CONTROL ROOM DESIGN REVIEW REPORT

SAN ONOFRE
NUCLEAR GENERATING STATION
UNITS 2 & 3

SCE DOCUMENT NO. M37328

SCE Southern California Edison Company

SDG&E SAN DIEGO GAS & ELECTRIC COMPANY

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REVISION 0

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
A/D	Analog-to-Digital
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ANSI	American National Standards Institute
BA	Batchelor of Arts
BOP	Balance of Plant
BPC	Bechtel Power Corporation
BSB	Batchelor of Science in Business
BSEE	Batchelor of Science in Electrical Engineering
BSME	Batchelor of Science in Mechanical Engineering
BWR	Boiling Water Reactor
CCW	Component Cooling Water
CE	Combustion Engineering
CFM	Cubic Feet per Minute
CFMS	Critical Function Monitoring System
CRDR	Control Room Design Review
CRT	Cathode Ray Tube
CSAS	Containment Spray Actuation System
CSR	Computer Systems (Design) Review
CVCS	Chemical and Volume Control System
dBA	Decibels (A-weighted)
DC	Direct Current
DCN	Drawing Change Notice
DCP	Design Change Package

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

EOP	Emergency Operating Procedures
EPG	Emergency Procedure Guidelines
EPRI	Electric Power Research Institute
ESF	Engineered Safety Features
FMEA	Failure Modes and Effects Analysis
FPM	Feet per Minute
FRM	Functional Recovery Method
FRP	Functional Recovery Procedure
FSAR	Final Safety Analysis Report
GE	General Electric
HED	Human Engineering Discrepancy
HPSI	High Pressure Safety Injection
HVAC or HV&AC	Heating, Ventilating and Air Conditioning
I/C	Instruments and Controls
ID	Identification (Number)
IRR	Instruction Resolution Request
LM/FBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss of Coolant Accident
LOF	Loss of Feedwater
LOFC	Loss of Forced Circulation
LPSI	Low Pressure Safety Injection
MBA	Master of Business Administration
MS	Master of Science

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

NOP	Normal Operating Procedures
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
OD	Outside Diameter
OP	Operating Procedure
ORM	Optimal Recovery Method
ORP	Optimal Recovery Procedure
P&ID	Piping and Instrumentation Diagram
PFD	Process Flow Diagram
PhD	Doctor of Philosophy
PIPM	Project Internal Procedures Manual
PMS	Plant Monitoring System (Computer)
PSE&G	Public Service Electric and Gas Company
PWR	Pressurized Water Reactor
QA	Quality Assurance
QSPDS	Quality Safety Parameter Display System
RC	Reactor Coolant
RCS	Reactor Coolant System
RSP	Remote Shutdown Panel
RTR	Reactor Trip Recovery
SCE	Southern California Edison
SER	Safety Evaluation Report
SGTR	Steam Generator Tube Rupture
SI	Safety Injection
SIL	Speech Interference Level
SLB	Steam Line Break
SMM	Subcooled Margin Monitor
SONGS	San Onofre Nuclear Generating Station

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

SPDS	Safety Parameter Display System
SPR	Startup Problem Report
STI	Speech Transmission Index
SWO	Simulator Work Order
TMI	Three Mile Island
TRW	Thompson Ramo Woolridge
TSC	Technical Support Center
TVA	Tennessee Valley Authority
UHF	Ultra High Frequency
VEPCO	Virginia Electric and Power Company
WA	Whitston Associates

EXECUTIVE SUMMARY

This summary presents a condensed description of the Human Factors Control Room Design Review activities carried on in the Unit 2 and Common control room.

The activities of the CRDR Working Group were started in early June 1980 in accordance with the CRDR plan with the purpose of assessing the degree to which the control room conformed to applicable human factors criteria and principles. The primary effort was directed to those aspects established by NRC precedent to be most relevant and contributory to reducing risk of operator error.

A review of past NRC audits and reviews of other power utilities plants such as: TVA Sequoyah Plant -Essex Corp. Consultants; PSE&G Salem, Unit 2 - Essex Corp. Consultants; and Duke-McGuire, Unit 1 - Biotechnology Inc. was conducted by the CRDR Working Group. Additional guidance was derived from other documents such as; NUREG 0585, NUREG 0660, NUREG CR-1580, EPRI NP-1118 and Human Factors Engineering Guidelines Required for Control Design and Evaluation provided by Whitston Associates. An analysis of the above data revealed that the majority of design deficiencies requiring back-fit were related to:

- Insufficient functional system demarcation.
- Inadequate labeling and instrument scale coding.
- Component arrangement deficiencies.
- Objectionable format and content of operating instructions.
- Lack of annunciator prioritization, alarm clear, and status presentation.
- Environmental constraints: lighting, glare, noise, color, etc.

The following is a summary of recommendations made by the CRDR Working Group to SCE Management for implementation:

- o Provide functional system demarcation of the control panels by repainting the panels and color coding of the instrument bezels.
- o Install new labels color coded to the respective system to provide a labeling hierarchy with clear, concise and consistant information; relocate the labels to the top of the instruments; and install new antiglare push-button lenses with revised labels.
- o Provide scale coding of indicators and recorders to show key operating information.
- o Prioritize the annunciator system by use of colored windows and also provide modifications to improve the system operability. Install master mimic indicator panel and remove master acknowledge push buttons. Add annunciator reflash capability.
- o Review Plant Computer System and update data base.
- o Relocate approximately 150 instruments on Unit 2 and common control panels, and a corresponding number on Unit 3.
- o Review and correct as necessary the environmental conditions such as noise, lighting, and heating, ventilating, and air conditioning (HVAC).
- o Review and modify the communications system, as required.
- o Review and modify the normal and emergency operating procedures, as required.
- o Develop ESF Pattern Recognition charts.

The above recommendations were forwarded to the SCE Steering Committee, who determined the priority of implementation. The project engineering group was authorized to implement the CRDR Working Group recommendations approved by the Steering Committee.

The above recommendations have all been completed with the exception of the noise survey, HVAC survey and the control room carpeting which are scheduled to be completed prior to plant startup following first refueling.

Operating experience to-date indicates that no unacceptable Human Engineering Discrepancies (HED) exist in the Control Room man-machine interface. However, SCE is fully committed to assessing and resolving any previously undetected HEDs as they surface during actual operations or simulator training exercises. Two official, formalized procedures exist to identify and resolve these future HEDs: the Instruction Resolution Request and the Startup Problem Report. These procedures are discussed in the main body of the report.

SCE believes that this CRDR conforms to the guidelines and meets the intent of the NUREG-0700. Therefore, except for the noise survey, HVAC survey, and control room carpeting, no further action is planned. The submittal of this CRDR report closes the action required in NUREG 0737, Supplement 1, Section 5.2.b.

1.0 INTRODUCTION AND DESCRIPTION

1.1 FOREWORD

This report summarizes the Control Room Design Review (CRDR) activities conducted by the Southern California Edison (SCE) Company on the San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 Control Room.

This Control Room Design Review Report is being submitted to the NRC in compliance with NUREG 0737, Supplement 1, Item 5.2.b.

The activities described in this report derived their bases from the "Control Room Design Review Plan" written by SCE to implement the CRDR. The plan encompassed the guidelines provided in NUREG 0700, "Guidelines for Control Room Design Reviews."

The content of this report reflects the evolution of CRDR activities conducted on SONGS 2 and 3 by SCE. Specific details of each area of the CRDR process are addressed generically so that the reader can comprehend the scope of each item without excessively burdening the report.

This report is submitted to provide documentation of SCE's commitment to control room enhancement. It is the position of SCE that the activities described in this report meet the functional intent of NRC NUREG 0737 Supplement 1, Item 5.1.b. However, recognizing the dynamics of continual plant design evolution and of continued operating experience, the criteria developed as part of the CRDR will be factored into any future control room modification. To this end, the information contained in this report is considered a "snap-shot" of a continuing process as well as a statement of SCE man/machine interface philosophy.

Based on the completion of this task, it is the position of SCE that the control rooms for SONGS 2 and 3; (1) meet the established criteria provided in NUREG 0700, and (2) conform to good Human Engineering practices currently employed in the industry.

1.2 GENERAL PLANT DESCRIPTION

1.2.1 Site Description

The San Onofre site is located on the coast of Southern California in San Diego County, approximately 62 miles southeast of Los Angeles and 51 miles northwest of San Diego. The site is located entirely within the boundaries of the United States Marine Corps Base, Camp Pendleton, California, near the northwest end of the 18-mile shoreline. The site is approximately 4,500 feet long and 800 feet wide, comprising 84 acres. Approximately 16 acres are occupied by Unit 1. Units 2 and 3 cover 52.8 acres of which the power block and site switchyard occupy 27.7 acres and the batch plant, temporary switchyard, and parking and access area another 25.1 acres. The remaining 15.2 acres are occupied by the administration building, visitors center, or are available for auxiliary usage. Units 2 and 3 are located southeast of and immediately adjacent to Unit 1.

