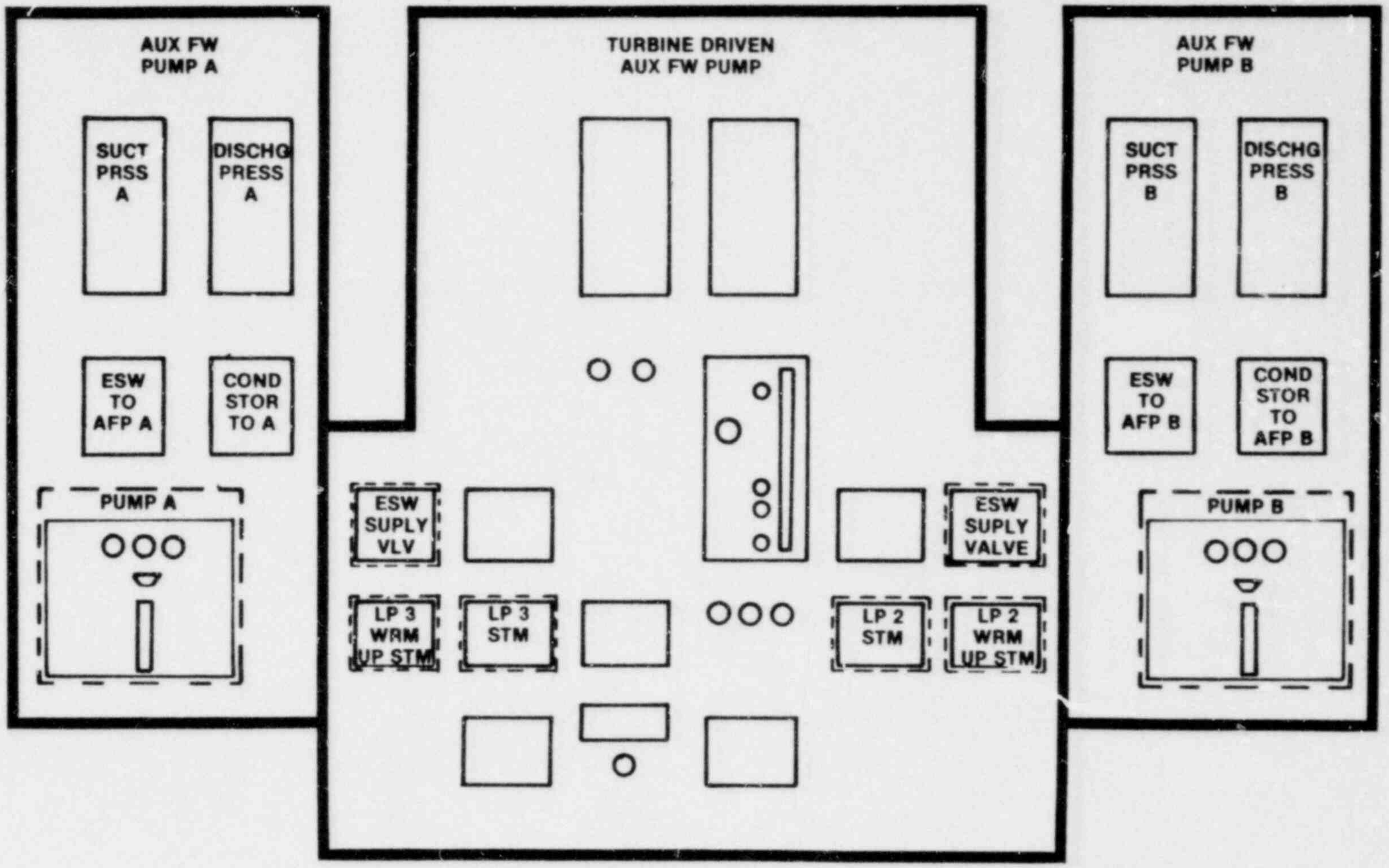


FIGURE 6

AUX FW SYSTEM IS VISUALLY SYMMETRICAL, BUT NOT COMPLETELY MIRRORED IN CONTROL/DISPLAY FUNCTIONS. ADDITIONS OF DEMARCATION LINES (HEAVY LINES) WILL HELP TO SHOW GROUPS, BUT ADD TO SYMMETRY. CONTROLS OUTLINED IN DASHED LINES ARE MIRRORED FUNCTIONS.

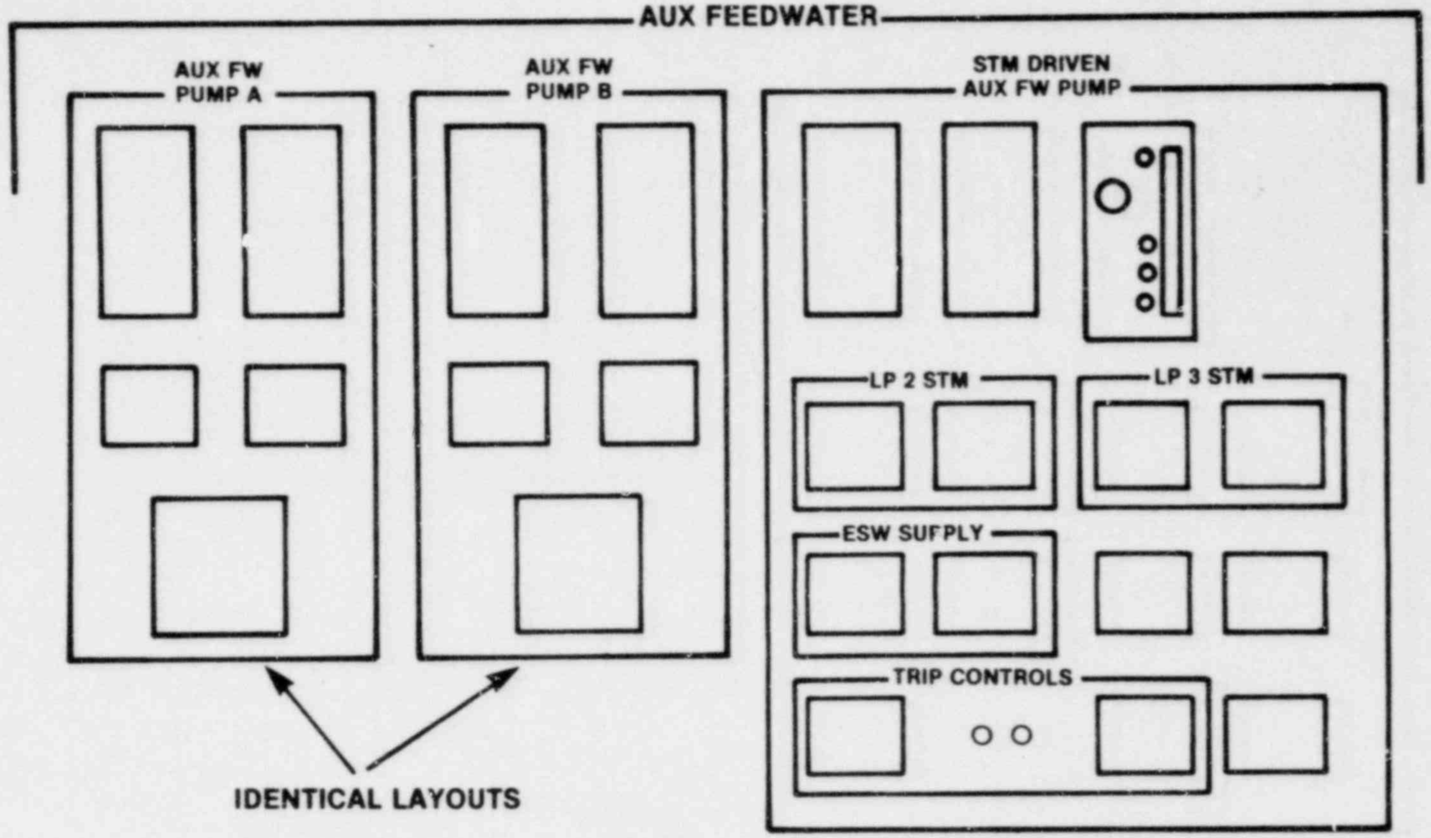


FIGURE 7
EXAMPLE AUX FW REDESIGN

as PUMP A breaker control, thereby reducing the appearance of mirror imaging. Also, add lines of demarcation to visually break up respective pumps (see Figure 8).

3. Demarcate as shown in Figure 6, and provide switch guards over steam supplies and ESW supply for the TURBINE DRIVEN AUX FEED PUMP. This solution to the mirroring problems is not highly regarded since it only partially ameliorates the problems and introduces others (e.g., limiting switch access).

B) Component Cooling Water. This particular system is arranged, left to right, as follows:

1. Train B component cooling supply functions
2. Component cooling (CC) isolation
3. CC to rad waste
4. Train A component cooling supply functions.

Only the two outboard sections (Trains B and A supply) are mirrored (see Figure 9). CC is also heavily mimicked. In addition to being mirrored, which is demonstrably poor design, the mimicked portions of CC are segregated by nonmirrored (or "nonmirrorable") functional groups, increasing the level of difficulty and unreliability of use. The following are means (ranked in order of HFE preference) to reduce or eliminate these difficulties:

1. Redesign the CC system layout such that:

   a. mirror imaging is eliminated
   b. functional groups are maintained and visually distinct
   c. mimics are maintained and enhanced.

   Figure 10 contains a concept whereby this can be done. Note that the details of layout are not accurate in Figure 10, which is only provided to demonstrate a good HFE design concept that does not contain mirror images. Each train of CC supply is identical in layout.

2. Identify groups by means of demarcation or background coloring. Given that CC is heavily mimicked, lines of demarcation may add excessively to visual clutter. However, background coloring increases the number of color meanings in the CR, a situation which is also to be avoided.

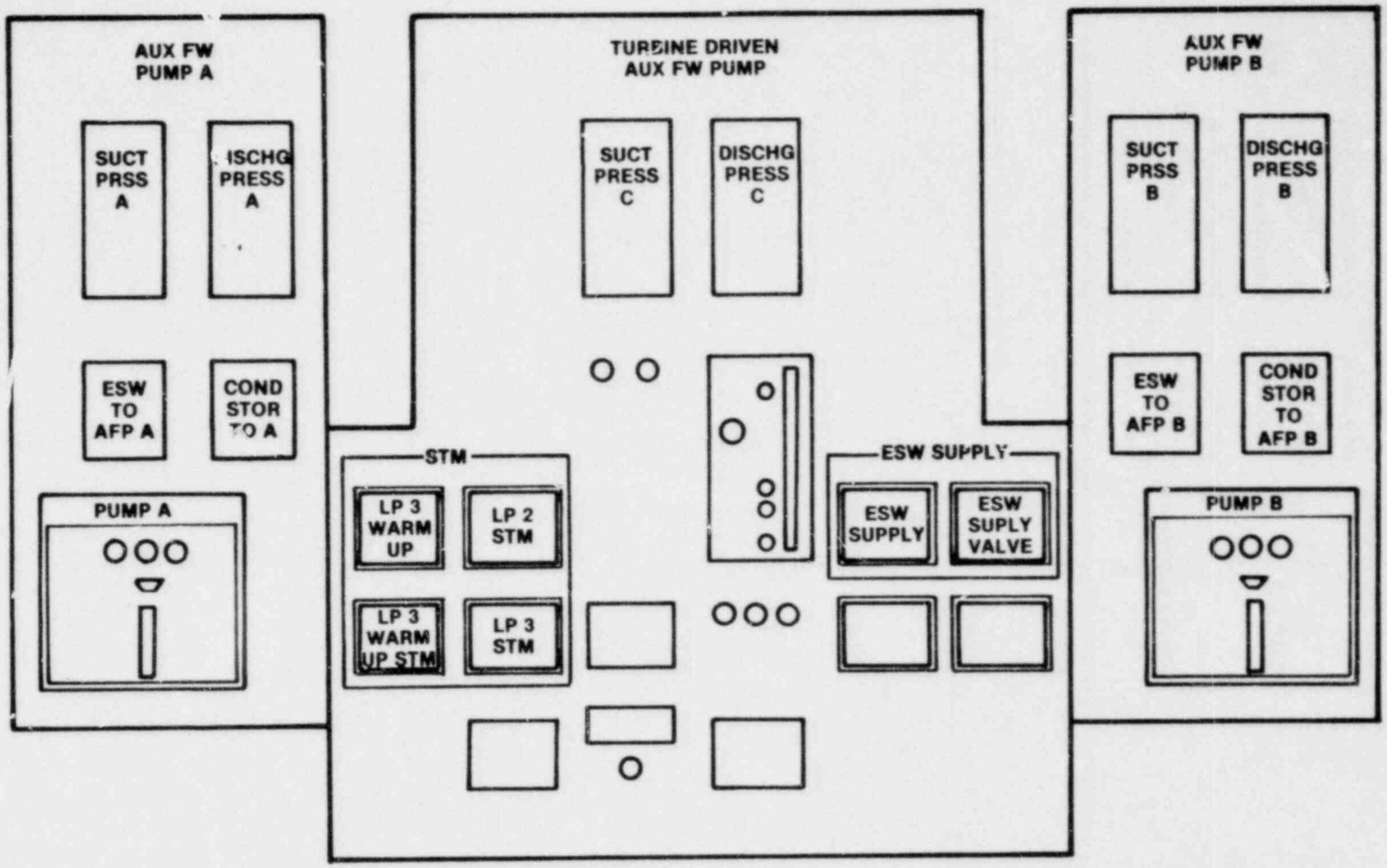


FIGURE 8
MODERATE REARRANGEMENT OF AFWP SYSTEM WITH FUNCTIONAL DEMARCATIONS

FIGURE 9
SECTIONALIZED CC

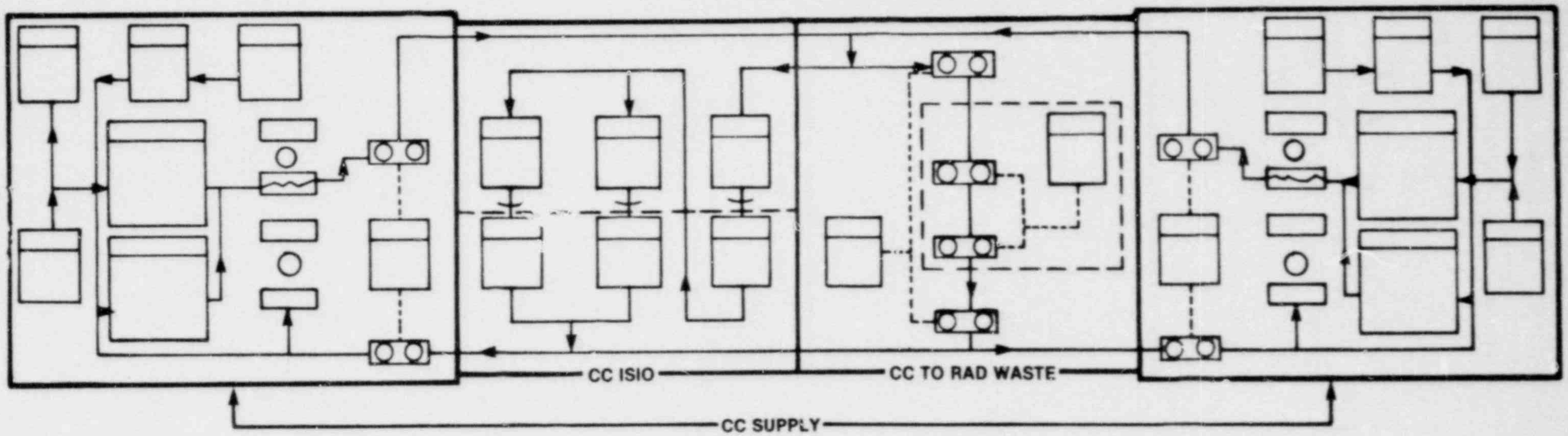
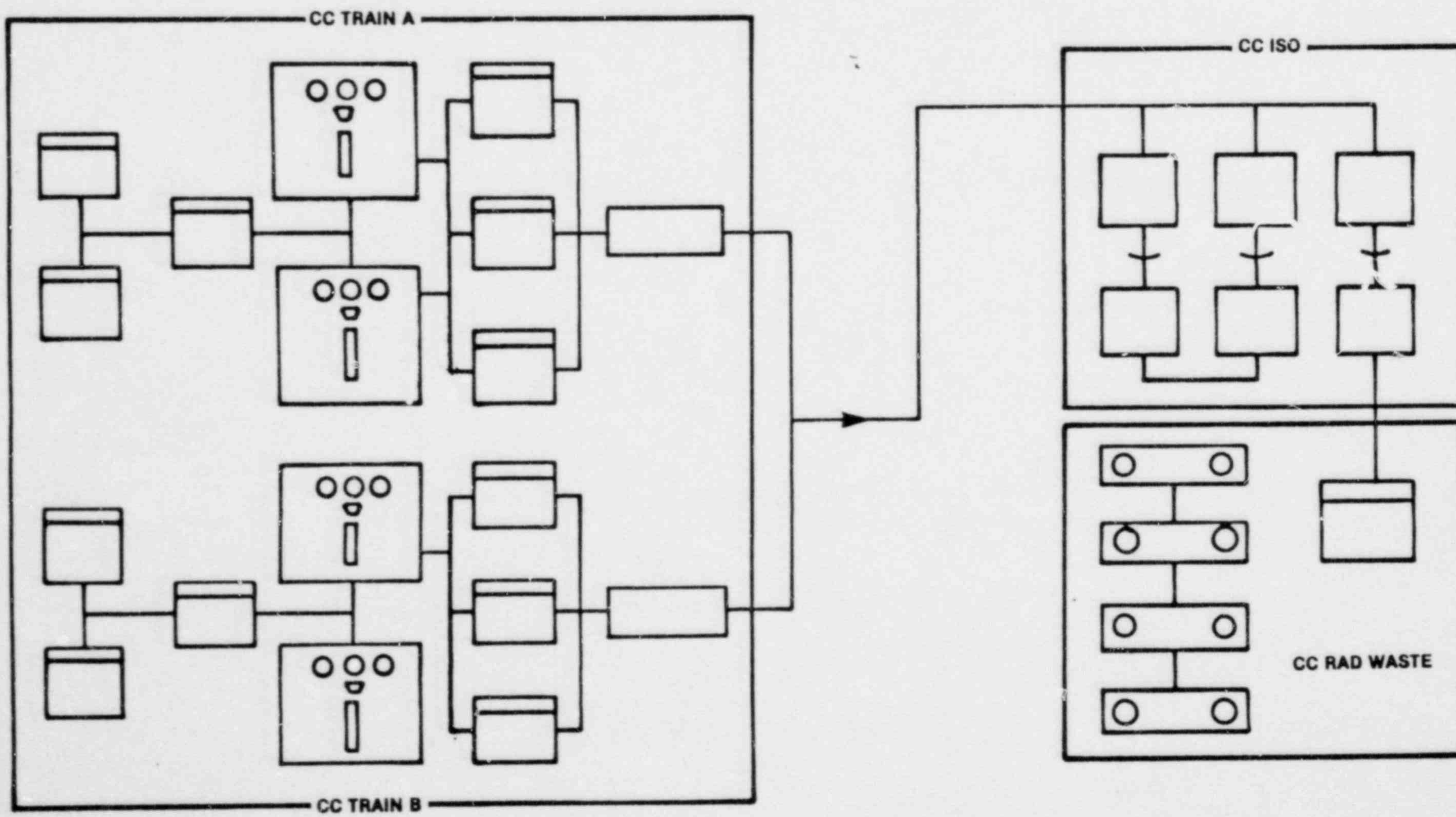