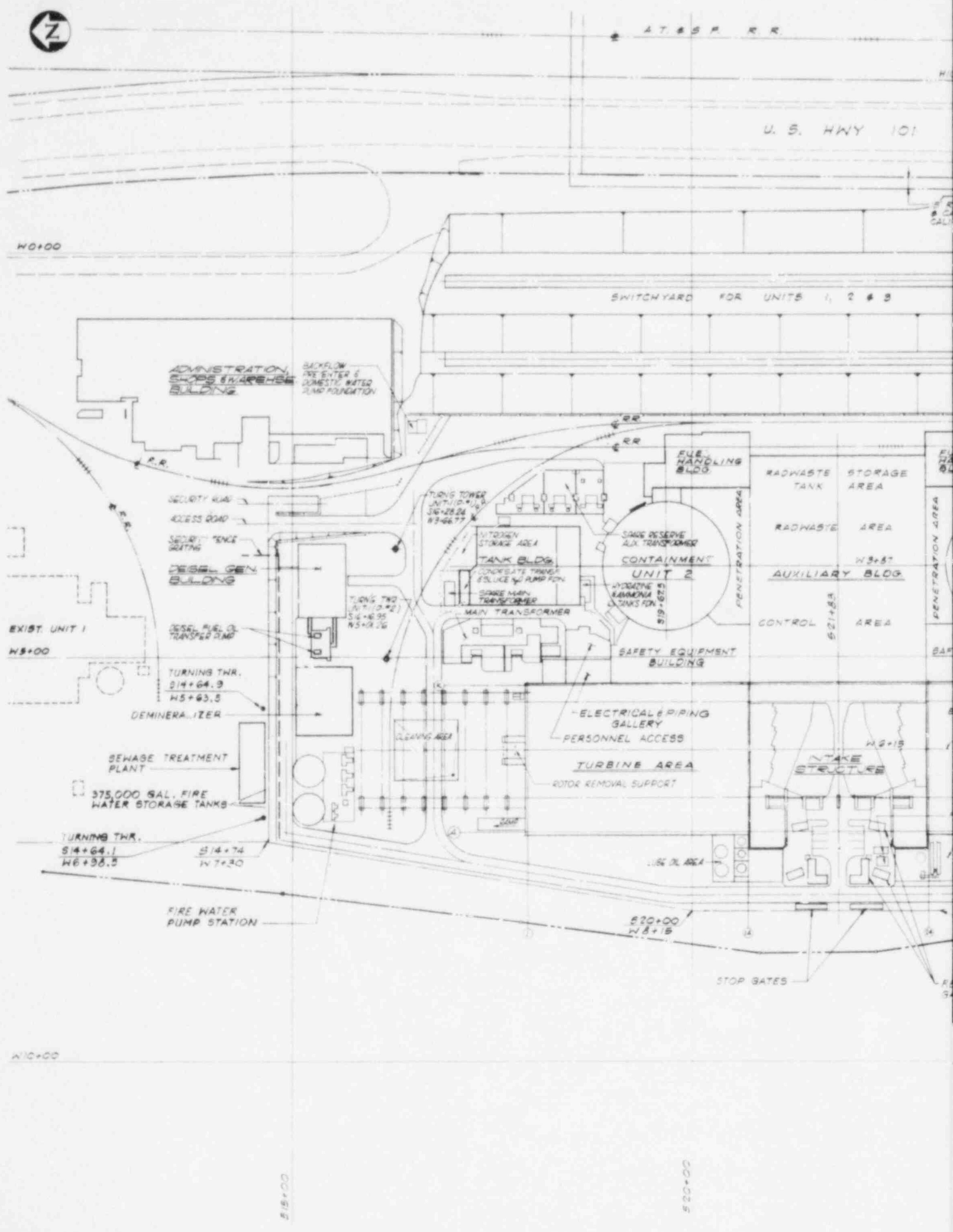
1.2.2 Plant Arrangement

Units 2 and 3 of the San Onofre Nuclear Generating Station consist of two Combustion Engineering pressurized water reactor (PWR) nuclear steam supply systems (NSSS) that produce a nominal net output of 1,100 MWe per unit. The turbine generators were supplied by General Electric Company, Limited. The station features separate containments, safety equipment buildings, turbine buildings, diesel generator buildings, and fuel handling buildings for Units 2 and 3, and a shared auxiliary building and intake structure (figure 1.2-1). The ultimate heat sink for all Seismic Category I cooling water systems is saltwater from the Pacific Ocean, supplied to the component cooling water heat exchangers by saltwater cooling pumps located within separate intake conduits for each unit. Seawater pumped from the intake conduits by the circulating water pumps serves as the heat sink for heat rejected by the main condensers and the turbine plant cooling water system.

1.2.3 Control Room Complex Configuration

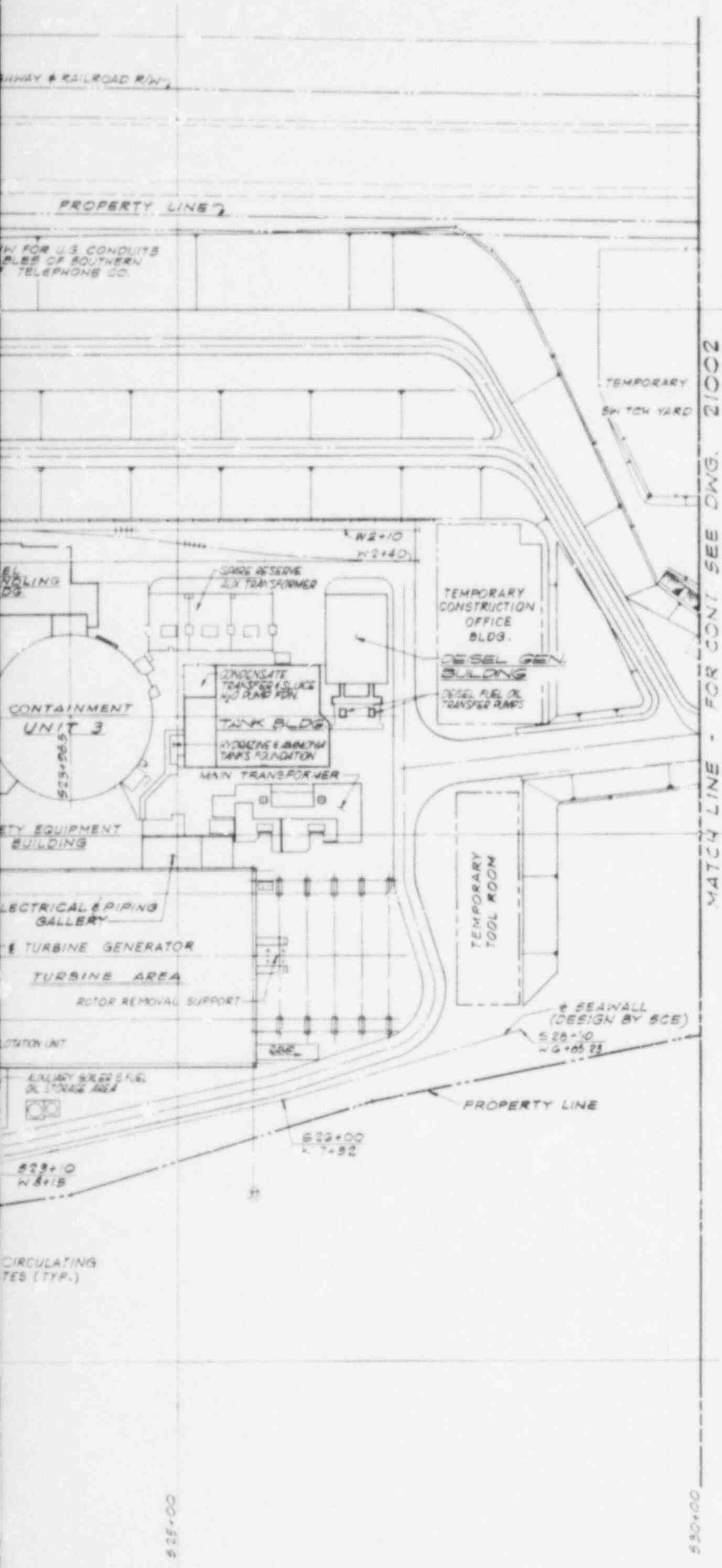
The SONGS 2 and 3 control room complex is shown in figure 1.2-2. A single control room area houses the control panels for both units. The main control panels for each unit are U-shaped, joined by a single panel that contains instrumentation and controls common to both units.

Dedicated operators' desks and computer consoles are located within the U-shaped portion for each unit. The open portion of the double U contains panels for electrical mimic buses and heating and ventilating. Behind the main control panels are additional panels accommodating needs such as post accident monitoring, demineralized water makeup, miscellaneous recorders, radiation monitoring, and the computer line printers.



A.T. & S.F. R.R.
U. S. HWY 101
W0+00
SWITCHYARD FOR UNITS 1, 2 & 3
ADMINISTRATION, SHOPS & WAREHSE BUILDING
BACKFLOW PREVENTER & DOMESTIC WATER PUMP FOUNDATION
R.R.
FUEL HANDLING BLDG
RADWASTE TANK
STORAGE AREA
RADWASTE AREA
W3+87
AUXILIARY BLDG
CONTROL
AREA
PENETRATION AREA
SECURITY ROAD
ACCESS ROAD
SECURITY FENCE GRATING
DIESEL GEN. BUILDING
NITROGEN STORAGE AREA
TANK BLDG.
SPARE RESERVE AUX. TRANSFORMER
CONTAINMENT UNIT 2
HYDRAZINE & AMMONIA TANKS FDN.
SPARE MAIN TRANSFORMER
MAIN TRANSFORMER
EXIST. UNIT 1
W3+00
DIESEL FUEL OIL TRANSFER PUMP
SAFETY EQUIPMENT BUILDING
TURNING THR. S14+64.9 W5+63.5
DEMINERALIZER
ELECTRICAL & PIPING GALLERY
PERSONNEL ACCESS
SEWAGE TREATMENT PLANT
TURBINE AREA
ROTOR REMOVAL SUPPORT
INTAKE STRUCTURE
375,000 GAL. FIRE WATER STORAGE TANKS
TURNING THR. S14+64.1 W6+98.5
S14+74 W7+30
LUBE OIL AREA
FIRE WATER PUMP STATION
S20+00 W8+15
STOP GATES
W10+00
S15+00
S20+00

21001



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SAN ONOFRE NUCLEAR GENERATING STATION Units 2 & 3
PLOT PLAN
Figure 1.2-1

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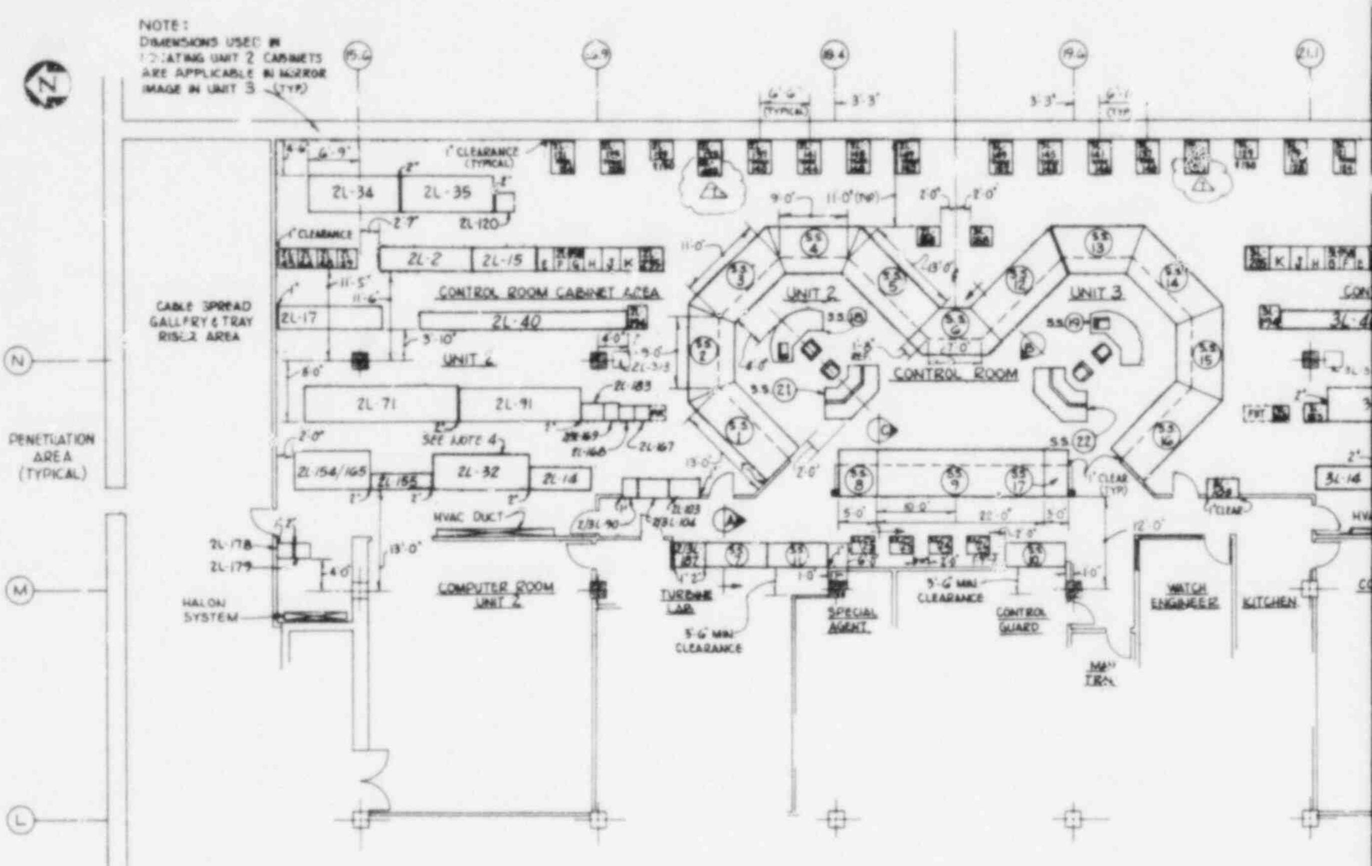
The configuration of the main control panel sections is shown in figure 1.2-2. These main panel sections utilize a combined bench/vertical operating surface contour. Those panels and instrumentation cabinets located behind the main control panel and external to the main control room are vertical panels.

The instrumentation and controls for each unit are identical. The layout of the separate unit control panels is identical, that is same hand not mirror image, with the exception of the common area panel (CR61) which is laid out functionally.

Since both unit control panels are identical in design, the activities described in this report are discussed relative to Unit 2, the lead unit, and the common area, but are also aplicable to Unit 3. The Plant Monitoring System Computer and the Critical Function Monitoring System Computers are located in a separate computer room across the hall from the control room.

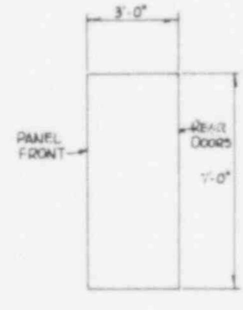


COLOR DESIGNATIONS (SEE NOTE 11)

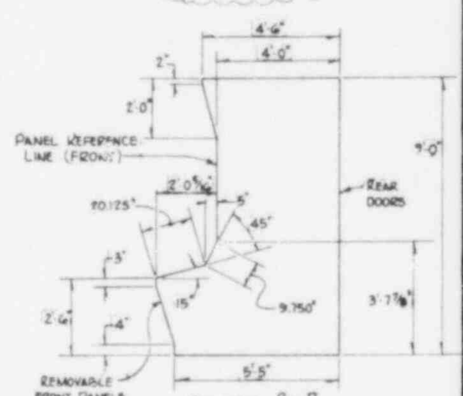
COLOR CODE	COLOR NO.	COLOR SYSTEM
A	297D COVEY GRAY	AMERITONE
C	292A PRAIRIE SUNSET	AMERITONE
D	283A TAMBOREE ORANGE	AMERITONE
E	291B TROPIC TAN	AMERITONE
F	296B PINE CONE	AMERITONE
G	297C VIKING GRAY	AMERITONE
H	297G NEUTRAL TINT	AMERITONE
I	298B CLOVE GRAY	AMERITONE
K	298C GRAY FOX	AMERITONE
L	261E BONNIE BLUE	AMERITONE
M	169C JEWEL	AMERITONE
N	169B MARTINIQUE	AMERITONE
S1	297A UMBER BROWN	AMERITONE
S2	282B ORANGE BLAZE	AMERITONE
T1	299-1T LAVENDER WHITE	AMERITONE
T2	839A ORANGE	PANTONE
W	296A DAKOTA	AMERITONE

NOTES:

1. TOP SECTION OF PANEL (ANNUNCIATOR PORTION) IS
2. ALL CABINET HEIGHTS IN THE CONTROL ROOM CABIN
3. ANNUNCIATOR CABINET MOUNTED IN PANEL
4. HEIGHT IS 8'-6" (FOR DISPLAY PNL) LOCATED AT CABIN
5. TOP ENTRY IS LIMITED DUE TO LOCATION OF DISPLA
6. INTERCONNECTING CABLE INCLUDES PRE-FABRICATE INSERTS AND CABINETS WITHIN CONTROL ROOM
7. SHIPPING SECTIONS 1 THRU 19 ARE FURN ARE FURNISHED BY COMBUSTION ENGINEER
8. DIMENSIONS SHOWN IN PLAN VIEW ARE LOCATED ON ELECTRICAL FLOOR PENETR
9. FOR ARRANGEMENT OF TURBINE LAB AN
10. TOP ENTRY FOR INTERCONNECTING CABLE IS CHANNEL A, B, C & D CABLE WILL ENTER PAN
11. COLORS SHOWN ARE THE COLOR OF CONTROL ROOM SYSTEM DEMARCATION FOR INDIVIDUAL INSTRUMENT BEZEL, PANEL APPROPRIATE DRAWINGS

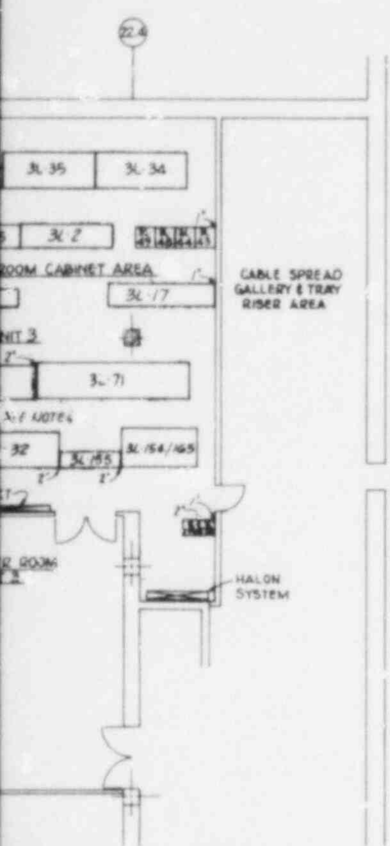


SECTION A-A
VERTICAL PANEL
SCALE: 1/2" = 1'-0"



SECTION B-B
BENCHBOARD
SCALE: 1/2" = 1'-0"

53000



PANELS & CABINETS WITHIN MAIN CONTROL ROOM

SHIPPING SECTION	BECHTEL DWG NO.	BECHTEL PANEL NO.	DESCRIPTION	PANEL ENTRY (FIELD CABLE)	PANEL ENTRY (INTERCOM CABLE) (NOTE 6)
1	53017 & 117	2CR-57	ENGINEERED SAFETY FEATURES SYSTEM	BTM	TOP
2	5301[illegible] & 116	2CR-56	PLANT PROT. SYST. & REACTOR COOLANT PUMPS	BTM	TOP & BTM
3	53018 & 118	2CR-58 50, 51	CHEM. VOL. CONTROL, REACTOR COOLANT AND REACTIVITY SYSTEMS	BTM	TOP & BTM
4	53013 & 113	2CR-52 & 53	STM. GEN. WATER LEVEL CONTROL AND FEEDWATER & CONDENSATE	BTM	TOP & BTM
5	53014 & 114	2CR-54 & 64	TURBINE AND SALTWATER & COMPONENT COOLING WATER SYST.	BTM	TOP
6	53021 & 121	2/3CR-61	COMMON SYSTEMS	BTM	BTM
7	53022	2/3CR-62	CHEMICAL CONTROL	BTM	BTM
8	53020	2/3CR-49	HEATING & VENTILATING-UNIT 2 & COMMON (SEE NOTE 1)	BTM	BTM
9	53031 & 131 53032 & 132 530[illegible]	2/3CR-63	ELECTRICAL MIMIC [illegible] (SEE NOTE 1)	BTM	BTM
10	53029	3CR-59	RECORDERS	BTM	BTM
11	53019	2CR-59	RECORDERS	BTM	BTM
12	53017 & 117	3CR-57	ENGINEERED SAFETY FEATURES SYSTEM	BTM	TOP
13	53016 & 116	3CR-56	PLANT PROT. SYST. & REACTOR COOLANT PUMPS	BTM	TOP & BTM
14	53018 & 118	3CR-58, 50 & 51	CHEM. VOL. CONTROL, REACTOR COOLANT AND REACTIVITY SYSTEMS	BTM	TOP & BTM
15	530[illegible] & 113	3CR-52 & 53	STM. GEN. WATER LEVEL CONTROL AND FEEDWATER & CONDENSATE	BTM	TOP & BTM
16	53014 & 114	3CR-54 & 64	TURBINE AND SALT WATER & COMPONENT COOLING WATER SYST.	BTM	TOP
17	53029	3CR-60	HEATING & VENTILATING UNIT 3 (SEE NOTE 1)	BTM	BTM
18	VENDOR DWG	2CR-65	OPERATORS DESK - UNIT 2	BTM	BTM
19	VENDOR DWG	3CR-65	OPERATORS DESK - UNIT 3	BTM	BTM
20	—	—	—	—	—
21	VENDOR DWG	2CR-55	COMPUTER CONSOLE	BTM	BTM
22	VENDOR DWG	3CR-55	COMPUTER CONSOLE	BTM	BTM
23	VENDOR DWG	2L-100	OPERATOR'S PRINTER	BTM	BTM
24	VENDOR DWG	3L-100	OPERATOR'S PRINTER	BTM	BTM
25	VENDOR DWG	2L-101	DOCUMENTATION PRINTER	BTM	BTM
26	VENDOR DWG	3L-101	DOCUMENTATION PRINTER	BTM	BTM

PANELS & CABINETS WITHIN CONTROL ROOM CABINET AREA

BECHTEL PANEL # UNIT 2	BECHTEL PANEL # UNIT 3	DESCRIPTION	PANEL ENTRY (FIELD CABLE)	PANEL ENTRY (INTERCONN. CABLE) (NOTE 6)	SPEC. NUMBER
2L-2	3L-2	TURBINE PROTECTION CUBICLE (ELECT)	BTM	TOP	401-A
2L14	3L-14	UNITISED ACTUATOR PANEL (NOTE 3)	BTM	TOP	401-M
2L-15	3L-15	TURBINE SUPERVISORY EQUIP. CUBICLE	BTM	TOP	401-P
2L-17	3L-17	ELECTRIC GOVERNOR CUBICLE (EHG) (NOTE 3)	BTM	TOP & BTM	401-M
2L-32	3L-32	PLANT PROTECTIVE SYSTEM CABINET (NOTE 4&5)	BTM	TOP & BTM	944
2L-34	3L-34	ENG. SAF. FEAT. ACT. SYST. AUX. CAB. "A"	BTM	TOP	953
2L-35	3L-35	ENG. SAF. FEAT. ACT. SYST. AUX. CAB. "B"	BTM	TOP	953
2L-40	3L-40	ANNUNCIATOR LOGIC CABINET	BTM	TOP & BTM	502-4
2L-43	3L-43	REACTIVITY REGULATING SYST. NO 1 RACK	BTM	BTM	943
2L-44	3L-44	REACTIVITY REGULATING SYST. NO 2 RACK	BTM	BTM	943
2L-48	3L-48	FEEDWATER CONTROL SYSTEM NO 1 RACK	BTM	BTM	934
2L-49	3L-49	FEEDWATER CONTROL SYSTEM NO 2 RACK	BTM	BTM	934
2L-71	3L-71	NSSS AUX. RELAY CABINET			306-1
2/3L-90		RADIATION MONITOR SYSTEMS	BTM	BTM	931 & 946
2L-91	3L-91	AUXILIARY PROTECTIVE CABINET	BTM	TOP & BTM	907
2L-103	3L-103	RADIATION MONITOR SYSTEMS	BTM	BTM	606-1
2/3L-104		RADIATION MONITOR SYSTEMS	BTM	BTM	606-1
2L-120	3L-120	STEAM BYPASS CONT. SYSTEM RACK	BTM	BTM	946
2L-121 THRU 2L-152	3L-121 THRU 3L-152	SPEC. 200 CABINETS (EXCEPT 2&3L-151, 132, 134, 135 & 136) NOT REQUIRED	BTM	TOP	924
2L-154A/A	3L-154A/A	HVAC SYSTEMS CONTROL	BTM	TOP	410-6
2L-155	3L-155	HVAC SYSTEMS CONTROL	BTM	TOP	410-1
2L-158	3L-158	BECHTEL INTERFACE CABINET (BOP) (SPEC 200)	BTM	TOP	504-1
2L-167	NONE	SEISMIC EVENT RECORDING	BTM	TOP	508-9
2L-168	3L-168	CIRC. WATER TEMP. DATA LOGGER	BTM	TOP	508-15
2/3L-169		CIRC. WATER FLOW MEASUREMENT	BTM	TOP	508-14
2L-178	3L-178	HYDROGEN RECOMBINER CONTROL	BTM	TOP	607-1
2L-179	3L-179	HYDROGEN RECOMBINER CONTROL	BTM	TOP	607-1
2L-185	3L-185	F.W. PUMP & TURB. SUPERVISORY INSTR. PANEL	BTM	—	502-2
2/3L-187		METEOROLOGICAL DATA LOGGER	BTM	—	508-10
2L-188	3L-188	BECHTEL INTERFACE CABINET (NSSS) (SPEC 200)	BTM	TOP	502-2
2L-194	3L-194	LOOSE PARTS MONITORING CABINET	BTM		
2L-235	3L-235	MISC. NSSS EQUIPMENT RACK	BTM	TOP	502-[illegible]
2L-313	3L-313	INSTRUMENT GROUNDING CABINET	TOP	TOP	306-38