FIGURE 10
COMPONENT COOLING REDESIGN CONCEPT



Of the two approaches discussed above, the first is highly favored since it fully addresses the mirroring problems and introduces no others (demarcation lines will not interfere with mimic lines if designed properly). The background coloring (or demarcation) of the existing layout contributes to visual clutter and only serves to enhance the areas of mirror imaging, as an aid to the operator, rather than eliminating mirror imaging.

C) Essential Service Water. This system is completely mirrored, without any of the additional difficulties of the system discussed previously. Means to reduce the problems of mirror imaging include: 1) redesigning the A&B trains to run left to right in identical layouts (as recommended for component cooling); and 2) background code, via color, as recommended for CC, each train of ESW. Again, a rearrangement with demarcations is preferred over demarcation or background coloring alone.

D) Engineered Safeguards. Probably the worst instances of mirror imaging in the SNUPPS CR, from a human factors viewpoint, is the engineered safeguards panel. This panel is a sort of a cross design with both mirror imaging and identical design layouts being employed (see Figure 11). The following are true in relationship to the safeguards panel:

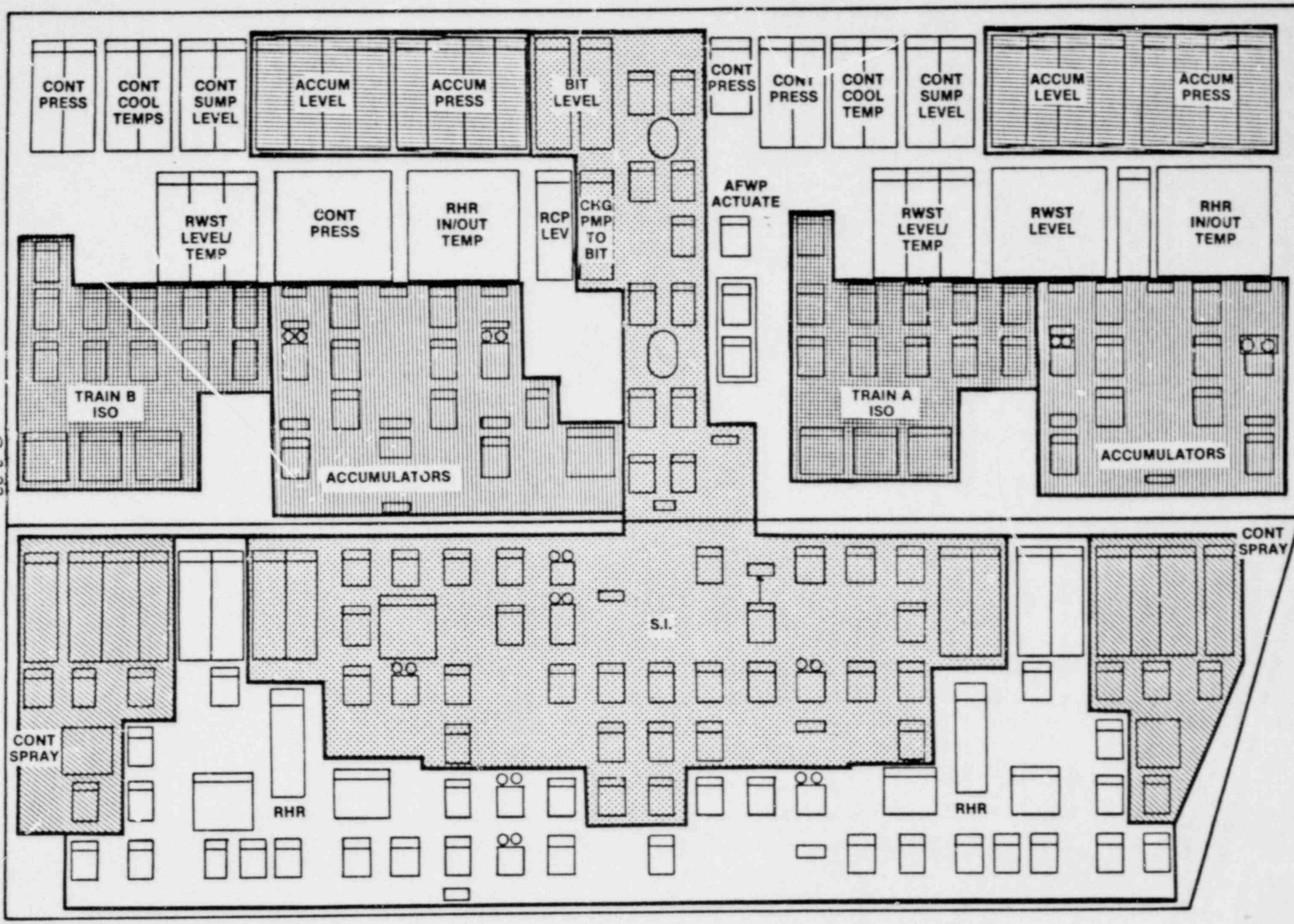
- Controls for RHR and SI are mirrored, but the displays are not
- Containment spray, RHR, and SI are basically mirror imaged, while Phase A & B isolation and accumulator controls are not
- Of the four accumulators, B and D are grouped in a mimic design, as well as A and C. These two groups are not mirrored with regard to one another, but the two accumulators within a group are mirrored (see Figure 12).
- All of engineered safeguards systems are mimicked
- Functionally correspondant controls and displays are separated up to five feet due to the mirror image design.

Operationally, this panel will be low-use, and learning of component locations will be long-term.

During periods of time constraints and high operator stress levels, the following error types may be induced by the mirror image design:

- OMISSIONS – failure to activate a control or reference a display
- SUBSTITUTIONS – operating the wrong control or reading the wrong display
- TEMPORAL – taking too much time to locate controls and displays.

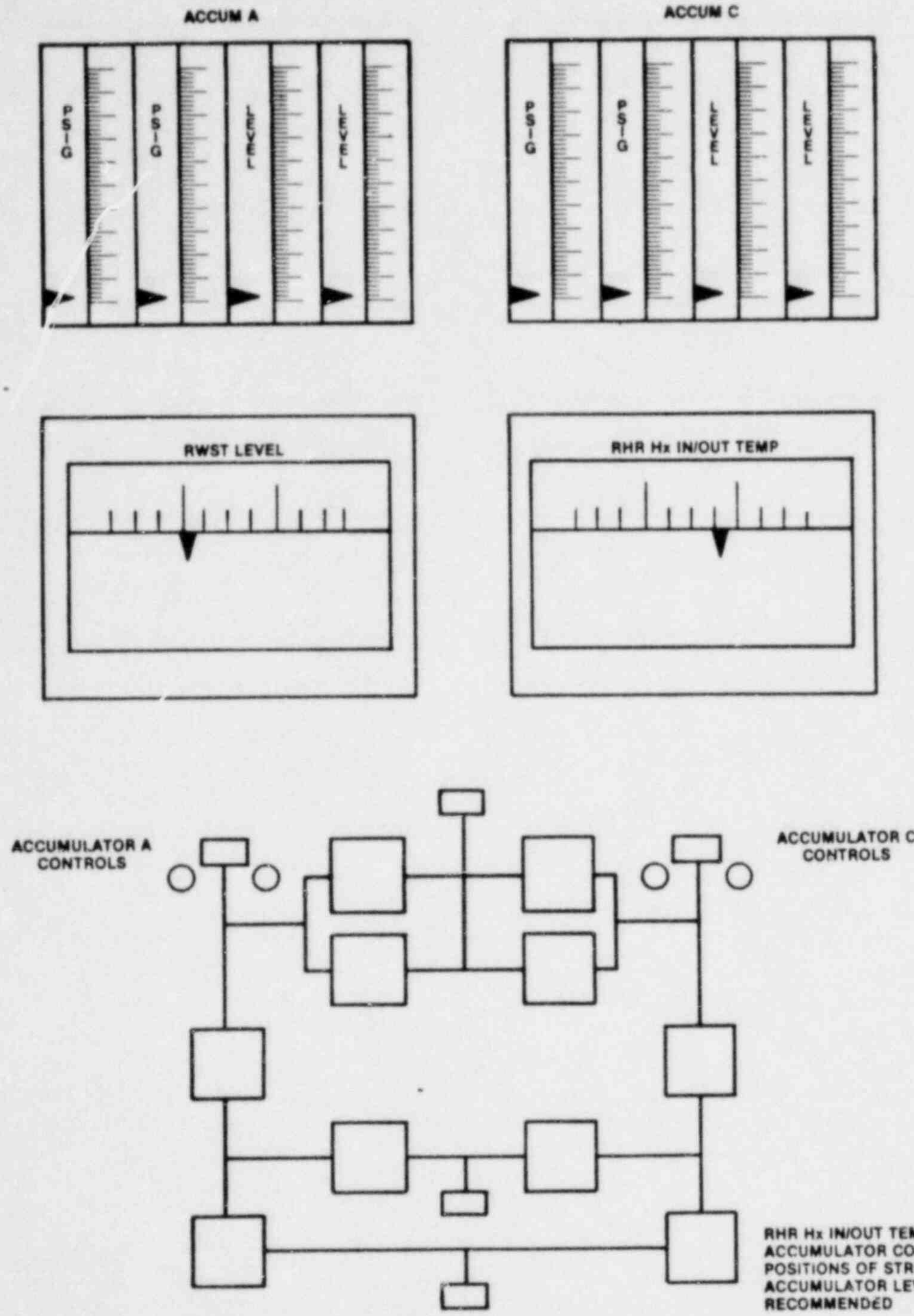
The following recommendations are made regarding backfitting this panel:



C-3 22

FIGURE 11
SNUPPS ENGINEERED SAFEGUARDS SYSTEM

FIGURE 12
LAYOUT OF TWO ACCUMULATORS



RHR Hx IN/OUT TEMP AND RWST LEVEL SEGREGATE ACCUMULATOR CONTROLS AND DISPLAYS. SWITCHING POSITIONS OF STRIP CHART RECORDERS AND ACCUMULATOR LEVEL AND PRESSURE GUAGES IS RECOMMENDED

1. It is highly recommended that the panel be redesigned without incidences of mirror imaging, since:

   - It is a low-usage panel, and learning will be long-term
   - It is a highly important panel
   - There is a high likelihood of operator error in using this panel
   - Little can be done to ameliorate panel problems without extensive redesign; good alternative backfits just don't exist.

   During redesign, system components (e.g., all accumulators, containment spray) could be colocated. Using mimics would then be a recommended practice. A left-to-right operational orientation should be employed, that is, SI, accumulators, containment spray, RHR, etc.

2. An alternative backfit, which is recommended only as an interim measure to complete redesign, is as follows:

   a) Remove all instances of "part mirroring" from the boards, i.e., change some components such that systems are reliably and completely mirrored

   b) Identify the following groups:

      - SI
      - RHR
      - Containment spray
      - Accumulators
      - Phase isolations

      by background coloring on the boards. Demarcation lines are not highly recommended, since mimics and demarcation lines would be more difficult to use.

      Also, provide summary labelling for each system (see Figure 13).

Again, it is pointed out that Recommendation 2 above is made only as an interim to implementing Recommendation 1.

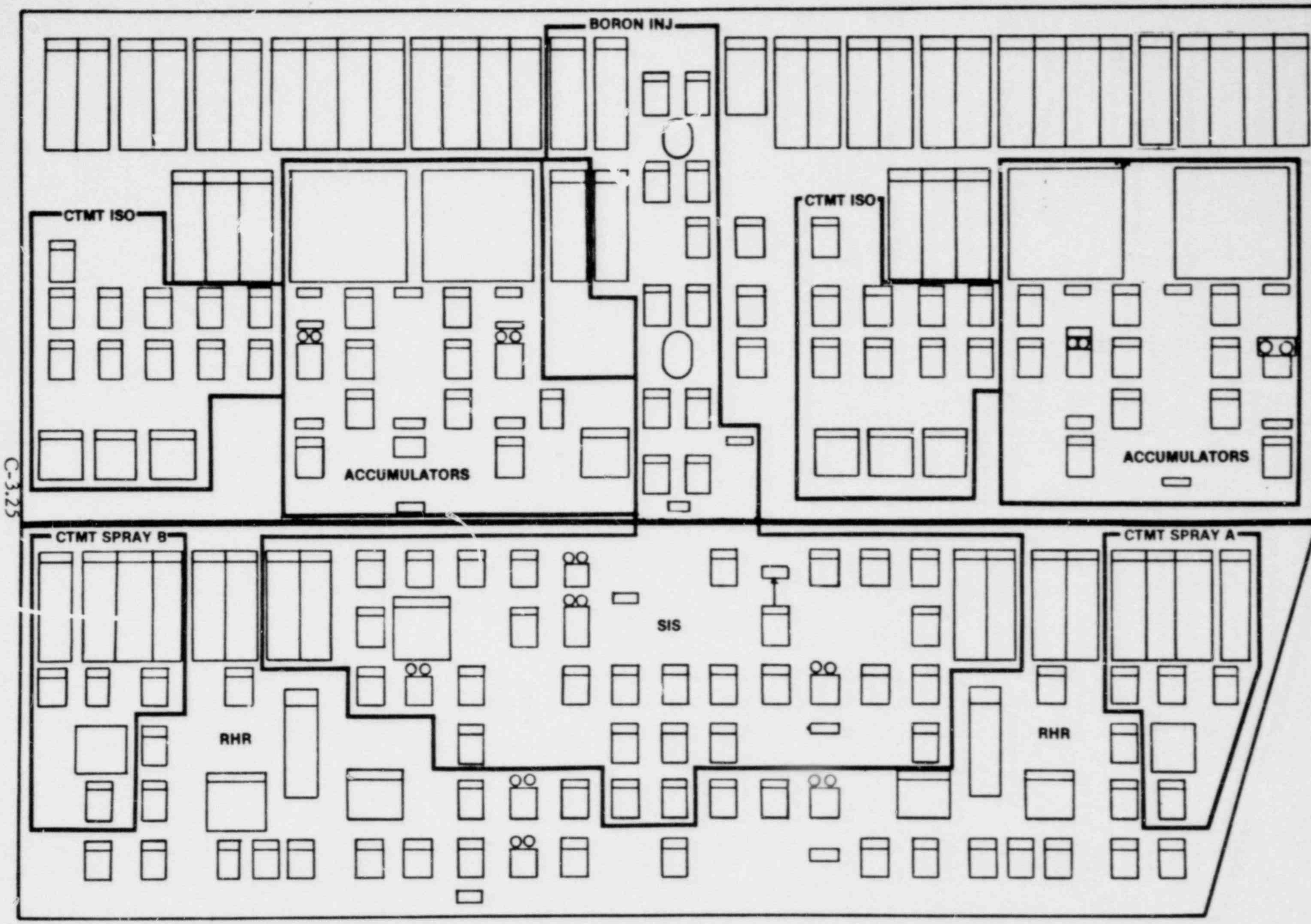


FIGURE 13
HIGHLIGHTED CONTROL GROUPS

5.0 GREEN BOARD CONCEPTS

"Green board" design control rooms philosophies are such that all subsystem and component status indications are designated by the color Green (indicator lights, etc.) when these functions are within programmed limits for all operational situations (for nuclear power stations — start-up, full power, S.I., recirc, and so forth). This approach is typically applied to aerospace and military systems to indicate system readiness and/or availability. These applications usually are designed for specific operational conditions (e.g., fire control, launch, etc.). A similar approach is provided at SNUPPS in the safeguards status panel, indicating "lineup" for safety injection, containment spray actuation, FW isolation, etc. However, a true green board design would cover the entire control room, for example, any time a red, yellow, or any other color light appears, a component or function is out of tolerance.