MOVABLE FOR PANEL INSTALLATION

TO BE 90" HIGH UNLESS OTHERWISE NOTED

T OF 2L-32 & 3L-32

L

S FOR ANNUNCIATOR, CONTROL PANEL
CABINET AREA

BY BECHTEL AND 21 THRU 26

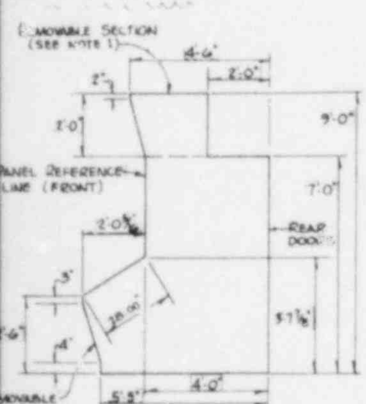
IMATE. FIRM DIMENSIONS ARE
DRAWINGS 35515 & 35516.

PUTER ROOMS SEE DWG. 10116.

CHANNEL CABLE ONLY.
ROUGH BOTTOM.

AND INSTRUMENT BEZELS FOR

ON AND SYSTEM COLORS. SEE



SECTION C-C
BENCHBOARD
SCALE: 1/2"=1'-0"

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QUALITY CLASS II

UNITS 2 & 3

SAN ONOFRE
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Units 2 & 3

MAIN CONTROL ROOM
PANEL ARRANGEMENT

Figure 1.2-2

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2.0 MANAGEMENT ORGANIZATION AND STAFFING

2.1 MANAGEMENT APPROACH

2.1.1 Introduction

SCE's approach to management of the control room review is outlined in figure 2.1-1. The primary elements include the Steering Committee, the CRDR Working Group, the SCE and Bechtel Power Corporation (BPC) line organizations, and Whitston Associates (consultants).

The primary responsibility of the Steering Committee was to provide management overview, guidance, personnel resources, and backup authority for the CRDR Program.

The CRDR Working Group reported to the Steering Committee and was responsible for detailed planning, scheduling and coordination of the total integrated control room review including the assignment of particular technical support activities to existing SCE and BPC line organizations as well as recommending specific activities to be performed by Whitston Associates.

The SCE and BPC line organizations carried out some of the technical activities associated with the review and worked with the CRDR Working Group in developing procedures and reports.

2.1.2 Responsibilities

2.1.2.1 Steering Committee

The Steering Committee's primary responsibility was to provide management overview to assure integration of the project objectives for meaningful control room improvement, as well as to fulfill regulatory intent for SONGS Units 2 and 3 in a cost-effective manner. In addition, the Steering Committee was responsible for assembling the required expertise to carry on the project, the formulation of the overall program and its scope, and assuring coordination to accomplish the job in a timely manner.

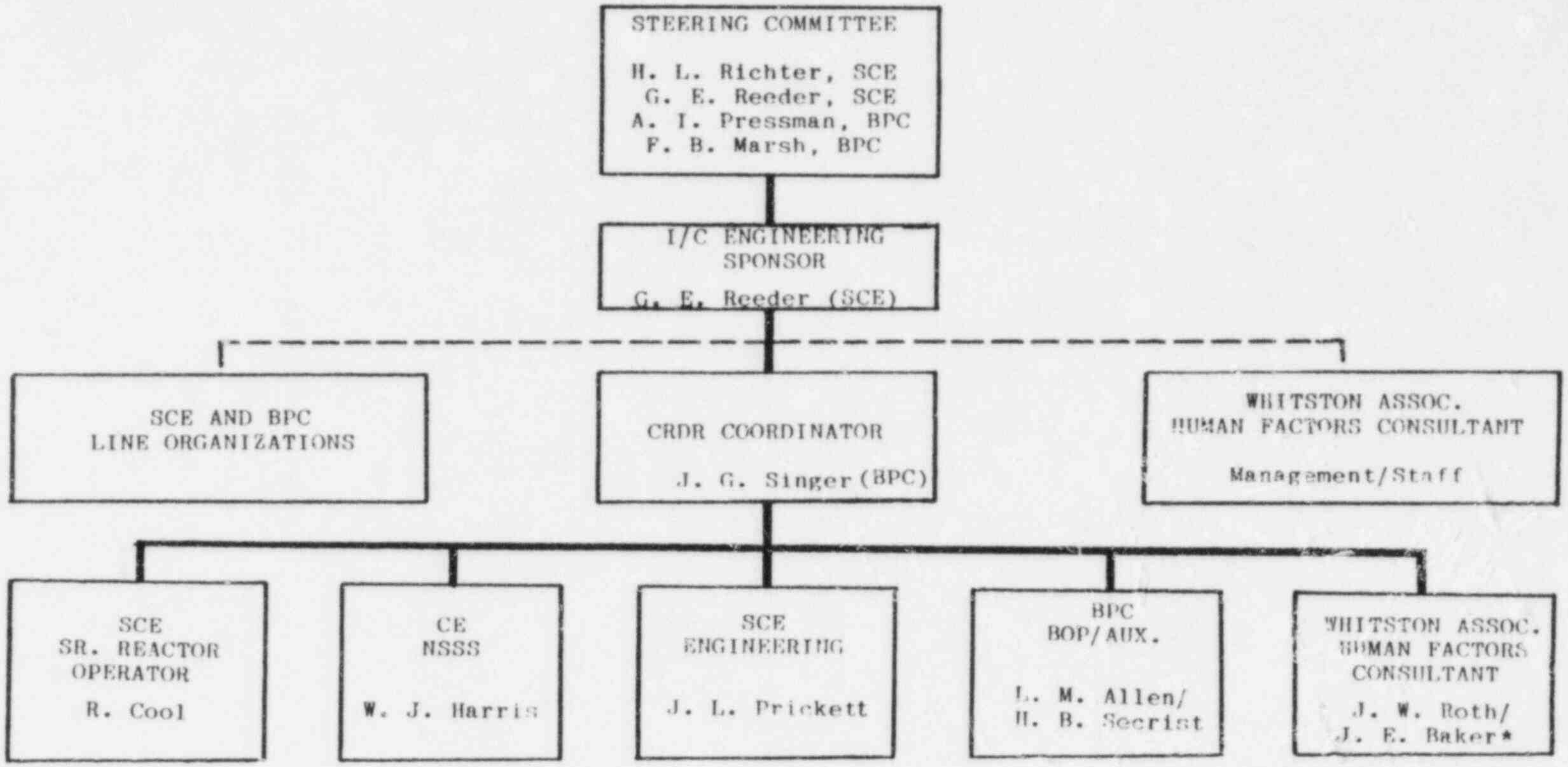
The Steering Committee also provided the necessary backup authority to the CRDR Group for dealing with other departments and groups in the SCE and BPC organizations such as Operations, Engineering, and Licensing.

The final responsibility of the Steering Committee was review and approval of the final CRDR Working Group recommendations to management for implementation authorization.

2.1.2.2 CRDR Working Group

The CRDR Working Group was responsible for planning, scheduling and conducting the detailed, integrated control room review and the work activities performed by the SCE and BPC line organizations, and Whitston Associates. See figure 2.1-1, Organization Chart.

The CRDR Working Group members were relieved of all other responsibilites and relocated to a separate work area so they could concentrate solely on the CRDR effort. CRDR Working Group activities included developing the methodologies for the review, establishing the detailed plan and



SCE - Southern California Edison
BPC - Bechtel Power Corporation
CE - Combustion Engineering
* - Part Time

Figure 2.1-1 ORGANIZATION CHART OF THE CONTROL ROOM DESIGN REVIEW WORKING GROUP schedule for the control room design review and the assessment of discrepancies, as well as, providing guidance to the SCE and BPC line organizations and coordinating all items requiring action. They were given direction that cost, schedule and original design considerations should not be taken into account when making findings or recommendations. The CRDR Working Group was responsible for preparing the initial recommendations relating to the CRDR Program.

2.1.2.2.1 CRDR Line Organization Support

The SCE and BPC line organizations provided support for assigned portions of the control room review activities which were related to their normal activities. For example, the control room lighting survey was performed by the SCE Apparatus Group.

2.1.2.3 Human Factors Engineering Consultant

The Human Factors Engineering Consultant, Whitston Associates, researched and provided existing recognized Human Engineering Factors Criteria for the CRDR Program. Whitston Associates also provided a full-time team member of the CRDR Working Group who actively participated on a day-to-day basis in the review and provided indoctrination on Human Factors Engineering considerations for the CRDR Working Group team members. In addition, Whitston provided several other human factors consultants on an as-required basis.

2.1.3 Interfaces

In order to perform the control room design review expeditiously, existing SCE and BPC technical line organizations were designated to perform specific tasks. The relationship between the CRDR Working Group and the technical line organizations was organized as follows:

- Based upon the objectives defined by the CRDR Working Group, the technical line organization performed each assigned activity under the guidance of the CRDR Working Group to assure the activities would satisfy the requirements and support the overall effort.

- The technical line organization was responsible for producing viable solutions for each assigned activity. The resulting documentation describes the actual conditions, summarizes the factors considered, and describes recommended solutions.

- The CRDR Working Group Leader had the authority to contact the appropriate manager of the technical lead line organization to establish a cooperative working relationship with the SCE or BPC line organization.

Whitston Associates worked with the CRDR Working Group and the SCE/BPC line organizations to meet the HED objectives of the CRDR and was encouraged to express independent judgements not only to the CRDR Working Group but directly to SCE's Management, as well.

2.2 STEERING COMMITTEE COMPOSITION AND QUALIFICATIONS

The Steering Committee was composed of four members representing Engineering-Management within both SCE and BPC, all of whom are Registered Professional Engineers with extensive Control Systems Design experience.

- H. L. Richter, SCE - Project Engineer
- G. E. Reeder, SCE - Control Systems Lead Engineer
- A. I. Pressman, BPC - Engineering Manager - Los Angeles Power Division
- F. B. Marsh, BPC - Control Systems Chief Engineer - Los Angeles Power Division

2.3 CRDR WORKING GROUP COMPOSITION AND QUALIFICATIONS

The CRDR Working Group was composed of a core team of seven full-time members. Additional members from the SCE/BPC line organization provided assistance for certain planned tasks. The core team members included Human Factors Engineering consultants, a Senior Reactor Operator, Instrumentation and Control Engineers, NSSS Engineers and BOP Engineers.

The team members were carefully selected to obtain an optimum blend of past experience to ensure the best possible CRDR, analysis, and recommendations.

All CRDR Working Group Members were chosen to be part of the group because of their past experience with nuclear power plant fundamentals and operation. General academic background, as well as, nuclear academics and extensive control systems design experience were considered as part of the qualifications.

No CRDR Working Group member had any direct association with the design development of the original control room or control panel design.

The selected members provided a combined total of over 150 years experience in the specific areas required to be addressed during the CRDR. The qualifications for CRDR Working Group members are shown as follows:

A. CRDR Working Group Leader
John G. Singer, BPC, Engineering Supervisor

- BSME - 1951, Registered Professional Engineer in California
- Principles of Supervisory Management Training -BPC and General Electric Co.
- Control Systems Engineering Group Supervisor at BPC for the Willow Glen fossil fuel power plant and the Blue Hills, Kuosheng, and SONGS nuclear power plants.
- Industrial Automation Specialist for sales and application of process control computers for industrial applications (G.E.)
- Regional Sales Manager for process control computers for power and industrial applications (Bunker-Ramo)
- District Sales Manager for power and industrial instrumentation and control equipment (Republic Flow Meters Co.)

B. SCE Senior Reactor Operator
R. Cool, SCE, SONGS Unit 2 and 3 Senior Reactor Operator

- Reactor Operator at SONGS Units 2 and 3.
- Training Instructor for Reactor Operators at SONGS Units 2 and 3.
- Senior Reactor Operator at SONGS Unit 1.
- Core member of SONGS Unit 2 operation team from late construction through unit startup.

C. NSSS Supplier Engineering Representative
W. J. Harris, C.E. Projects Management, Nuclear Projects

- Naval Nuclear Power School, Naval Electronics School, and Naval Officer Indoctrination School
- Project Manager, Nuclear Project, nine and one half years experience in commercial nuclear power plant instrumentation and control systems in positions of increasing responsibility. Participated in NSSS startup activities at SONGS Unit 2 with responsibility for the plant computer and digital protection system.
- Member of the TMI-2 Industry Advisory Group during the initial phase of the accident.
- Three years experience at Bechtel Power Corporation as Instrument and Control Engineer with responsibilities for NSSS interface with balance of plant including preparation of logic diagrams and a detailed FMEA of BOP safety related control systems.

- Twenty three years experience in the U.S. Navy, of which seven years were in the navy nuclear program as a technical advisor for development of engineering training manuals, instructor in nuclear systems, and as a maintenance officer. Retired as a Lieutenant Commander. Duties included reactor operator, engineering officer of the watch, engineering duty officer, assistant maintenance officer and training officer.

D. SCE Engineering Representative

J. L. Prickett, SCE, Senior Control Systems Engineer on the project.

- BSEE-1956, Registered Professional Engineer in California.
- Courses in Computer Design (Hardware/Software), Data Acquisition Systems, several Management and Supervisory courses, CE/NSSS, and Aircraft Instruments and Electrical Systems.
- Extensive supervisory and lead engineer positions in Control Systems Design, Installation, and testing experience for NASA, AEC, USAF and commercial projects (Aerojet-General Corp.) including the LM/FBR program at Hanford, Washington.
- Supervisory Positions in Operations/Test for complex, heavily instrumented and computerized facilities (Aerojet-General and TRW Systems)
- US Navy - Aviation Training, Flight Operations and Maintenance background; Project Manager, and Project Engineering Officer.

E. BPC BOP/AUX Engineering Representatives

1. L. M. Allen, BPC Control Systems Engineering Group Supervisor

- BSEE - 1950, Registered Professional Engineer in California
- Electronic Technician Training, USN Service School
- Process Computer Programming and Theory of Operation, G.E.
- BWR and PWR System Courses, BPC
- Control Systems Engineering Group Supervisor on Vogtle Nuclear Plant (PWR)
- 27 Years of varied power plant experience including process computer interface and application, control logic diagram design, burner control system application, tripping and protection circuitry, and control panel design.

2. H. B. Secrist, BPC, Senior Control Systems Engineer

- BA, math/physics 1956, Registered Professional Engineer in California
- US Air Force Technical Schools
- MS Program Management
- MBA, presently enrolled and 75 percent complete.
- Control Systems Engineer at BPC on various nuclear projects.
- Quality Assurance Engineer on the SONGS Unit 1 and Asco/Lemoniz projects.
- Quality Assurance Engineering at various instrumentation, aerospace companies, US Air Force and National Bureau of Standards.

F. Human Factors Consultant Representatives

1. J. W. Roth, W.A., Associate

- BSEE, BSB, 1950, Registered Professional Engineer in California
- Bailey Controls Company, 28 years of experience in the fossil and nuclear power industry holding the positions of Systems Service Engineer, Systems Sales Engineer, Los Angeles District Manager, Western Regional Sales Manager. During this time he was responsible for; unit startups, support of utility sales requirements, influenced logic systems design for major control systems in fossil and nuclear power plants.
- Member of Institute of Electrical and Electronic Engineers and Pacific Coast Electrical Association.
- Author of several technical papers in the fossil fired power generation area.

2. J.E. Baker, W.A., Associate (part time member)

- PhD, Industrial and Systems Engineering, with specialization in Human Factors Engineering.
- MS, Industrial and Systems Engineering
- BSME, Registered Professional Engineer in California
- Nine years Human Factors Engineering Consulting experience for various energy, manufacturing and aerospace firms.
- Positions held include project manager, management consultant, university lecturer and product and design engineering.
- University lecturer at USC and San Jose State University.

- Member of American Institute of Industrial Engineers, Human Factors Society, American Society for Engineering Education, Ergonomics Research Society, and the National Society for Scientific Research in North America.
- Author of several technical articles.