The chief benefits of a green board philosophy are:

1. Very high probability of detecting out-of-sequence/tolerance functions. This is due to:

   a. Vastly reduced operator memory requirements (specifically long-term memory, which is relatively unreliable during low stress periods and very unreliable during high stress periods)

   b. Greatly reduced perceptual requirements. Pattern recognition is time-consuming and subject to errors. Color discrimination dealing with uniform backgrounds and few color figures (e.g., the nongreen out-of-tolerance function) is nearly immediate and errorless.

2. Diagnosis of the problem (out-of-tolerance function) is more reliable since information processing requirements are practically eliminated. (Perceptual processing is reduced, memory recall is reduced, paired comparison of observed status and design status are eliminated.)

3. Operational response to out-of-tolerance condition is more immediate (problem is self-localizing) and accurate (control/display selection errors are reduced).

A green board philosophy is applicable to nuclear power plant control room design; however, it would require a great deal of engineering of circuits to achieve a green board for all operational modes and postulated accidents, and would disrupt nearly all current

industry design standards (for valve status, etc). Problems with employing green board design philosophies in nuclear power plants are:

- Cost, complexity, and reliability of processing equipment which would be required to drive controls and displays
- Disruption of current industry design philosophies
- The extreme number of design basis plant conditions
- Problems with indicating out-of-service systems and functions.

These are not, however, insurmountable problems. For existing plants, backfitting to a green board design would be excessively costly and time-consuming; since all plant control room logic would need to be redesigned, control electronics complexity would increase dramatically, and many plant functions could not be represented using green board design (nonbinary functions such as T-avg, power ranges, etc.).

For existing plants, backfit to a complete green board concept would not be economically feasible. Alternatives do exist in the form of status boards and summary indications. Specifically, these would be:

1. Summary boards for the immediate operator actions for the following procedures

   a. GEN-O-01 RX trip

   b. GEN-O-02 Turbine trip

   c. E-O Diagnostics

   d. E-O5 Station blackout

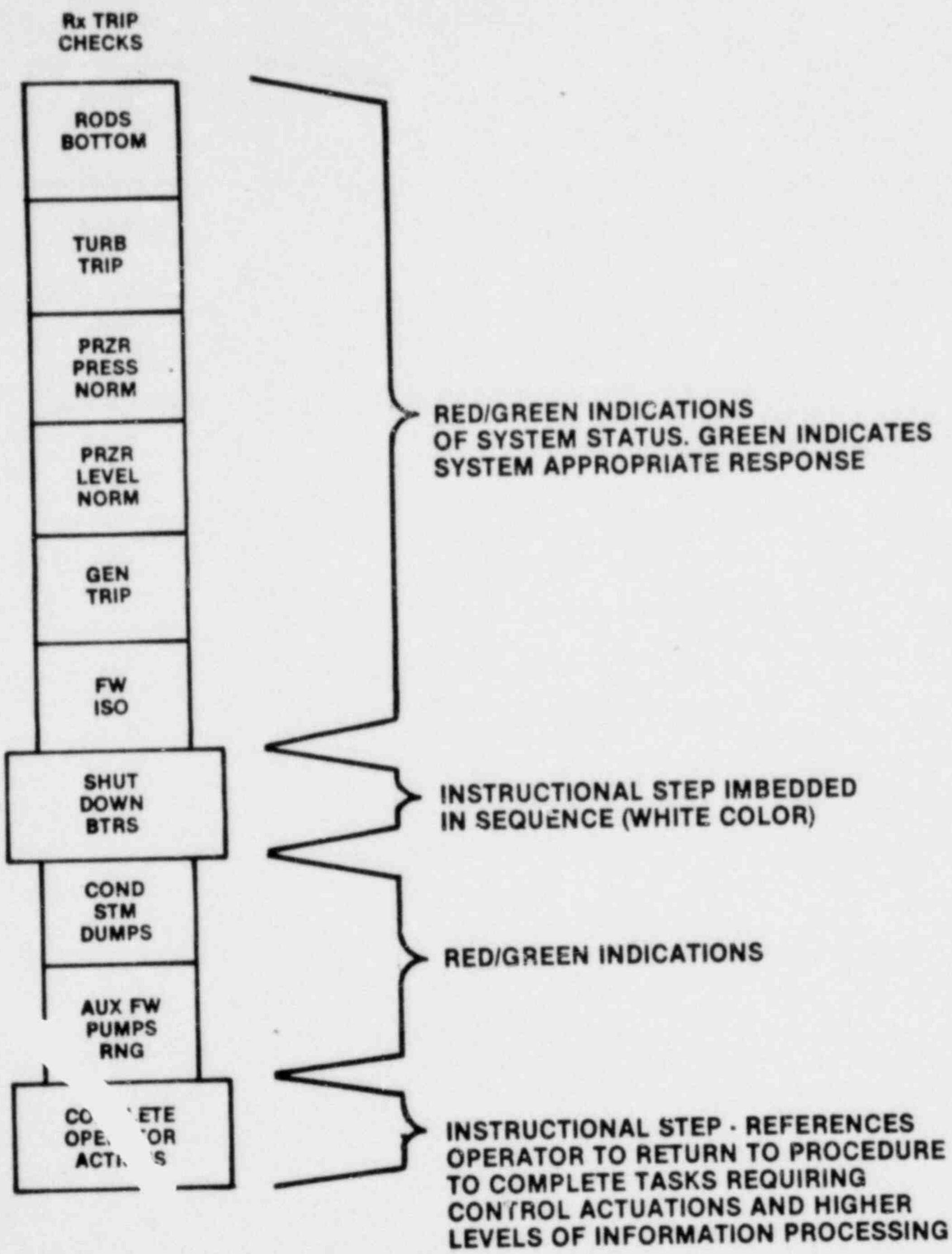
   These summary boards would establish the status of each set of emergency procedures. Redundant indications for appropriate system lineups per emergency procedure would be colored. See Figure 14 for example.

2. Provide summary information, related to procedures and system conditions, using SPDS type CRTs, color coding system lineup red/green.

3. Expand current status panel to incorporate other design basis lineups.

The requirement does exist, however, to reduce and summarize information for the operators of the SNUPPS plants. Assuming green board redesigns are eliminated as an alternative, other means of achieving this end are necessary.

FIGURE 14
EXAMPLE PROCEDURAL AID



TOP-DOWN SEQUENCE IS EMPLOYED

6.0 SUMMARY

With regard to the Control/Display special studies, the following summarizes many of the findings for the SNUPPS control room:

- Many instances exist where displayed parameters can be juxtaposed to directly provide system comparisons, which will aid in decisionmaking
- Several groups of controls can be integrated to permit one operation to initiate a sequence
- The problems and incidences of mirror imaging at SNUPPS are excessive. For some panels, current implementation of mirroring board layouts may be (operationally) debilitating. Several means to reduce the effects were suggested on a case-by-case basis. These means to address the problems include:
    - Panel redesign
    - Functional demarcation lines
    - Color coding of mirror imaged systems
- Given the state of design of the SNUPPS control room, addition of a complete green board design philosophy would be highly expensive. However, special areas of the control room could be designated and designed as "green board areas" to aid in the diagnosis and mitigation of plant accidents.

In conclusion, many human factors engineering design practices at SNUPPS, which may or may not be even traced in discrepancy findings, do not contribute to the efficiency and reliability of plant operations. Indeed, some design practices will interfere with safe operations. Commitment to implementing some of the backfit suggestions in this appendix will enhance system availability, reliability and safety by enhancing system operations.

APPENDIX D
MONITOR LIGHT BOARDS

APPENDIX D-1
ESF STATUS INDICATION EVALUATION

APPENDIX D-2
PERMISSIVE/BLOCKED/PARTIAL TRIP STATUS PANEL

APPENDIX D-1

ESF STATUS INDICATION EVALUATION

1.0 INTRODUCTION

Given the surfeit of information impinging on the sensory capabilities of a nuclear reactor operator, providing assistance in processing this information is crucial. This is especially true in the cases of availability and actuation of the engineered safety systems.

NUREG 1:47 requires that the operator have a system that allows him to monitor the status of the engineered safety features. To adequately perform this function, the monitoring system should provide the operator with only that information required to determine whether: 1) a required safety system will be unavailable due to intentional bypass or malfunction; and 2) a safety system has activated when required. The information should be presented in a manner that does not require interpretation. The operator should be able to make an immediate assessment.

The SNUPPS control room utilizes such a system. Early in the HFE evaluation it was apparent that certain problems existed in this system. This report details the review of the SNUPPS system. This review is based on the following documents:

- SNUPPS FSARs
- Engineered Safety Features Actuation System, System Description, Bechtel #10466-J-00SA, Rev. 5
- Technical Specifications for Status Indicating Systems (SNUPPS), 10406-E-094 (Q), Rev. 3
- Standardized Valve Nomenclature List, Rev. 0.

Part of the evaluation is based on a key assumption made by Essex personnel, namely, that Train A and Train B are completely redundant. This implies that even though both trains would normally activate, the loss of one train would not impede the completion of the safety function. Therefore, the compliment of components monitored should be completely redundant. This implies that a component that is on only one train may be monitored unnecessarily.

2.0 SYSTEM DESCRIPTION

The SNUPPS system consists of three Monitor Light Boards. These are located on RL018. The specific nomenclature is as follows:

- ESF System Status Indication SA066X — Group 1 (Train A)
- ESF System Status Indication SA066Y — Group 4 (Train B)
- ESF System Status Indication SA066Z — Group 2

SA066X and SA066Y are a 15 x 20 matrix. SA066Z is a 4 x 2 matrix. The larger matrices are divided into systems (e.g., SIS, AFAS). Each system has a system level light that activates white when all actuation conditions are met. If conditions are not met, the system level light should be amber. The operator should be able to determine the cause of an amber or an unlit system light by examining its component level lights. The system level light can be lit amber manually from the RL002 panel.

3.0 RESULTS

Results are organized by safety system. Certain problems are consistent throughout all the systems displayed. These generic problems include the following:

- Windows redundant to both Train A and Train B are not located in the same positions within each matrix. This creates difficulty in both pattern and location recognition. The specific items are identified in the system level results.
- Many window labels contain only component names and not the component engineering number. This increases the difficulty in locating specific components on the control room boards or in the field. Also, some of the names are not chosen from the standard valve nomenclature list or are not well chosen. Details are contained in the system results.
- The NSSS Monitoring System has windows on the ESF status panels (SIS and CISϕA) that do not compliment the ESF panel concept. This problem is discussed in the SIS section.
- The amber color for a bypassed component or system is difficult to discriminate from the white condition.

The documentation available to Essex did not answer all the questions posed. Since some of these questions signify potential problems, it is recommended that SNUPPS make every effort to resolve all the questions raised.

3.1 Safety Injection System (SIS)

The SIS portion of the ESF status panels is the largest and most complex. It also contains most of the NSSS indications. The potential problems are noted below.

3.1.1 NSSS Monitor Subsystem

This system is composed of windows that monitor not only SIS and containment spray but also cold and hot leg recirculation. These windows behave contrary to the other windows. According to system description, the windows will light white when not in their normal mode and will remain unlit when in their normal mode. This requires that the operator remember: 1) which windows are part of the NSSS system; 2) that a white light could indicate an abnormal condition; and 3) that a window out of phase with its surrounding windows is a problem. This memory requirement is extreme, especially given the inconsistent manner in which these windows behave relative to the remaining SIS windows. The fact that there are unlit windows during SIS will confuse the operator

tremendously, especially if SIS is not available due to certain component failures.

Recommendations for correcting this situation are as follows:

- Have the windows respond in a consistent manner. If they are in proper condition for SI, they should be lit. Therefore, at the initiation of SI, all windows in the SIS grouping will be white. During changes of mode (i.e., Hot Leg Recirc and Cold Leg Recirc), the system should recognize correct component conditions and continue to show the windows as lit unless something is wrong, in which case an amber light should appear.
- The windows for Hot Leg and Cold Leg Recirc should be grouped in separate subsystems and demarked in a manner that indicates to the operator that these are semi-independent subsystems from SIS. A subsystem level light would also help, (i.e., for Cold Leg Recirc, Hot Leg Recirc).
- Components that require a manual change of state (e.g., SI PMP A RET TO RWST EMHV8814A) should flash to indicate this requirement to the operator.

3.1.2 Windows Without Input to System Level Window

Certain windows in the SIS group have no input to the system level light. These are as follows:

Train A	Train B
BNHV8812A	BNHV8812B
EMHV8814A	ENHV8813
EMHV8807A	EJHV8804B
BNHV8806A	EMHV8807B
EJHV8716A	BNHV8806B
	EJHV8716B

These should be reviewed to determine whether they should have an input to the system level light or whether they should be a separate group from SIS.

3.1.3 Conflicting Redundant Valves

The following redundant valves are in conflict with each other, as some have an input to the system level light but others do not:

- EMHV8814A has no input when EMHV8814B does
- EMHV8804B has no input when EMHV8804A does.

These should be reviewed to determine whether both should have an input to the system level light.

3.1.4 Lack of Redundant Layout of Matrices

Train A and Train B are redundant but the physical layout of their window matrices is not the same. This causes significant learning problems for the operator. Suggested layouts are shown in Figures 1 and 2. These figures contain only the component number.

3.1.5 Lack of Component Numbers

As has been identified in previous paragraphs, many windows lack component numbers. These are supplied in Figures 1 and 2. Related to this are the following valves, which seem to have incorrect names on the simulator, according to the specification:

- EJHCV 606
- EJHCV 607
- EMHV 8809A
- EMHV 8809B.

3.1.6 Potential Improper Group Assignment of Valves

Valves in the NSSS system have been assigned to specific groups (1 through 5) that change state according to the mode (e.g., SIS, Hot Leg). There appear to be inconsistencies between some group designations in the System Description and Specification and the implication in the FSAR. Specifically, valves EJHV8716A and B are identified as NSSS Group 2, which is open for SIS and closed for Hot and Cold Leg Recirc.; but the FSAR (Figure 6.3-2) implies that these valves are open for SIS and Hot Leg Recirc., and closed for Cold Leg. Also, valve EMHV8835 is identified as NSSS Group 5 but the FSAR indicates that it should be part of Group 1.

These inconsistencies in the various documents should be investigated and resolved.