2.4 REPORTING RELATIONSHIPS

The CRDR Working Group Leader functionally reported to the SCE I/C Coordinator. CRDR Working Group members functionally reported to the CRDR Working Group Leader. Liaisons were established with the line organization for each major activity. Although the above described relationships were important for effective management of the review, recourse for any unresolved differences and other concerns among the CRDR Working Group members were through the CRDR Working Group Leader. Whitston Associates working group members also were responsible to the SCE I/C coordinator via the direct SCE-Whitston management relationship. If still unresolved, the Steering Committee or higher levels of management, as necessary, were responsible for resolving the differences.

2.5 ORIENTATION AND TRAINING

Whitston Associates provided orientation in human factors engineering considerations at the beginning of the CRDR effort. In addition, Whitston provided a Human Factors Design Checklist which covered anthropometrics, auditory communications, controls, control/display integration, design for maintainability, design for personnel capabilities, environment, hazards and safety, information utilization, labeling, visual displays, and work space.

Training was provided for the CRDR Working Group and participating line organizations to familiarize personnel with the principles of human factors engineering and their application to the CRDR. The importance of proper preparation and training for all CRDR activities was recognized. During the course of the CRDR, as specific areas of training were identified, appropriate training or orientation were provided to meet these needs.

3.0 DOCUMENTATION CONTROL

3.1 INTRODUCTION

Maintaining an efficient means of documenting all phases of the review effort was necessary to support a meaningful CRDR. The CRDR Program's approach to documentation is further discussed under the headings of Reference Documents, Documents Generated by the CRDR Working Group and Correspondence.

3.2 DOCUMENT TYPES - INPUT DATA/OUTPUT DATA

During the CRDR a substantial amount of reference material was used for guidance. The following is a list of the types of material that were used:

3.2.1 Reference Documents

- Regulatory Guides
- San Onofre Station Manuals
- EPRI Reports
- NUREGs
- MILSPECS
- Final Safety Analysis Report
- Safety descriptions
- Piping and instrumentation drawings
- Control room floor plan
- Panel layout drawings
- Panel photographs
- List of acronyms and abbreviations used in the control room
- Descriptions of coding conventions used in the control room
- Technical Specifications
- Licensee Event Reports
- Startup Problem Reports
- NRC Audits of other Utilities

- Software descriptions
- Typical computer printouts
- Procedures (emergency, operating, etc.)
- Operator training materials
- Human factors information and criteria
- Combustion Engineering Procedure Guidelines (CEN-152)
- INPO/NUTAC guidelines documents
- Whitston Human Factors Criteria and Studies

3.2.2 Documents Generated by the CRDR Working Group

- Control Room Design Review Plan
- Control Room Design Review Report for San Onofre Units 2 and 3
- Human Factors Design Criteria
- Checklists (that record control room components design discrepancies)
- Human Engineering Discrepancy (HED) forms
- Special measurement forms (for sound levels, ambient lighting, display lighting, climate)
- Whitston Color Scheme Study
- Photographic logs

3.2.3 Correspondence

All correspondence generated or received by the CRDR Working Group were filed in the temporary CRDR Working Group files. In addition, all correspondence was retained in existing project files in accordance with established project internal procedures.

3.3 RECORDS MANAGEMENT

The CRDR Working Group Leader was responsible for implementing and coordinating the CRDR records management.

- o Quality Assurance Records; documents identified as quality assurance (QA) records are stored in accordance with the requirements of ANSI-N45.2.9.
- o Storage Retention Time; CRDR Working Group files are maintained in accordance with project procedures to provide the required degree of protection prior to being entered into the permanent SCE filing system.

3.3.1 Human Engineering Discrepancies

The product of the review phase of the CRDR is the identification of HEDs. Components, equipment and other factors subject to scrutiny by the CRDR are documented by exception. All items that were not compliant with good Human Factors Engineering practices and were assessed as having a significant impact have been documented.

3.3.2 Assessment Records

Records were maintained, by exception, of the HEDs which were determined to be of sufficient significance to warrant correction. These HEDs are reported as either individual items or aggregations of related items with recommendations for improvement. The records may be in the form of sketches, drawing vellums, marked drawing prints, tables, check lists and forms.

3.3.3 Implementation Records

HEDs determined to have an adverse impact on the Control Room were identified for corrective action. The work associated with the corrective action is documented in Design Change Packages (DCPs). This is discussed in section 6.0 dealing with implementation.

4.0 DESIGN REVIEW PHASE

4.1 OBJECTIVE

The major goal of the CRDR was to identify Human Engineering Discrepancies (HEDs) that existed in the Control Room which may have created unnecessary difficulty or confusion for the operators in the performance of their duties or in recognizing and understanding existing and developing plant conditions.

HEDs were usually identified due to the control systems' failure to meet some criterion or standard of suitability or desirability. In some cases, an HED may have been noted simply because it embodied something less than optimal design.

The review was concentrated on the following subjects:

- Control Panel Instrumentation, Controls and Equipment
- Control Room Layout and Environmental Review
- System Function Identification
- Control Room Function Validation
- Normal and Emergency Operating Procedures
- Computer Systems
- Annunciator Systems
- Remote Shutdown Panel

4.2 REVIEW OF OPERATING EXPERIENCE

4.2.1 Plant Operating Experience

At the time of the original CRDR, the plant was in the late construction and initial startup phases. The actual operating experience gained was limited mainly to the operation of equipment or systems that had been scheduled for early startup. However, the panel instrument and annunciator layouts had been studied for several months prior to the CRDR Working Group's start of activity by plant operating personnel in their training programs. During the CRDR, observations and suggestions from the plant operators were provided through the reactor operator who was an active member of the CRDR Working Group. Informal contacts were made and comments were solicited from other plant operators. All of their comments and criticisms were taken into consideration during the Finding and Assessment Phase of the CRDR.

Since the original CRDR, during the completion of startup, continuing through low power operation, full power operation and up to the present, actual operating experience has been gained. Two formal procedures exist which enable the operators to provide on-going input to identify HEDs or problems in the Control Room. They are Startup Problem Reports (SPRs) and Instruction Resolution Requests (IRRs). For further discussion of these procedures, refer to paragraphs 4.7.9.1 and 5.7.

4.2.2 Control Room Operating Personnel Interviews

The interviews were intended to draw out the special knowledge of control room operating personnel about the problems and features that have been noted in the course of operations and preparation for operations. A range of the operating staff was interviewed including, auxiliary operators, reactor operators, senior reactor operators, shift technical advisors, and shift supervisors. In all cases the "interview survey" approach was used. It was recognized that the reviewer should not turn over responsibility for the interview to the respondents since operators are not designers or human factors engineers. Preferences and problems experienced by individual operators and other staff may have as much to do with their backgrounds, work experience, and knowledge as with the objective merits of the control room characteristics.

The interviews were intended only to acquaint the reviewers with the views of those immediately involved in operations. Their views were examined in the light of existing design criteria and practices. The selection of those personnel to be interviewed emphasized direct, day-to-day interfaces with the control room equipment. The survey objectives were accomplished by using a sample of operating shift personnel.

The content areas that were addressed in the survey of operating personnel are listed below:

- Workspace layout and environment
- Panel design
- Annunciator warning system
- Communications
- Process computers
- Lighting
- Noise
- Corrective and preventive maintenance
- Procedures
- Staffing and job requirements
- Training

All responses were examined for both positive control room features as well as problem areas, identified by the respondents. Their concerns are summarized below:

- Annunciators: Three concerns expressed.
- Storage space: Six concerns expressed.
- Console design: Three concerns expressed.
- Communications equipment: Four concerns expressed.
- Acoustical noise: Two concerns expressed.
- Lighting: Three concerns expressed.
- Console pushbuttons: Three concerns expressed.
- Plant computer (PMS): One concern expressed.
- Operator comfort: One concern expressed.

A total of 26 concerns were expressed during the plant interviews. These concerns were reviewed, assessed and received consideration for implementation in accordance with the assessment criteria established in section 5.1.

4.3 HUMAN FACTORS SURVEY OF THE CONTROL ROOM

4.3.1 General Procedure

The CRDR Working Group began its task by reviewing the existing control room layout, control panel configuration, instrumentation arrangements, annunciator system, and control panel labeling using existing engineering drawings and documents. Engineering drawings were arranged in proper physical sequence around the walls of the room to aid in pseudo walkdowns of operating sequences. Photographs were taken of the control panels and the overall control room for use by the CRDR Working Group. In addition, a full-size control room mockup of the Unit 2 and Common Panels was made for use during ongoing review activities. Concurrently with the control room and control panel design review, an evaluation of existing NUREGs, design guides, human factors criteria, and other specifications was undertaken to enable proper judgement to be made regarding the existing control room and control panel designs. The review was conducted within the constraints that recommendations shall be achievable, realistic in approach, integrated in implementation and justifiable.