3.1.7 Potential Removal of Component Windows

Based on the assumption regarding redundancy made in paragraph 1.0, the following components should be reviewed to determine whether they are necessary for SIS or whether they should be removed as they are monitored on one train only:

- EMHV8883
BORON INJ RECIRC PUMP TO BIT
ISO VALVE
- EMHV8835
SAFETY INJECTION COLD LEG ISO VALVE

		S	I	S	• GLHZ85	• GLHZ87
• PAL01A	• PEF01A	PEG01A	PEG01C	• GFHZ30A	• GKHZ150	
SGF02A	• PEF01C		SGL11A	• GFHZ30B	• GKHZ153	GLHZ80
PJE01A	• EFHV23	• EFHV42	• EGHV69A	• GFHZ32A	• GLHZ155	GLHZ81
• GFHZ101	• EFHV24	• EFHV45	• EGHV69B	• GFHZ32B	• GLH213	
• GFHZ103	• EFHV31	• EFHV49	• EGTV29	• CGG02A	• GLHZ32	• SGL15A
• CGM01A	• EFHV33	• EFHV51	GFHZ11	• GGHZ15	• GLHZ69	CGN03A
• GMHZ9	• EFHV37	• EFHV59	GFHZ14	• GGHZ40	• GLHZ71	CGN03A
GTHZ26	• EFHV41	• EFHV65	GFHZ20	• GGHZ41	• GLHZ73	SGN01A
GTHZ28	• LFHV106	• EFHV87	GFHZ22	• GGHZ42	• GLHZ75	SGN01C
EJHV8811A	BNHV8812A	PEV01A	SGL10A	EJHCV606	EPHV8808A	EPHV8802A
EMHV8814A	EMHV8814B	PEM01A	SGL09A	EMHV8923A	EPHV8808D	EMHV8821A
EJHV8804A	EMHV8807A	PBG05A	SGL12A	BNHCV8800A	BGLCV112B	EJHV8809A
BNLCV1120	BNHV8806A	PEM02A	EMHV8803A	BGHV8110	BGHV8106	
EJHV8716A		FMHV8883	EMHV8870A	EMHV8801A		

• Same location as simulator

FIGURE 1: SUGGESTED LAYOUT OF SIS, TRAIN A

		S	I	S	• GLHZ86	• GLHZ88
• PAL01B	• PEF01B	PEG01B	PEG01D	• GFHZ31A	• GKHZ151	
SGF02B	• PEF01D		SGL11B	• GFHZ31B	• GKHZ152	
PJE01B	• EFHV25	• EFHV40	• EGHV70A	• GFHZ33A	• GKHZ154	
• GEHZ102	• EFHV26	• EFHV46	• EGHV70B	• GFHZ33B	• GLHZ14	
• GEHZ104	• EFHV32	• EFHV50	• EGTV30	• CGG02B	• GLHZ33	• SGL15B
• CGM01B	• EFHV34	• EFHV52	GFHZ12	• GGHZ21	GLHZ70	CGN03B
• GMHZ19	• EFHV38	• EFHV60	GFHZ13	• GGHZ43	GLHZ72	CGN03B
• GTHZ27	• EFHV39	• EFHV66	GFHZ21	• GGHZ44	GLHZ74	SGN01B
• GTHZ29	• LFHV105	• EFHV88	GFHZ23	GLHZ62	GLHZ76	SGN01D
BNHV8811B	BNHV8812B	PEJ01B	SGL10B	EJHCV607	EPHV8808B	EMHV8802B
BNHV8813		PEM01B	SGL09B	FMHV8923B	EPHV8808D	EMHV8821B
BNHV8804B	EMHV8807B	PBG05B	SGL12B	BNHCV8800B	BGLCV112C	EJHV8809B
BNLCV112E	BNHV8806B	PEM02B	• EMHV8803B	BGHV8111	BGHV8105	EMHV8840
BNHV8716B			EMHV8870B	EMHV8801B	• EMHV8924	EMHV8835

• Same location as simulator

FIGURE 2: SUGGESTED LAYOUT OF SIS, TRAIN B

- EMHV8924
  RHR HX A/CVCS TO SI PUMP A
  UPSTREAM ISO
- EJHV8840
  RHR/SI HOT LEG RECIRC ISO VALVE

3.2 Containment Isolation System (CISϕA)

The CISϕA system also contains elements of the NSSS monitoring system. The recommendations for the SIS system (para. 3.1.1) apply here also. The other problem areas are given below.

3.2.1 Fire Protection System Valves

Valve KCHV253 and KCHV254 are identified by the FSAR (Figure 6.2.4-1) as being actuated by CISϕA. These valves are not monitored by the ESF status panel. If these are necessary for CISϕA, then they should be monitored by this system. Further review of this problem is recommended as this could be critical information to the operator if CISϕA became unavailable.

3.2.2 Monitoring of Inappropriate Valve

Valve HBLCV1003 (on Train A) is monitored by CISϕA but, according to the FSAR (Figure 11.2-1), this valve is not actuated by any ESF function. The correct valve appears to be HBNV7176. This should be corrected on the MLB and in the documentation.

3.2.3 Redundant Layout and Component Numbers

As in SIS, the redundant features of Train A and Train B are not laid out consistently. Also, many components lack numbers. Figures 3 and 4 provide recommendations for correcting this.

3.2.4 Potential Removal of Component Windows

Based on the assumption that Train A and B are redundant, the following valves should be reviewed for possible removal from the ESF status panels:

- EMHV8888
  ACCUMULATOR TANK FILL LINE
  ISO VALVE
- EPHV8880
  CONTAINMENT N2 SUPPLY ISO VALVE

	CI	SØA	
BGHV8160	ENHV1	GSHV13	KCHV253
BGHV8112	GSHV20	GSHV14	EMHV8881
SJHV6	BBHV8026	GSHV18	EMHV8964
SJHV13	LFFV95	GSHV3	
SJHV19		GSHV8	
EJHV8890A	KAFV29	HBHV7126	EMHV8823
EJHV8825		HBHV7176	EMHV8824

FIGURE 3: SUGGESTED LAYOUT OF CISØA, TRAIN A

	CI	SØA	
BGHV8152	ENHV7	GSHV4	KCHV254
BGHV8100	GSHV21	GSHV5	EMHV8843
SJHV5	BBHV8027	GSHV9	EMHV8871
SJHV12	LFFV96	GSHV12	
SJHV18	EPHV8880	GSHV17	EMHV8888
EJHV8890B		HBHV7150	
	BLHV8047	HBHV7136	

FIGURE 4: SUGGESTED LAYOUT OF CISØA, TRAIN B

- BLHV8047
  REACTOR M/U WATER CONTAINMENT ISO
- KAFV29
  RX BLDG INSTRUMENT AIR SUPPLY

3.2.5 FSAR Confusion

Paragraph 7.3.1.1.3 of the FSAR states that ". . . the H_2 mixing fans automatically start. . . on receipt of CIS." Figure 9.4-6 (Sheet 1) of the FSAR indicates that only SIS starts these fans. This discrepancy should be resolved.

3.3 Containment Isolation System — Phase B (CISϕB)

The only problem identified for this system concerns the lack of redundant layout. It is recommended that the Train B windows be located identically to those in Train A.

3.4 Containment Spray Actuation System (CSAS)

The only problem identified for this system is that the RWST SUPPLY TO CTMT SPRAY PMP valves do not incorporate numbers. It is recommended that the following numbers be added:

- BNHV3 to Train B
- BNHV4 to Train A.

3.5 Control Room Ventilation Isolation System (CRVIS)

The following paragraphs detail the problems associated with CRVIS.

3.5.1 Incorrect Assignment of Components

The LOWER CABLE SPREAD ROOM ISO DAMPERS, GKHZ59A and B, are located on Train B when the FSAR (Figure 9.4-1) indicates that they should be on Train A. It is recommended that where the error lies be determined and corrective action be taken.

3.5.2 Damper Indications Without Function

The CHASE AND TANK AREA DAMPERS, GKHZ113A and B, are on Train B but do not appear in the FSAR. This indicates that they have been deleted from the plant design and therefore should be deleted from the ESF status panel.

3.5.3 Lack of Redundant Layout and Component Numbers

Figures 5 and 6 provide suggested layouts for CRVIS and provide component numbers.

3.5.4 Potential Removal of Component Windows

Based on the assumption that Train A and B are redundant, the following components should be reviewed for possible removal from the ESF status panels:

- GKHZ55A
  UPPER CABLE SPREAD ROOM SUPPLY
- GKHZ55B
  UPPER CABLE SPREAD ROOM EXHAUST
- GKHZ59A
  LOWER CABLE SPREAD ROOM SUPPLY
- GKHZ59B
  LOWER CABLE SPREAD ROOM EXHAUST
- GKHZ122A
  CONTROL BLDG ESF SWGR RMS 1&2 SUPPLY DMPR
- GKHZ122B
  ESF SWGR ROOM 1 EXH ISO DAMPER
- GKHZ123A
  ACCESS CONTROL SUP SYS BOOSTER COIL SUPPLY
- GKHZ123B
  CHANGE AREA TO CONT BLDG EXH FANS ISO
- GKHZ98A
  CONTROL BLDG SWGR RM 4 SUPPLY DMPR
- GKHZ98B
  CONTROL BLDG BATTERY RMS EXHAUST DMPR

3.6 Fuel Building Ventilation Isolation System (FBIS)

3.6.1 Components Not Monitored

The EMERGENCY EXHAUST FANS CGG02A and B are actuated by FBIS and SIS. Only SIS monitors these fans. If they are necessary for FBIS to occur, then they should be monitored under FBIS also.

3.6.2 Inappropriate Nomenclature

Dampers RZ36 and RZ37, HZ40 and HZ43, and HZ42 and HZ62 have different nomenclatures in the FSAR, ESF status panel system description, and the matrix at the simulator. HZ42 and HZ62 are labeled differently between trains. These two are

CGK03A	CRV	IS	SGK05A
HZ19A	SGK04A	CGK04A	HZ160
HZ19B	HZ29A	HZ75A	
HZ19C	HZ29B	HZ75B	
HZ19D	HZ13A		HZ172A
HZ59A	HZ13B		HZ172B
HZ59B	HZ13F		HZ174A
HZ13D	HZ13G		HZ174B
HZ13E	HZ13C	HZ13H	LAMP TEST

FIGURE 5: SUGGESTED LAYOUT OF CRVIS, TRAIN A

CGK03B	CRV	IS	SGK05B
HZ30A	SGK04B	CGK04B	HZ161
HZ30B	HZ40A	HZ83A	HZ98A
HZ30C	HZ40B	HZ83B	HZ98B
HZ30D	HZ184A	HZ122A	HZ173A
HZ55A	HZ184B	HZ122B	HZ173B
HZ55B	HZ184C	HZ123A	HZ175A
HZ57A	HZ184D	HZ123B	HZ175B
HZ57B	HZ184E	HZ123C	

FIGURE 6: SUGGESTED LAYOUT OF CRVIS, TRAIN B

monitored under both SIS and FBIS but have different labels in the two systems. This nomenclature should be standardized in all sources.

3.7 Main Steam Isolation System (SLIS)

3.7.1 Inconsistent Order

The MAIN STEAM LOOP LOW POINT DRAINS are ordered 3,2,1,4, while the MAIN STEAM ISO VALVES and BYPASS VALVES are ordered 4,1,2,3. The order of these should be consistent, preferably 1,2,3 and 4. Also, the STEAM LOOPS should be identified with the same nomenclature as are the steam generators, i.e., A,B,C,D.

3.7.2 Lack of Valve Numbers

The LP 2 WARMUP STM TO AUX FW PMP TURB and LP 3 WARMUP STM VALVES (on Train A) lack component numbers. These are ABHV48 and ABHV49, respectively.

3.7.3 Potential Removal of Component Windows

The valves mentioned in 3.7.2 should be reviewed for necessity of display on the ESF status panels.

3.8 Containment Purge Isolation System (CPIS)

No problems were found in this section.

3.9 Feedwater Isolation System (FWIS)

The following main feedwater control valves and bypass control valves are closed by FWIS but are not monitored on the ESF status panels:

- AEFCV510
- AEFCV520
- AEFCV530
- AEFCV540
- AEFCV550
- AEFCV560
- AEFCV570
- AEFCV580

These should be reviewed to determine whether they should be monitored on the ESF status panels.

3.9.1 Feedwater Isolation Valve Order

The FW isolation valves are ordered A,B,C,D. While this is the preferred order, this is not the same order as the MAIN STM ISO VALVES (see paragraph 3.7.1). To facilitate operator recognition and use of the ESF status panels, the order of presentation of the primary cooling loop should be consistent. It is recommended, therefore, that the A,B,C,D order be applied throughout the ESF status panels.

3.10 Auxiliary Feedwater Actuation System (AFAS)

AFAS is monitored on all three panels (SA066X, SA066Y, and SA066Z).

3.10.1 Inclusion of Steam Generator Blowdown Isolation System (SGBSIS)

The SGBSIS is embedded in the AFAS system (SA066X and Y). This subsystem can be actuated independently of AFAS and therefore should be a separate group. The system description discusses a component level window labeled SGBSIS but none is present on the simulator or in the specification. It is recommended that the SGBSIS be separated out into its own group, as suggested by the system description (see paragraph 3.4.3.3j).

3.10.2 Loss of Suction Pressure (LSP) Subsystem

The system description (paragraph 3.4.3.3i) indicates that the following components do not respond to an AFAS signal, though they do input to the AFAS system level amber light:

SEP. GROUP 1 (SA066X	SEP. GROUP 4 (SA066Y)
ALHV31	ALHV30
ALHV32	ALHV[illegible]
ALHV35	ALHV34
ALHV36	EFHV25
EFHV23	EFHV26
EFHV24	PEF01B
PEF01A	EFHV66
EFHV65	

The system description goes on to say that these should be grouped under a subsystem window light for LSP because they respond to a specific LSP signal. The specification and

the example at the s ulator do not reflect this subgrouping. It is recommended that this subgroup window be incorporated into the matrices. Also, the essential service water components, while indicated as part of this system, are monitored only under SIS. It is recommended that these be examined for inclusion in the LSP subgroup.

3.10.3 Auxiliary Feedwater Supply Valves

Valves ALHV9 and ALHV11 (Train A) are monitored by one window. It is recommended that they be monitored by separate windows to facilitate fault diagnosis.

3.10.4 Lack of Redundant Layout

The AFAS, like most other sections of the ESF status panels, lacks a consistent layout from Train A to Train B. Given the questions raised by the lack of SGBSIS (paragraph 3.10.1) and LSP (paragraph 3.10.2) subsystem level windows, a layout has not been suggested. These issues need to be resolved first.

3.10.5 Potential Removal of Component Windows

Based on the assumption that Train A and B are redundant, the following component should be reviewed for removal from the ESF status panels:

- o ALHV36
  CST TO TD AUX FW PUMP

3.10.6 System Level Window on SA066Z

The AUX FW ACTUATION SYSTEM light is one window. To maximize readability, it should be two windows, as are the system level windows on SA066X and SA066Y.

3.11 CLASS 1 ELECT

The breakers are grouped according to voltages. This does not reflect any source/load condition or relationship. Figures 7 and 8 provide suggested layouts for the Callaway site and Figures 9 and 10 provide suggested layouts for the Wolf Creek site.

	CLASS 1 ELECT		
NB0109	NB0112	NB0111	KKJ01A
NB0110	NB0113	NB0106	NB0116
NG0301	NG0101		NB0117
NG0306	NG0106		NG0705
NG0307	NG0107		

FIGURE 7: SUGGESTED LAYOUT OF CLASS 1 ELECT FOR CALLAWAY, TRAIN A

	CLASS 1 ELECT		
NB0209	NB0212	NB0211	KKJ01B
NB0210	NB0213	NB0208	NB0216
NG0401	NG0201		NB0217
NG0406	NG0206		NG0805
NG0407	NG0207		

FIGURE 8: SUGGESTED LAYOUT OF CLASS 1 ELECT FOR CALLAWAY, TRAIN B

	CLASS 1 ELECT		
NB0109	NB0112	NB0111	KKJ01A
NB0110	NB0113	NB0106	NB0116
NG0301	NG0101		NB05E
NG0306	NG0106		
NG0307	NG0107		

FIGURE 9: SUGGESTED LAYOUT OF CLASS 1 ELECT FOR WOLF CREEK, TRAIN A

	CLASS 1 ELECT		
NB0209	NB0212	NB0211	KKJ01B
NB0210	NB0213	NB0208	NB0216
NG0401	NG0201		NB06E
NG0406	NG0206		
NG0407	NG0207		

FIGURE 10: SUGGESTED LAYOUT OF CLASS 1 ELECT FOR WOLF CREEK, TRAIN B

3.12 General Comments

3.12.1 Lamp Test

A lamp test is to be located on each ESF status panel. The simulator has only one shown. It is recommended that these definitely be incorporated.

3.12.2 Essential Service Water Isolation

ESW isolation occurs automatically for various causes (system description, paragraph 3.1.2) but is monitored only under SIS, which is not actuated by all the causes that activate ESW isolation. It is recommended that the possibility of separating out ESW isolation windows be explored.

3.12.3 Manual Bypass Controls

The system level lights can be put in a bypass condition manually from panel RL003. It is recommended that a method for logging the cause for this manual bypass be developed to keep all shifts aware of plant status.

4.0 CONCLUSIONS

The concept of an ESF Status Monitoring System is essential for effective operator performance. The system should provide an operator with the minimum information necessary for assessing the availability of the various ESF systems. This information should be presented in a simple format that minimizes the operator's need to interpret. Given these requirements, the SNUPPS ESF Status Indication Monitor Light Boards are deficient.

The major deficiencies are as follows:

- The NSSS subsystem behaves in a manner not typical of the other subsystems displayed
- The redundant components of Train A and B are not ordered consistently
- Certain subsystems should have their own subsystem level light, instead of being incorporated within larger systems
- The lack of component numbers makes locating these components difficult
- Errors exist in component names and groupings.

As the system stands now, it does not adequately perform the function intended. It is recommended that the questions raised in this paper be explored and that the recommendations contained herein be implemented. A further recommendation is that a hierarchical approach be taken: Subsystems should be grouped under a subsystem level light which then imputs to the system level light.

The potential exists in the ESF Status Indication System to provide a needed tool to the operator. Unfortunately, for the intended function to be performed, the present system must be reevaluated and redesigned.

APPENDIX D-2

PERMISSIVE/BLOCKED/PARTIAL TRIP STATUS PANEL

1.0 INTRODUCTION

During the initial phase of Data Collection for the SNUPPS control room review, the permissive/blocked/partial trip status panel (RL022) was identified by operators as being difficult to use. A preliminary look indicated the potential for human engineering problems. Further study was initiated using the following sources:

- FSAR, Rev. 0
- Engineered Safety Features Actuation System, System Description, 10466-J-00SA, Rev. 5
- Technical Specification for Status Indicating Systems for SNUPPS, 10466-E-094, Rev. 3
- Photographs of the simulator at Zion.

This report details the results of that study.

2.0 RESULTS

The permissive/blocked/partial trip status panel concept is a good one and should be maintained. However, the status panel in its present format is of almost no use in situations where the operator needs to quickly assess the plant condition. To properly use the panels, the operator must be able to associate the trip channel indicators with the bypass and block indicators.

An example of how the operator would need to search the panel in order to gain information follows. The reactor trip, Source Range High Neutron Flux, is the "first" trip visually encountered on the panel. The two trip channels are located at position ① on Figure 1. The trip channels can be bypassed; bypass indicators are located at position ② . The trip can be blocked, position ③ , if permissive P6 ④ is satisfied. Permissive P6 is satisfied when one of the two neutron flux detectors (intermediate range) is above the setpoint, position ⑤ . As Figure 1 indicates, the operator must integrate information scattered all over the board. This causes a tremendous load on his short-term memory and information processing ability. The operator cannot use any techniques of pattern recognition.

There appear to be no effective means for relocating windows that would measurably improve the utility of the status board. The board represents logic flows. Therefore, the most effective way to provide this information would be in a mimic. The permissives could be grouped in a status panel and the trip logic could be diagrammed in flow lines. Figures 2 and 3 illustrate how this could be done.

Other problems found with this panel are listed below.

- Window Color Coding — The present color coding emphasizes the protective channels. This information is of little value to the operator. His concern is with how many windows are lit. If color were used, it would convey more information to the operator by coding the trips with one color, the permissives with one color, the blocks with one color, etc.
- Window Labeling — The window labeling is 0.125 inches high. This is grossly inadequate for reading from the Operator's Control Console.
- Inadequate Monitoring of Instruments — The FSAR (Figure 7.2-1, sheet 7) indicates that two of four instruments in any loop for Steam Generator Low-Low Water Level and two of three instruments in any loop for Low Steamline Pressure initiate a reactor trip and SIS, respectively. The panel only monitors three instruments per loop in the former case and only one instrument per loop in the latter case.

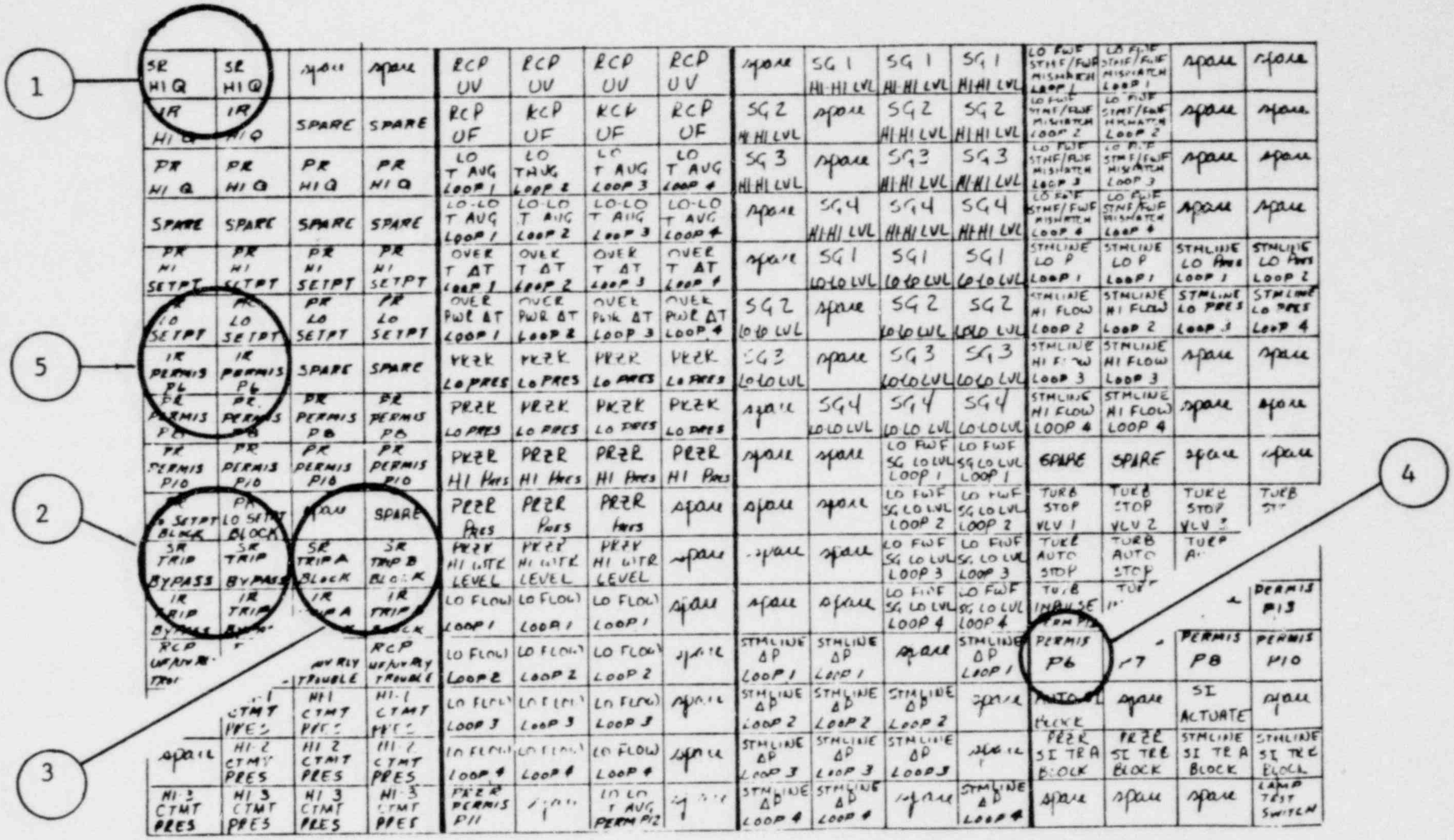


FIGURE 1. Reactor Trip : Source Range High Neutron Flux

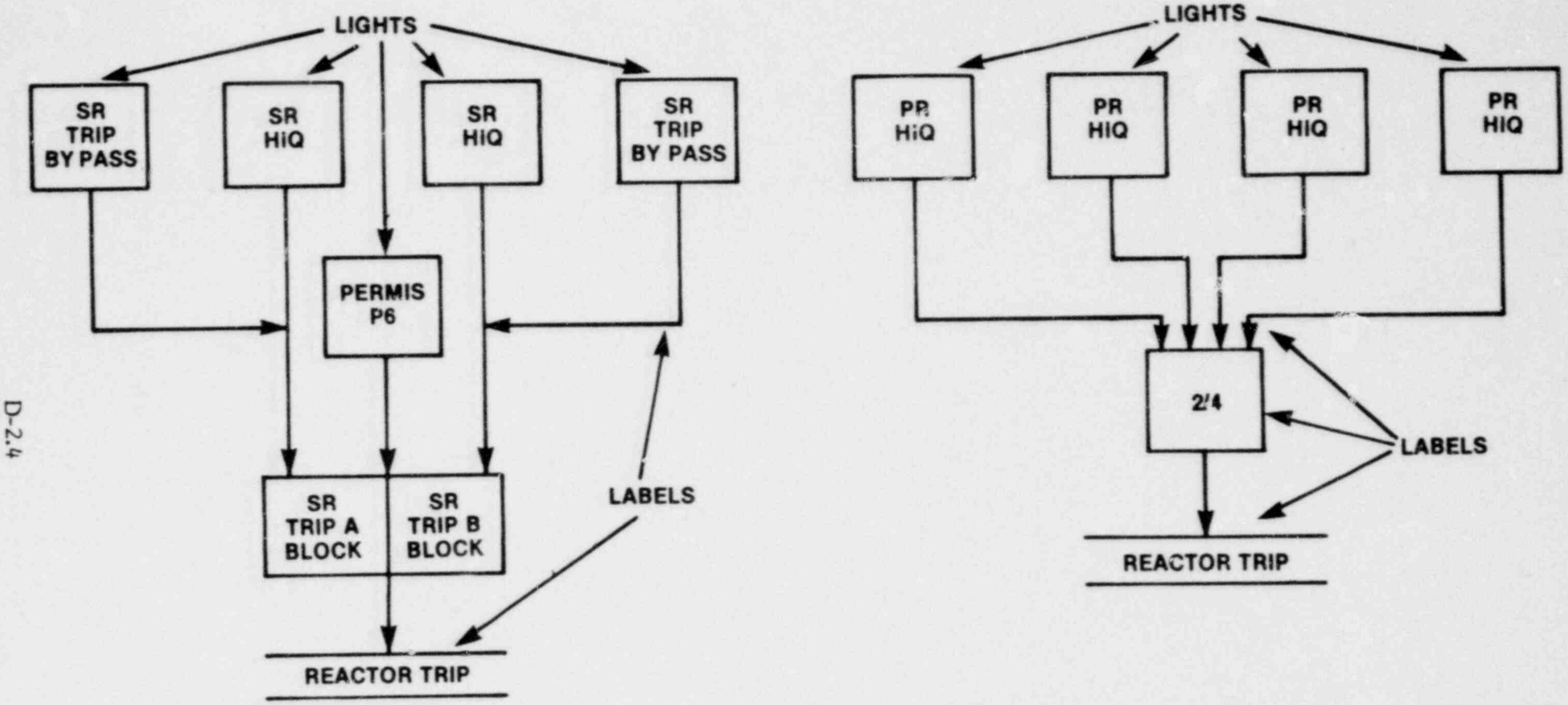


FIGURE 2. TYPICAL MIMIC · POTENTIAL FORMAT

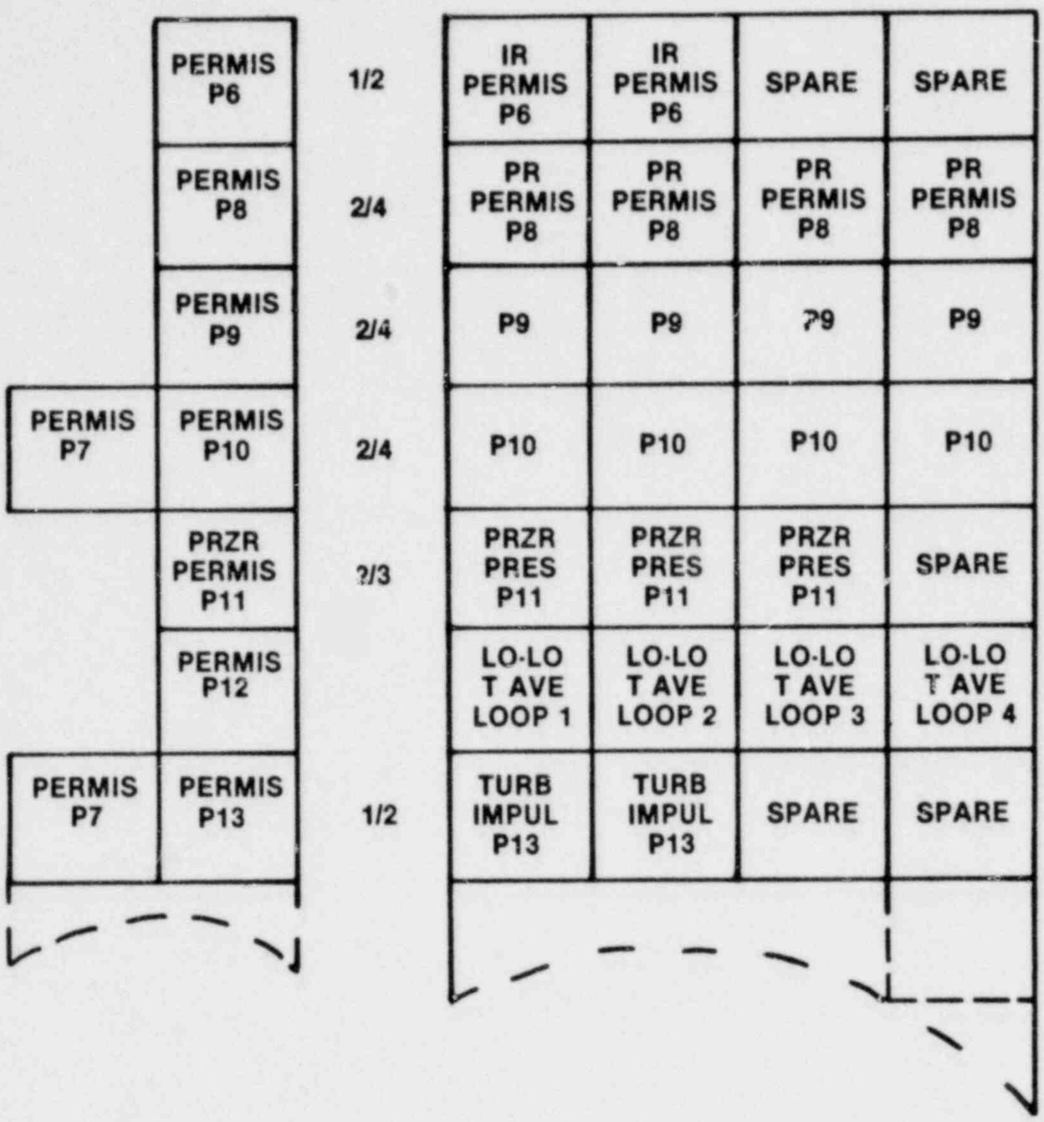


FIGURE 3. PERMISSIVE STATUS - POTENTIAL FORMAT

- Potential Lack of Lamp Test — The specification indicates that the panel should have a lamp test but that the simulator is not equipped with this capability.

- Potential Mislabeling — In the specification (Figure 5), two windows labeled STMLINE LO P LOOP 1 appear to be additional to those required. It is suspected that these should be STMLINE HI FLOW LOOP 1.

- Potential Lack of Adequate Monitoring — The FSAR indicates that steam line isolation is initiated by high steam pressure rate, low steam line pressure and Hi-2 containment pressure. High steam pressure rate is not monitored on this panel, but the possibility exists that it should be.

- Potential Monitoring of Inappropriate Items — It could not be determined from the FSAR why the following items are monitored on the panel:
    - STMLINE ΔP LOOP 1-4
    - LO FWF SG LO LVL LOOP 1-4
    - LO FWF STM/FWF MISMATCH LOOP 1-4
    - STMLINE HI FLOW LOOP 1-4
    - AUTO SI BLOCK
    - SI ACTUATE.

  These should be examined for potential removal.

3.0 RECOMMENDATIONS

The permissive/blocked/partial trip status panel should provide the operator with an easy way to monitor the automatic reactor protection system logic and make appropriate decisions and control actions. Given the current design, this is extremely difficult. It is strongly recommended that the panel be redesigned. Mimics lend themselves well to logic flows and allow the operator to make accurate and timely decisions. PSE&G Salem 1 and 2 plants have incorporated this method. The other questions raised by this evaluation should be resolved and corrected to make this panel an effective operator tool.

APPENDIX E

RESULTS OF AN EVALUATION OF THE GENERAL ATOMIC RADIATION MONITORS

1.0 INTRODUCTION

The SNUPPS control room design incorporates into the immediate operator environment the process radiation monitoring system. This system is being designed and built by General Atomic Company (GA). As part of the human engineering control room evaluation, Essex reviewed a General Atomic system at the factory.

This review was conducted by Dr. Robert Kinkade, Mr. Larry Durham and Mr. Charlie Wright of Essex Corporation's San Diego facility. In attendance were Mr. David Phipps of Carolina Power and Light, and Mr. Bud Perkins and Mr. Jim Ward of General Atomic Company. As the specific equipment being developed for SNUPPS was not available, the review was conducted on a system being tested for another GA client.

The interface between the radiation monitoring system and the operator consists of two components, RM-23 and RM-11. The RM-23 component review contained twelve RM-23 modules and eight Leeds and Northrup strip chart recorders. The RM-11 component consisted of one CRT terminal and a supporting line printer. According to General Atomic System Manual E-115-838 and Bechtel drawing 10466-J-04001, Rev. 1, the SNUPPS configuration will consist of the following:

- One RM-11 CRT display terminal, located in the immediate control room (SPO56A)
- One RM-11 support printer, located adjacent to the CRT terminal (SPO56B)
- One RM-23 cabinet with eight RM-23 modules, located on a back panel (about 25 to 30 feet from the main control room).

An assumption is being made (without any immediate means to verify it) that the SPO10-Radiation Recorder Panel wil contain strip chart recorders for the radiation monitoring system.

Figures 1 through 3 illustrate typical RM-23 modules and a CRT terminal. The labeling shown, including pushbutton labels on the RM-23 module, varies according to customer requirements. Complete sets of black and white and color photographs are on file.

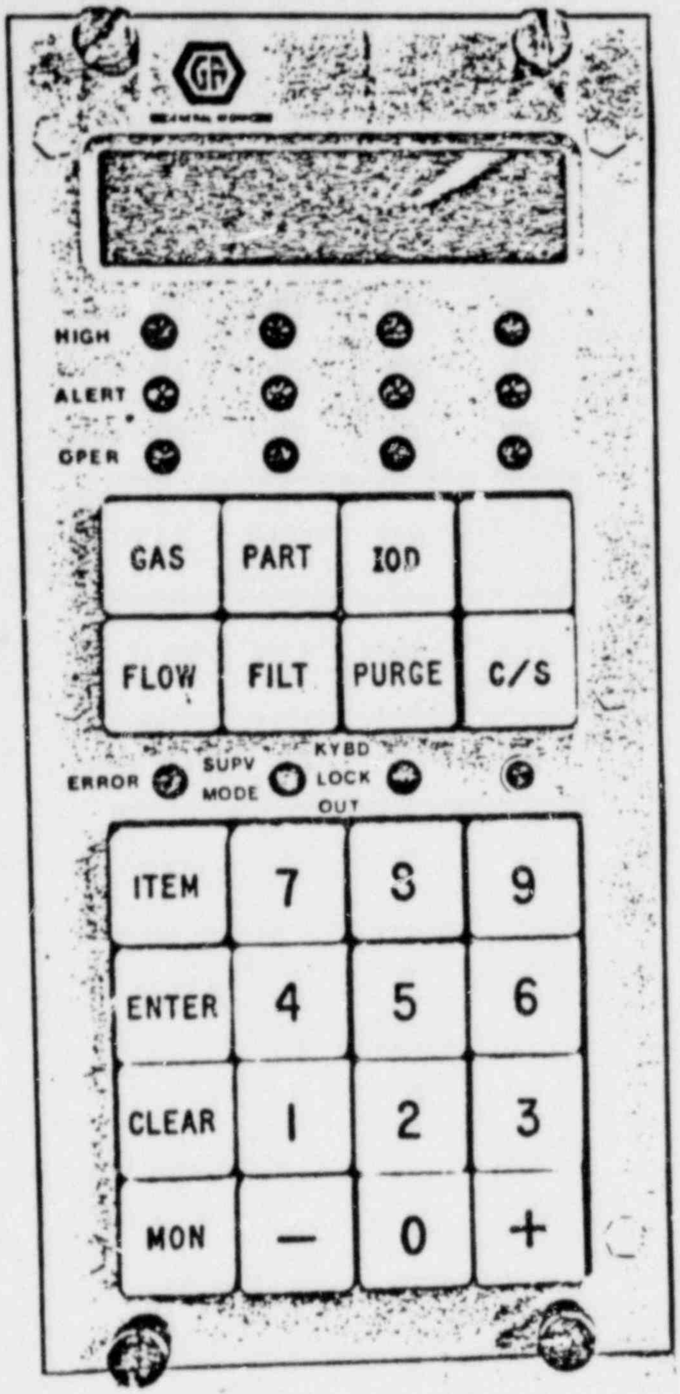


FIGURE 1 - A typical RM-23 module. Labeling of the eight-pushbutton matrix is a client specified option and varies with the desired monitoring function.

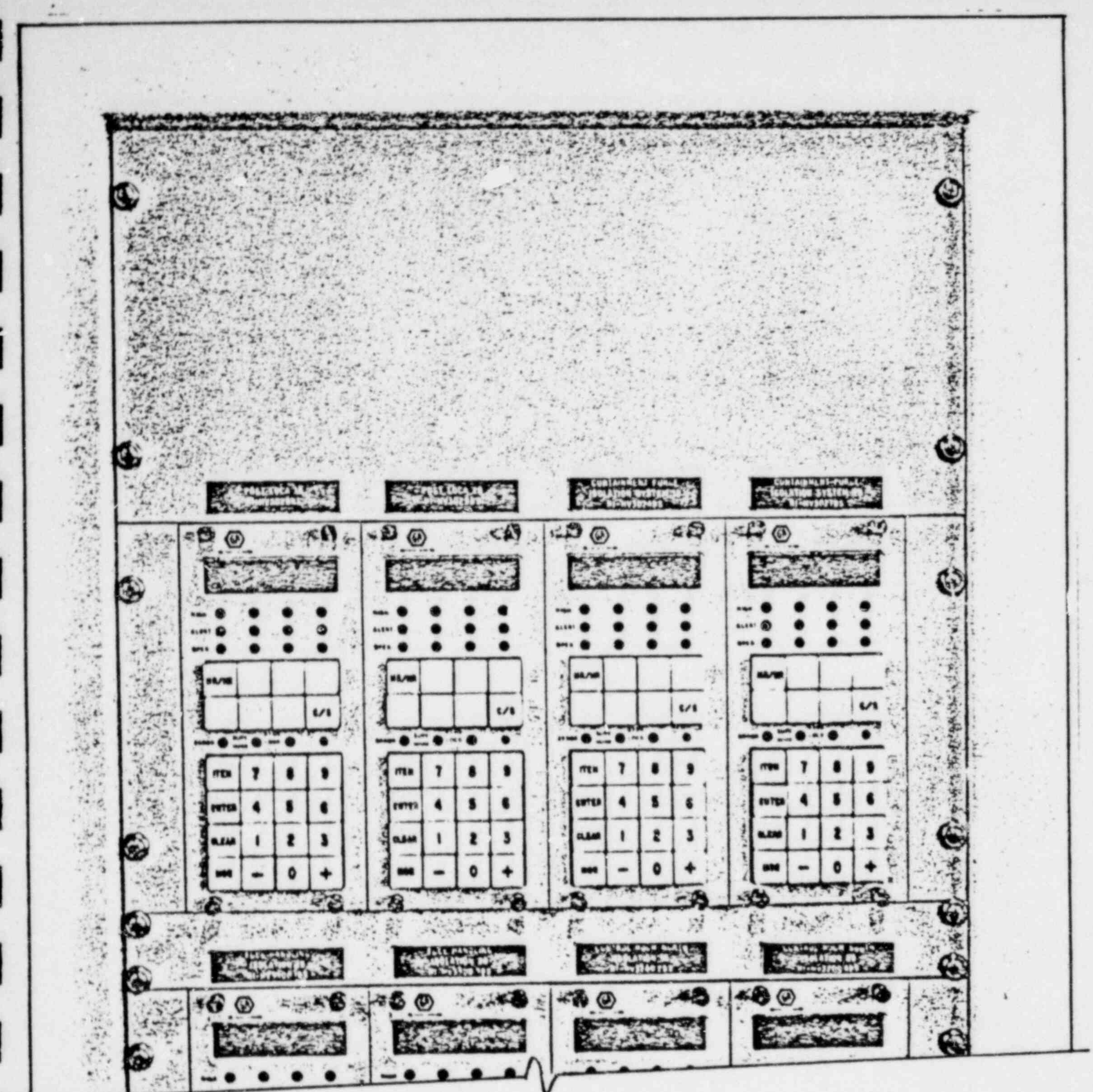


Figure 2 - Typical RM-23 module installation in the RM-23 cabinet. Locations and labels are dependent upon client requirements.

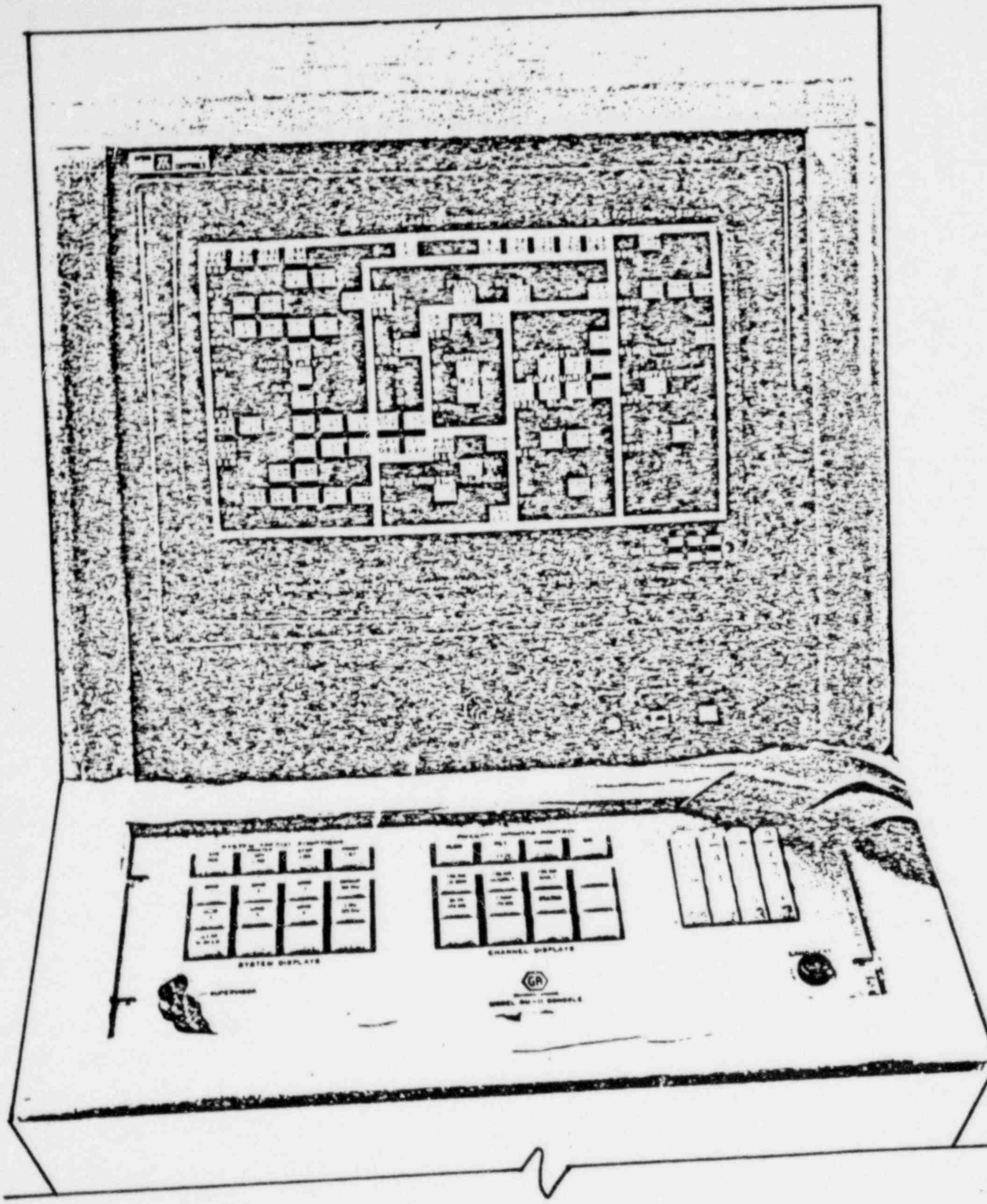


Figure 3 - A typical RM-11 CRT Console (base not shown). Conductor tapes at lower right of CRT are for testing and are not part of the permanent console.

2.0 RESULTS OF REVIEW

2.1 Overall System

2.1.1 The light intensity of both digital displays and CRT displays appears to be satisfactorily clear and the displays are legible.

2.1.2 The noise output from the printer could affect efficient CR voice communications and efficient use of the CRT terminal. Noise damping, such as internal (to the printer cabinet) acoustic foam, and/or transparent noise shields over the printer should be considered.

2.1.3 Labeling of all equipment will be a key factor and should be addressed by SNUPPS as early as possible, thereby avoiding A&E recommended labeling that may be unclear or confusing.

2.1.4 GA reports that the system is limited to six grids and six display terminals. From an engineering standpoint these could be significant limiting factors. It also appears that this systems does not address perimeter or outlying radiation monitors. If not, where these monitor outputs are displayed should be considered if CR operators need this information.

2.1.5 Each CRT terminal is reported to be capable of addressing any monitor or grid in the system. Interaction issues need to be addressed to determine the effect of two CRT terminals addressing the system simultaneously.

2.2 RM-11 CRT Terminal

2.1.1 The reviewed CRT display uses colors to code boundaries, headings and abnormal values. The colors are easily discriminated when both hue and saturation are varied. It is unknown whether the same CRT will be used in the SNUPPS system.

2.2.2 The RM-11 system uses a grid display (schematic layout) to represent monitor locations within the plant. A grid display logo located in the lower right corner of the screen will flash when an alarm condition is found, directing the operator to the correct grid. This grid logo lacks specific grid numbers but resembles the location of the Grid Selection buttons. Labeling of function and selection buttons is not the best, but could be sufficient with proper training. SNUPPS grid assignments and the associated schematic layouts may need to be developed.

2.2.3 The Lamp Test button only lights those buttons that have an on/off function; however, as these appear to be the only simple indicator lights (or backlight pushbuttons) on the keyboard, this appears to be adequate.

2.2.4 The display terminal has a "HEALTH" label near the "POWER" label and is reported by GA to represent power to the terminal. However, GA is not entirely sure of this. If true, the label should be changed to "POWER ON".

2.2.5 The "ENTER" function button is located on the left side of the numeric keyboard, the second in a column of identically appearing buttons, and could cause some delay in operating. This is not a time-critical system; however, better location of the "ENTER" button could improve operator performance.

2.2.6 The brightness control is located right on the front for individual operator use, with the other control buttons (Vertical/Horizontal hold, etc.) located behind a locked panel on the CRT.

2.2.7 There is also a Degaussing button located on the front panel. GA says the CRT needs to be degaussed at intervals. With all the automation of this system, it seems logical that this function could also be automatic; otherwise, a preventive maintenance program needs to be included for it.

2.2.8 The "LIT" button converts all function keys to alphabetical keys for system programming. This capability imposes the requirement for a number of buttons that are not used by Control Room Operators. This could cause some confusion; however, this is not a time-critical system. It is recommended that this label be changed to one which is more descriptive of its function, such as "NOR/ALPHA" for normal or alphabetic. Additionally, all function keys should carry a double label indicating function (under normal conditions) and the alpha character (when programming function is on).

2.3 RM-23 Cabinet, Modules and Recorders

2.3.1 The RM-23 display/control modules are digital display units that are backup units for safety system monitors only. This is due to the CRT not being seismically qualified. The RM-23's will primarily be used by maintenance personnel or in the event of an accident that includes failure of the CRT terminal. Rm-23's will require extensive operator training as all failure indications are in numerical code.

2.3.2 The "ON", "ALERT" and "HIGH ALARM" lights are very small and not very intense. This makes them difficult to detect under normal illuminance conditions. These should be enlarged and their intensity increased if there is any possibility that they must function as primary displays (i.e., primary radiation annunciators).

2.3.3 There is an unequal number of strip chart recorders compared to the RM-23 modules. Different combinations of readings from RM-23 modules (up to 3) will be displayed on these recorders. The rationale for this is unclear at this time.

2.3.4 The strip chart recorders must be read up close. Beyond four feet an observer cannot determine if they are standard scale or log scale.

2.3.5 There is no alarm mechanism to notify the operator of strip chart failure, paper running out, or exhausted ink supply.

2.3.6 The strip chart recorders can be fully removed from the cabinet once the retainers are loose. Locks should be installed such that they cannot be inadvertently pulled all the way out and dropped when changing ink and paper.

2.3.7 The pen/channel to color on these Leeds and Northrup recorders are different from the majority found in NPP CRs. Based upon a previous recommendation, it is suggested that the sequence be changed to the following:

Pen/Channel	Color
1	Red
2	Green
3	Blue

2.3.8 The status indicator lights located on the RM-23 cabinets between the modules and recorders are reported by GA to indicate which RM-23 module is not in service. The fuel handling area monitors have redundant RM-23's, one set in Unit 1 and the other in Unit 4. This option and the reason for the redundancy are unclear at this time. Also, the location of the switch for determining Unit 1 or Unit 4 operation is not known. It is possible that these lights, when lighted, will indicate a deactivated unit. This could be confusing as it establishes a lighted=off and unlighted=on relationship. Alternatives to this type of relationship should be seriously considered.

2.3.9 SNUPPS should require that no RM-23 modules be mounted such that the readout and associated "HIGH" and "ALERT" lamps are above 70 inches or below 41 inches from the standing surface. If any such modules are to be used as primary displays which must be read precisely and frequently, these modules should be mounted such that their

displays are no higher than 65 inches or lower than 50 inches from the standing surface. From the drawing in GA System Manual E-115-838, it appears that the top of the highest RM-23 module will be mounted about 65 inches off the floor.

3.0 RECOMMENDATIONS

Based on the above results, the GA Digital Process Radiation Monitoring System appears to have some human engineering design problems. The above evaluation is based on a very preliminary and cursory review and should not be considered definitive. The CRT displays and the interactive sequences could not be adequately evaluated, nor could the SNUPPS specific configuration. The recommendation of Essex is that the SNUPPS configuration, once operational, be evaluated in detail.

APPENDIX F

DEMARCATION OF THE CONTROL PANELS

The following figures represent the minimum areas that should be demarcated either by lines or background coloring. These areas should include summary labels. For consistency, other panel areas should also be labeled with summary labels. This will significantly reduce visual search time and memory load.

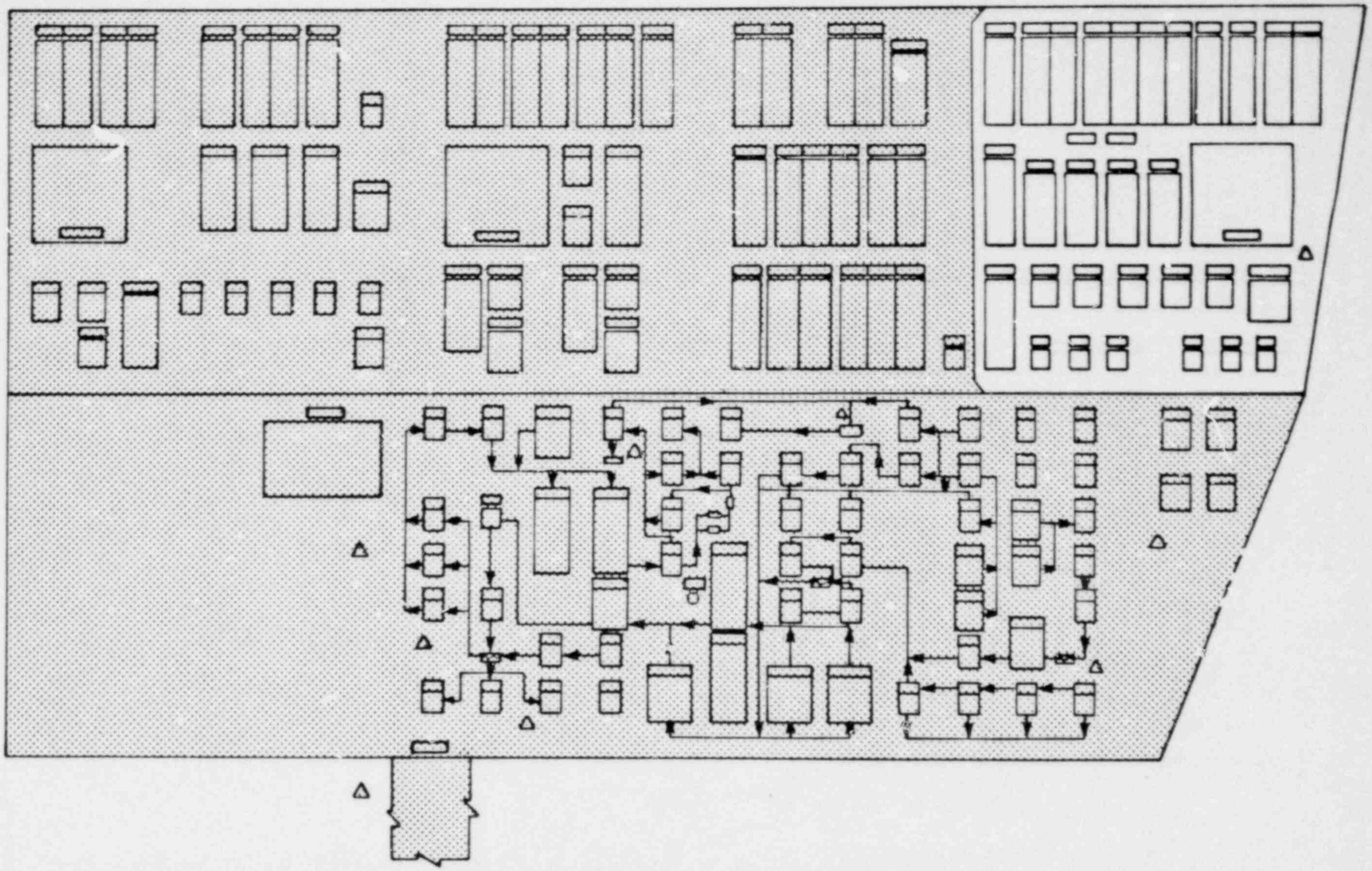


FIGURE 1: DEMARCATION ZONES FOR RL002, SNUPPS

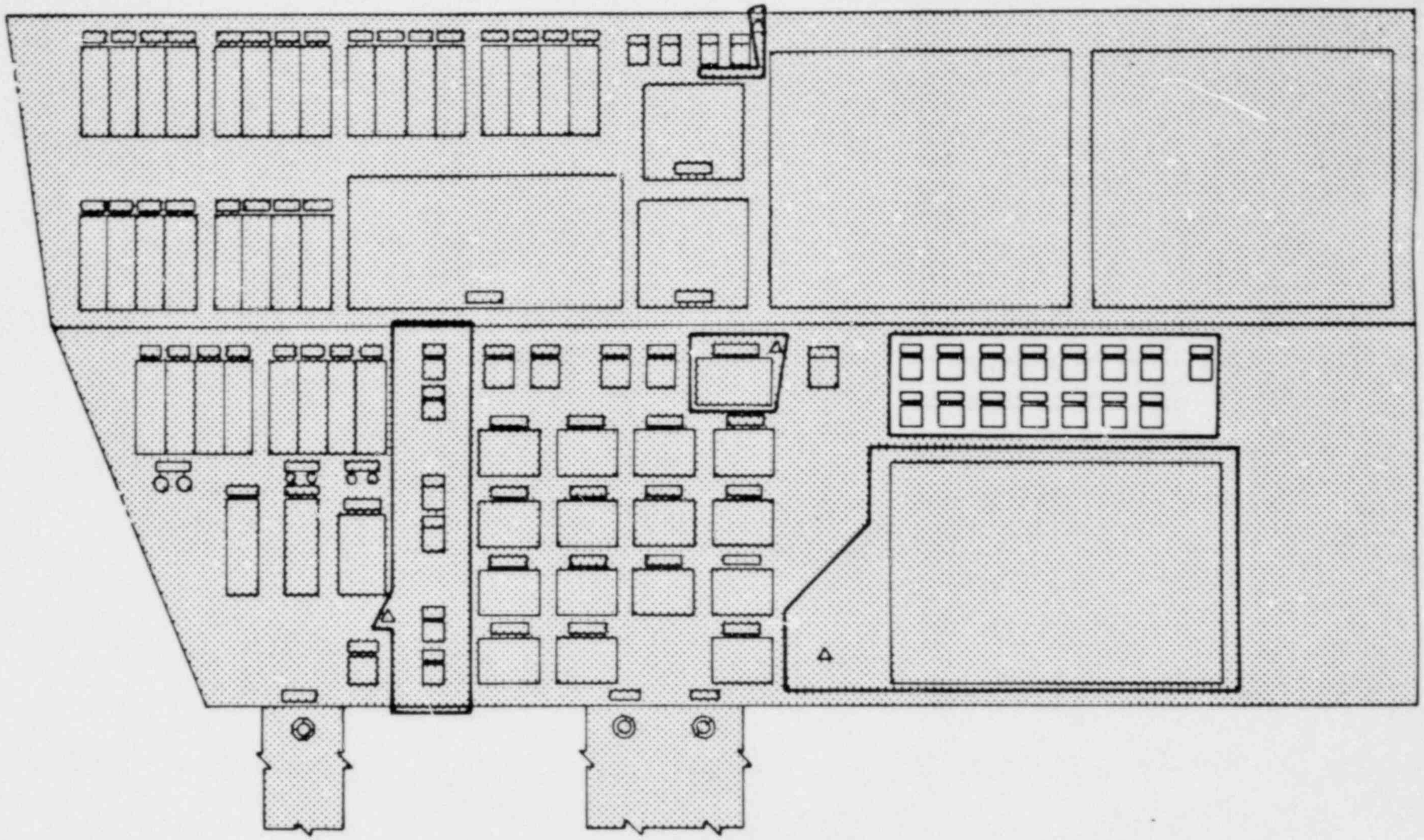


FIGURE 2: DEMARCATION ZONES FOR RL003, SNUPPS

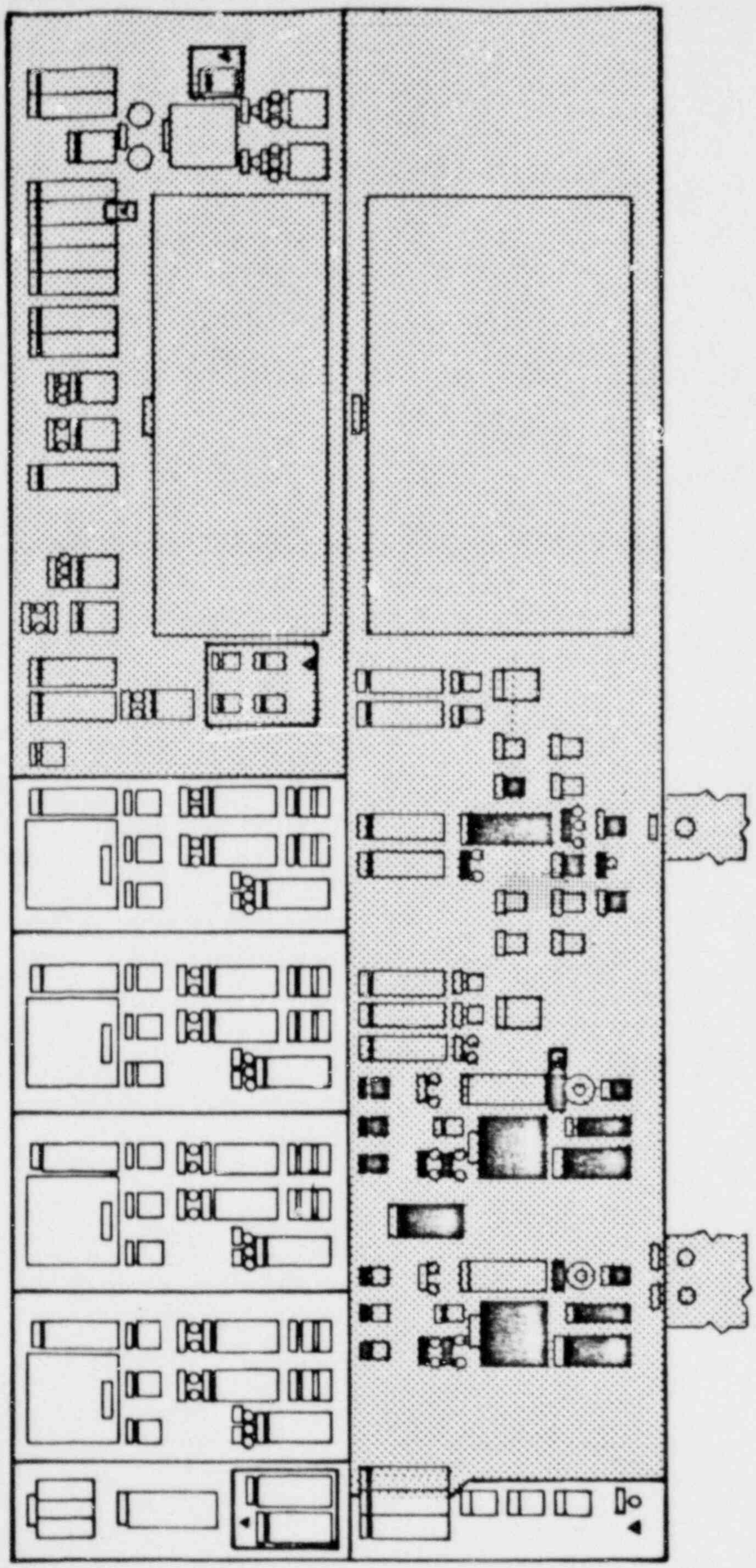


FIGURE 3: DEMARCATION ZONES FOR RL005 AND RL006, SNUPPS

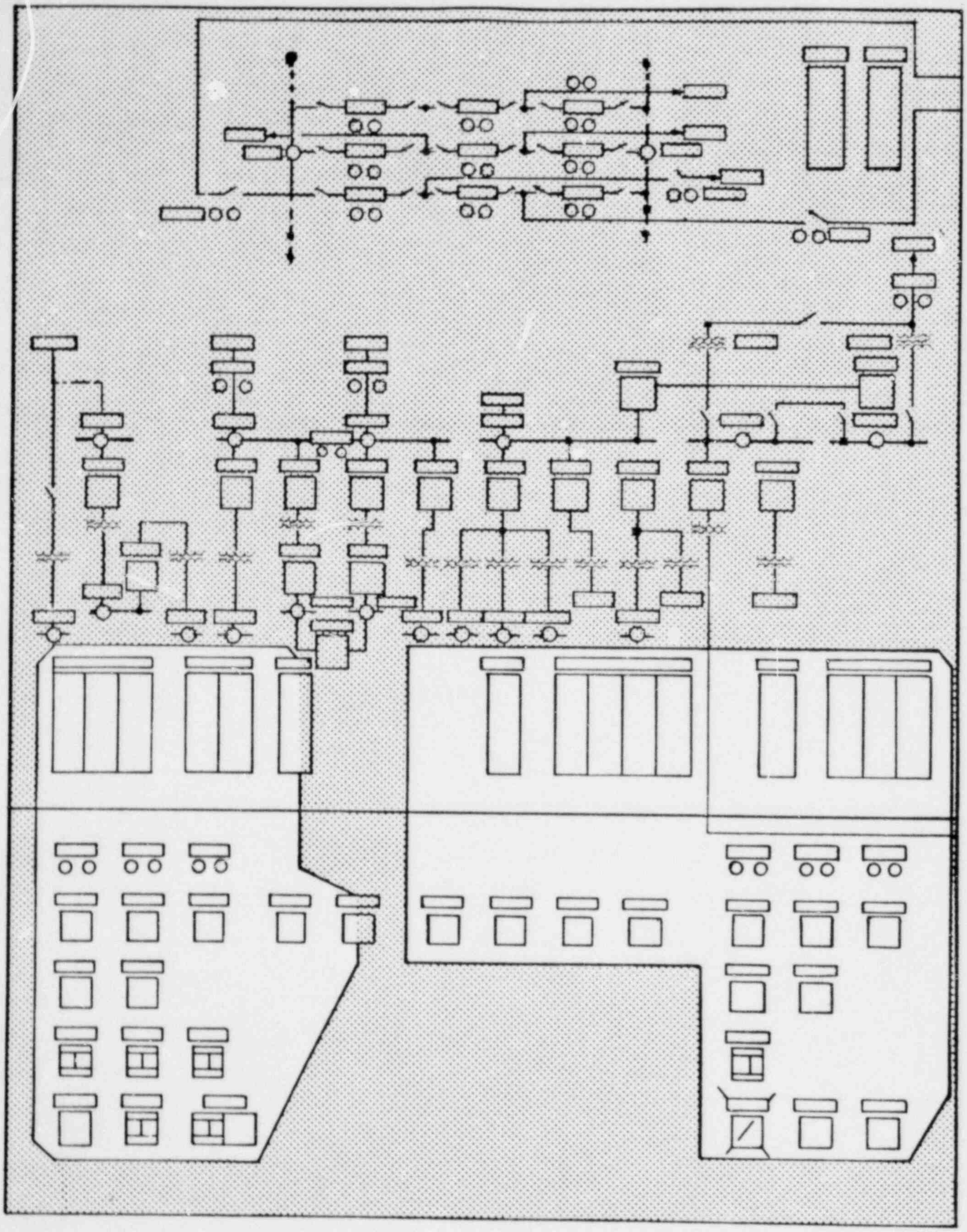


FIGURE 4: DEMARCATION ZONES FOR RL013 AND RL014, WOLF CREEK

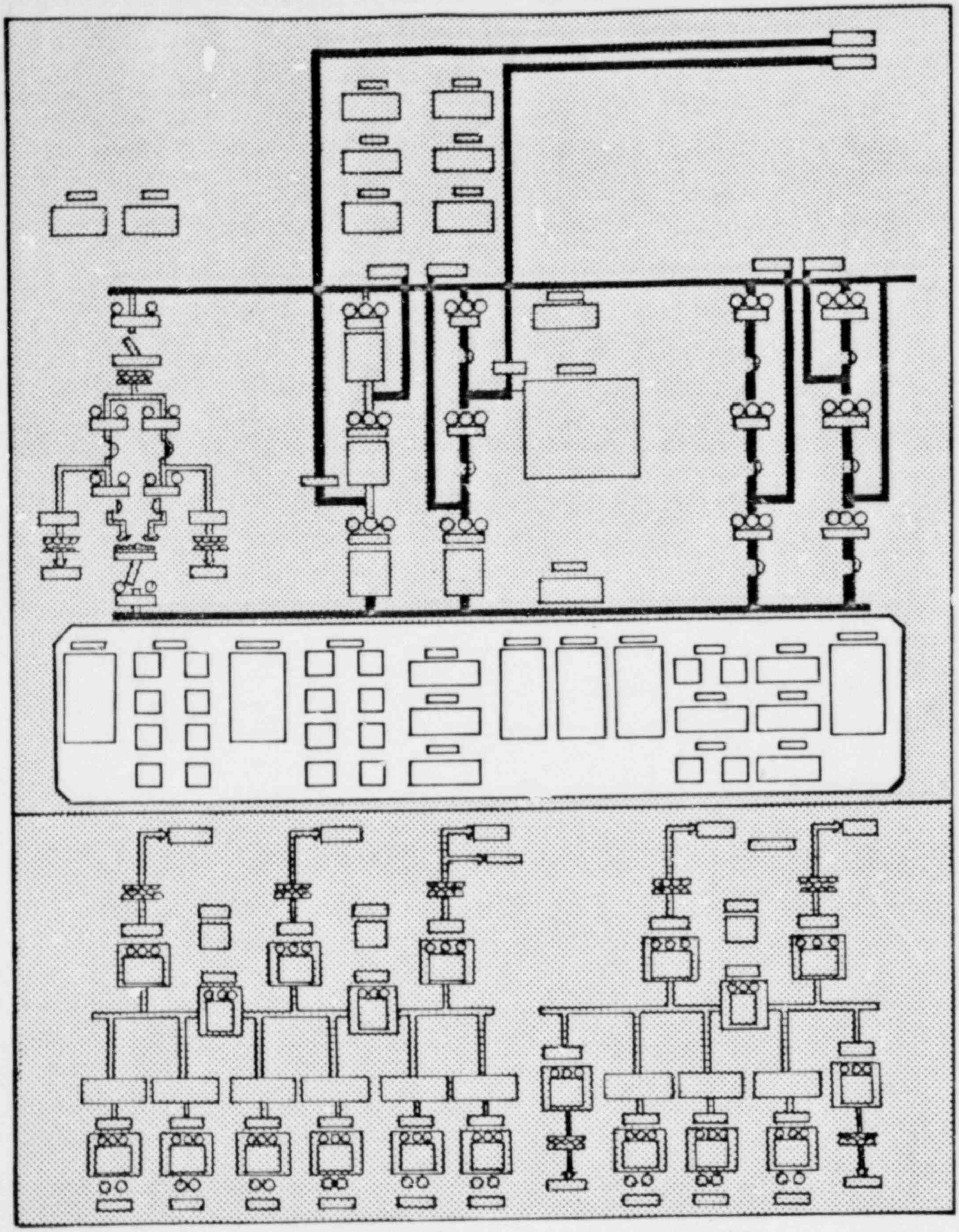


FIGURE 5: DEMARCATION ZONES FOR RL014, CALLAWAY

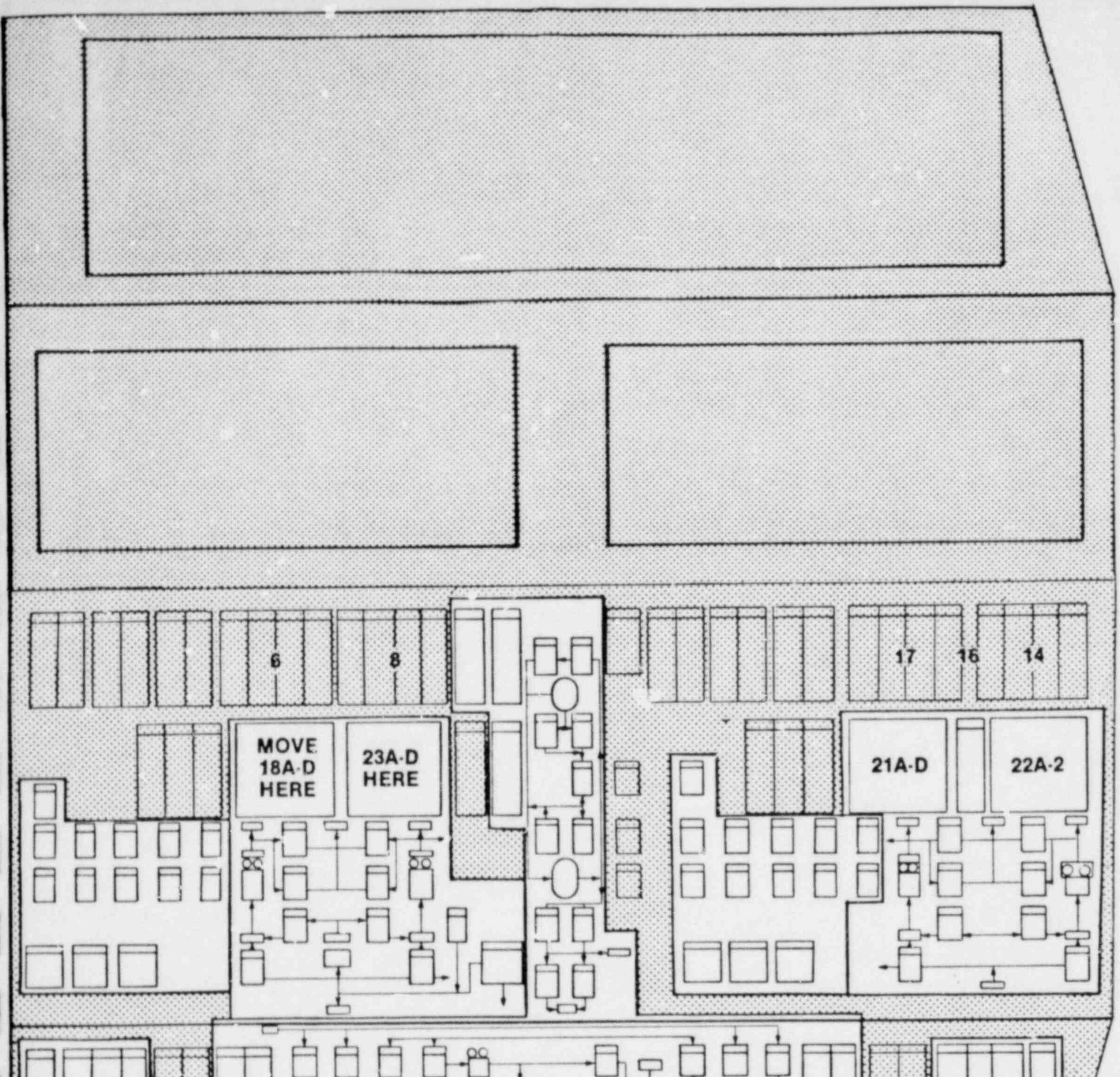


FIGURE 6: DEMARCATION ZONES FOR RL017 AND RL018, SNUPPS

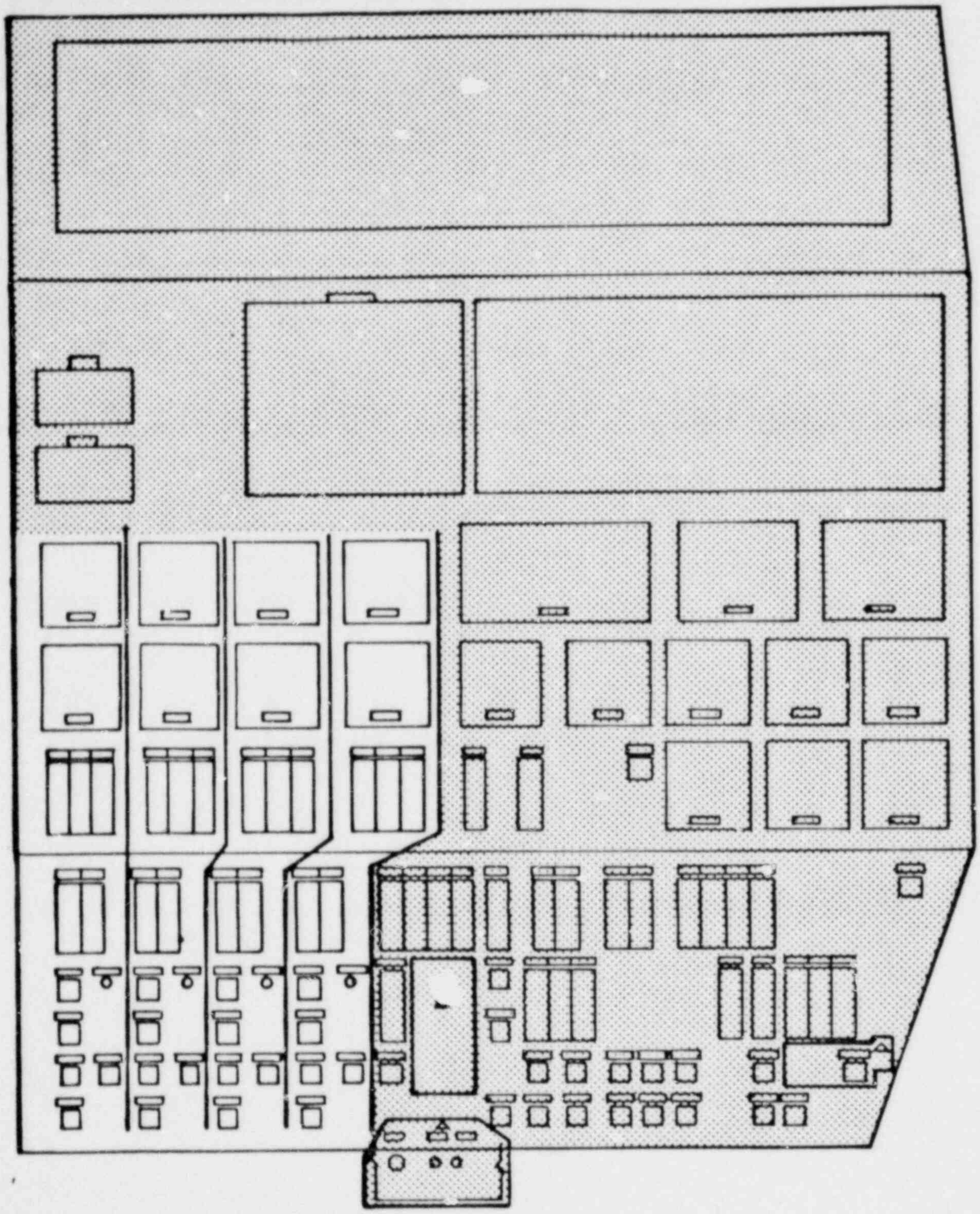


FIGURE 7: DEMARCATION ZONES FOR RL021 AND RL022, SNUPPS

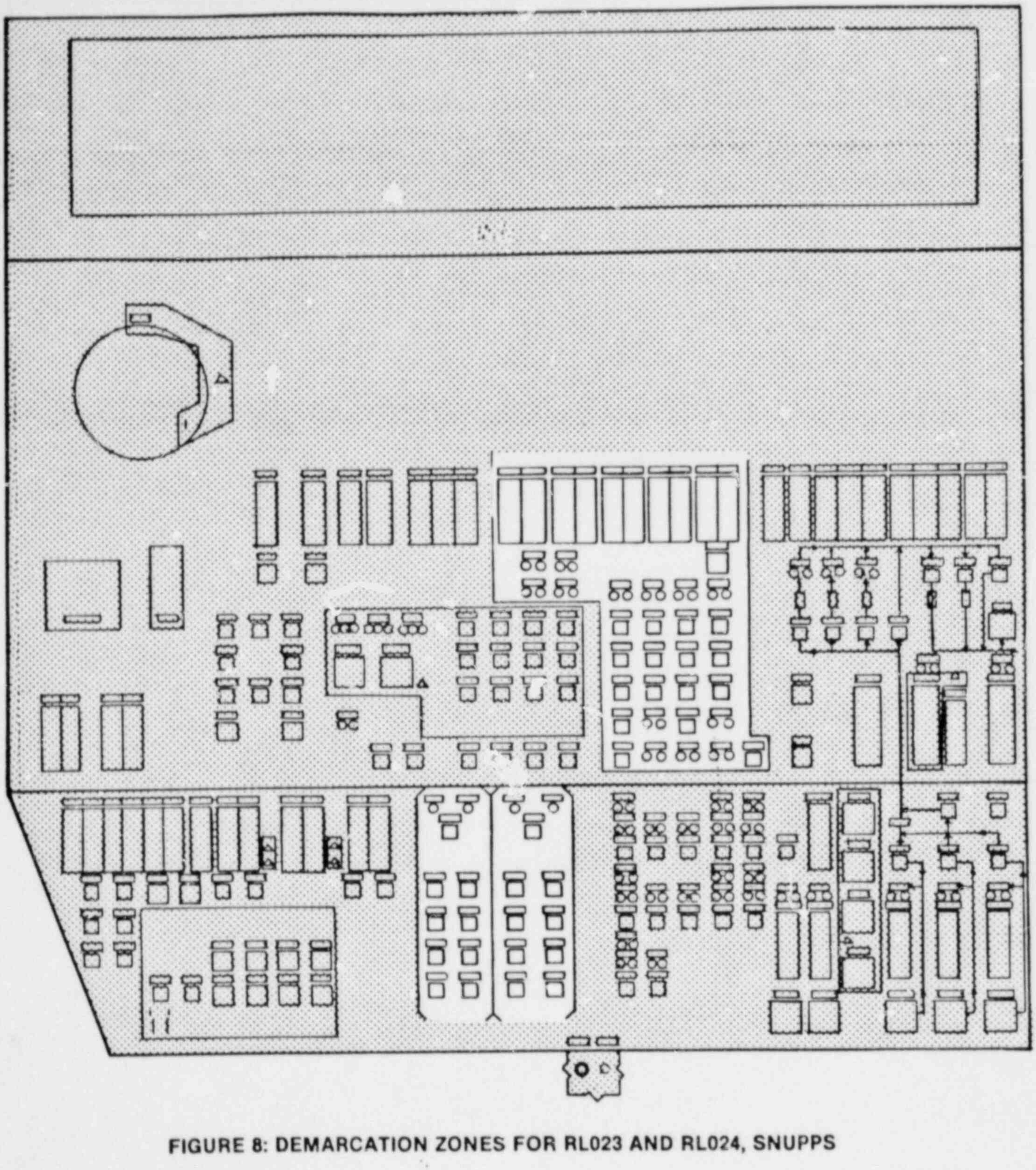


FIGURE 8: DEMARCATION ZONES FOR RL023 AND RL024, SNUPPS

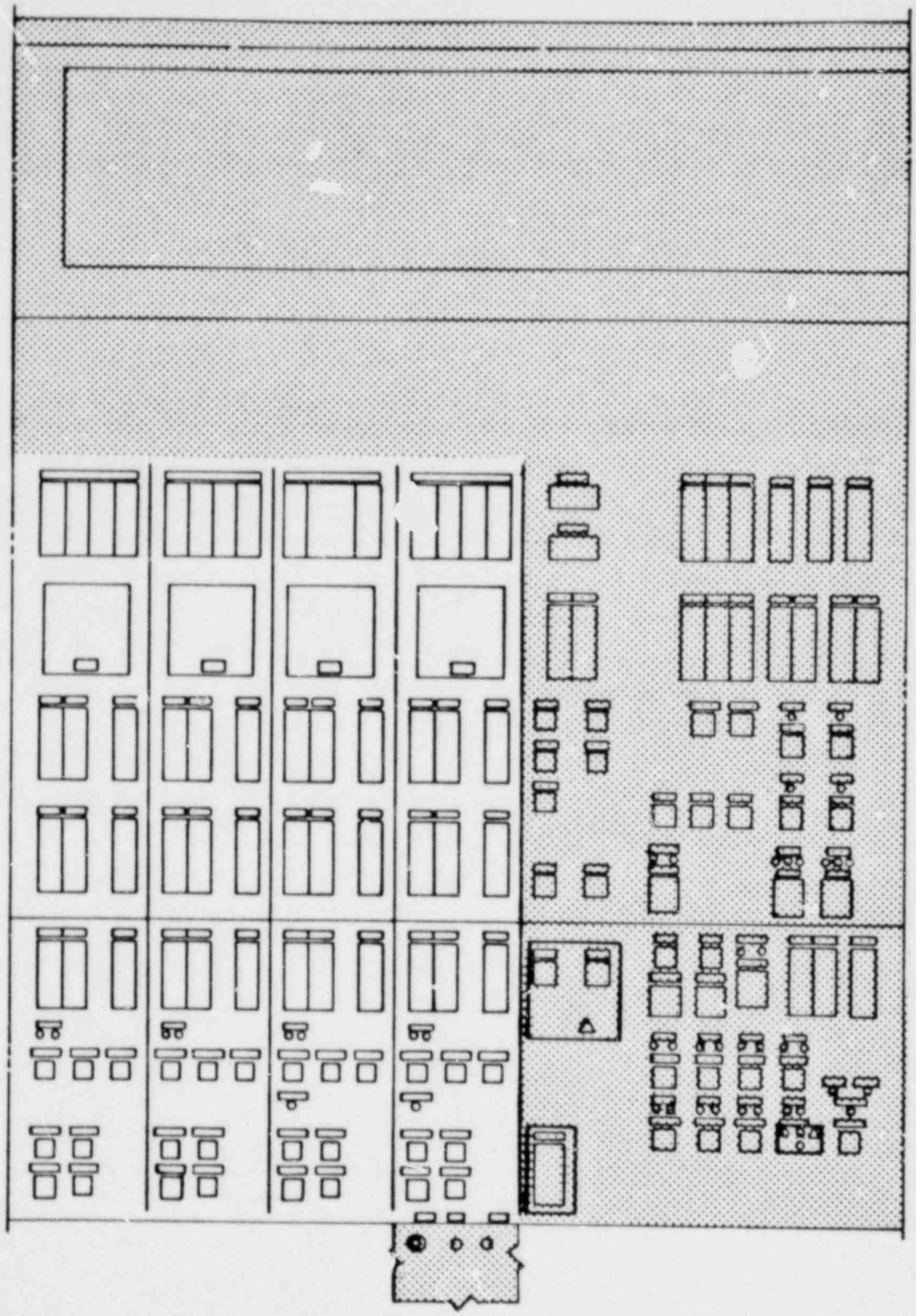


FIGURE 9: DEMARCATION ZONES FOR RL025 AND RL026, SNUPPS

APPENDIX G

HEER FILES

The HEER files contain component sheets. Each component reviewed by Essex has a sheet that lists the finding, HEF number, priority, and recommended backfits. The files arranged by panel. Within a panel, each component type is grouped in a left-to-right and top-to-bottom order. These files also contain copies of the HEFs and sample checklists.