The individual item analyses in Sections 5.2 and 5.4 of this report describe the approach used to identify and develop solutions for potential problem areas. A set of criteria was prepared and verified for each identified area that was studied.

4.3.2 Development of Guidelines and Criteria

Guidelines to be used in this review were generated after reviewing the results of the various NRC control room audit findings, NUREGs 585 and 660, and discussions with the Human Factors Engineering Consultant.

Based on NUREG 660 - NRC Action Plans Developed as a Result of the TMI-2 accident (5/80) and NUREG 585- TMI-2 Lessons Learned Task Force Final Report (10/79), the San Onofre CRDR Working Group addressed the following tasks in their survey of the control room.

- o Identification of potential and real problem areas in control room and panel design.
- o Recommendations for on-going study of other problem areas.

Additional insight on a method for conducting a human factors review of a control room was gained from EPRI NP-1118 - Human Factors Methods for Nuclear Control Room Design - Final Report 11/79 and 2/80.

An audit summary of the following control room reviews was compiled to reveal common problems or deficiencies in other plants.

- o NRC Review - VEPCO North Anna Unit 2 - Essex Corporation - Consultants
- o NRC Review - TVA Sequoyah Plant - Essex Corporation - Consultants

- NRC Review - PSE&G Salem Unit 2 - Essex Corporation - Consultants
- NRC Review - Duke-McGuire Unit 1 - Biotechnology Inc., - Consultants

This review of the above NRC audits concluded that the majority of noted design deficiencies requiring back-fit are related to:

- Insufficient functional system demarcation
- Inadequate labeling and instrument scale coding
- Component locational arrangement deficiencies
- Lack of annunciator prioritization and alarm clear status presentation
- Environmental constraints: lighting, glare, noise, color, etc.

The control room and panels were reviewed with respect to established human factors criteria and operability. Table 4.3-1 shows a matrix based upon Human Factors Engineering Guidelines Required for Control Room Design and Evaluation prepared by Whitston Associates which was used in this evaluation. The review covered all of the systems and related components on the control room panels.

NUREG CR-1580, Human Engineering Guide to Control Room Evaluation, Volumes 1 and 2, August 1980 was received just prior to completion of the study. The CRDR Working Group reviewed NUREG 1580 and determined that the basic thrust was similar to the EPRI NP-1118 Human Factors Methods for Nuclear Control Room Design that was used in the CRDR. In addition, there were human factors checklists referred to but not included in NUREG 1580.

CRITICAL SAFETY FUNCTIONS FO

HUMAN FACTORS EVALUATION CRITERIA	SAFETY CONTROL SYSTEMS													POWER PRO
	Annunciators	Containment Cooling	Containment Spray	Containment Isolation	Safety Injection	Cont. Sump Recirc.	Main Steam Isolation	Auxiliary Feedwater	Control Room Isolation	Toxic Gas Isolation	Fuel Handling Isolation	Cont. Purge Isolation	Cont. Comb. Gas	Nuclear Ins
CONTROLS Location, Movement, Spacing, Coding, Accidental Activation			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
VISUAL DISPLAYS Orientation, Location, Viewing Distance, Coding, Scale Ranges, Scale Coding, Lamp Test	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CONTROL/DISPLAY INTEGRATION Location, Grouping, Group Layout, Group Identification	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LABELING Abbreviations, Consistency of Location, Functional, Viewing Distance, Coding	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AUDITORY COMMUNICATIONS Types, Signal Variations, Discrimination	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
STATIC ANTHROPOMETRICS Structural, Passageway & Accesses, Reach, Movement, Position														
ENVIRONMENT Ventilation, Temperature, Humidity, Dust, Odors, Illumination, Noise														
WORKSPACE DESIGN Kickspace, Handles, Work Surface, Storage Space, Knee Room, Armrests														
HAZARDS AND SAFETY Safety Labels, Emergency Exits, Stairs Obstructions, Access, Edge Rounding, Electrical, Mechanical, Toxic					✓					✓	✓	✓	✓	
DESIGN FOR MAINTAINABILITY Malfunction Identification, Removal, Repair, Adjustments, Access, Instructions	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
INFORMATION ENTRY, ACCESS, STORAGE & RETRIEVAL Visual or Auditory, Type of Display, Stimulus Dimension	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DESIGN FOR PERSONAL REQUIREMENTS Sensory/Perceptual, Intellectual, Output, Physical Skills	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

able 4.7-1

MAINTAINING NUCLEAR POWER PLANT SAFETY

TION CONTROL SYSTEMS — OPERATING INSTRUCTIONS

...ation	...tor Regulation	Feedwater Regulation	Reac. Chem. & Volume	Reactor Protection	Main Steam	Feedwater & Condensate	Main Turb. Hydraulic Gov.		SO23 3-2.7 Safety Inj. Sys. Oper.	SO23 3-2.17 Main Stm. Iso. Valve Oper.	SO23 3-2.9 Cont. Spray Sys.	SO23 2-4.0 Aux. Feed Pump Oper.	SO23 3-5.1 Emerg. Plant Shut Down	SO23-3-5.15 Reac. Reg. Sys. Malfunc.	SO23-3-2.1 CVCS Chg. & Letdown	SO23-2-1.0 Main Feedwater Pump Oper.			Control Boards - Physical	Control Room & Furnishings
✓	✓	✓	✓	✓	✓	✓	✓													
✓	✓	✓	✓	✓	✓	✓	✓													
✓	✓	✓	✓	✓	✓	✓	✓													
✓	✓	✓	✓	✓	✓	✓	✓													
✓	✓	✓	✓	✓	✓	✓	✓													
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✓	✓	✓	✓	✓	✓	✓	✓													
✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓

The review of the pertinent points of NUREG 1580 concluded that the work accomplished in the study with respect to the control room and remote shutdown panels satisfied the requirements. Subsequent review of NUREG 0700 has been performed and the information contained in this report is submitted to satisfy the intent of the CRDR process described in the NUREG.

4.4 CONTROL ROOM INVENTORY

It was unnecessary to make a new actual inventory of control room instruments since complete documentation and description of the instruments existed for use by the CRDR Working Group.

The instruments are shown to scale on panel drawings that had been issued for fabrication and installation. These drawings had been kept up-to-date with changes that occurred since panel installation by issuance of Drawing Change Notices (DCNs) and subsequent drawing revisions. Instruments were identified on the drawings by instrument tag number which could be traced through the Instrument Index to individual Instrument Data Sheets which provided complete details. The Instrument Index also provided references to Piping and Instrumentation Diagrams (P&IDs) and Electrical Elementary Diagrams so the application of the instrument in its system could be fully understood. Thus, the "official" panel drawings provided an ideal tool for use in Verification of Task Performance Capabilities (section 4.6) and Control Room Functions Validation (section 4.7)

4.5 SYSTEM FUNCTION IDENTIFICATION AND ANALYSIS

4.5.1 Objective and Scope

A part of the CRDR Working Group objective was examination of the functional grouping of instrumentation and controls in the control room. To facilitate this, a review of system functions was undertaken.

The objective of the System Function Identification and Analysis was to establish the function of each major system and subsystem. From this the needs of the control room operator to accomplish these functions were determined. The result of this task area was the development of functional grouping used for demarcation, development of Process Flow Diagrams (PFDs), and identification of HEDs.

The work developed from the System Function Identification and Analysis was then directly used in the Verification of Task Performance Capabilities (section 4.6) and Control Room Functions Validation (section 4.7).

4.5.2 Functional Grouping

The starting point for the CRDR Working Group was development of functional grouping. Initially, each major plant operational area was identified and given a functionally oriented name. They are:

- Engineered Safety Features

- Reactor Support

- Primary Energy
- Secondary Energy
- Electrical Energy
- Heat Rejection
- Plant Services
- Emergency Services

Each major functional group was then broken into the supporting subfunctions and finally a hierarchical grouping was established. The results of this grouping activity is discussed in subsection 5.2.2 of the review phase of this report and was used for the hierarchical labeling criteria of the control panel. The original control panel design criteria employed at SONGS 2 and 3 gave very favorable major system grouping between panel sections and greatly reduced the scope of work for relocating components based on functional grouping.

4.5.3 Process Flow Diagrams

The next logical step following the functional grouping activities was the development of process flow diagrams (PFDs). Figure 4.5-1 depicts a typical PFD for the Reactor Coolant System and its major supporting system the Chemical and Volume Control System. The bold demarcation lines are applied to show the functional grouping. This demarcation of function was applied to the control panel survey and resulted in numerous instrument relocations to optimize the grouping.

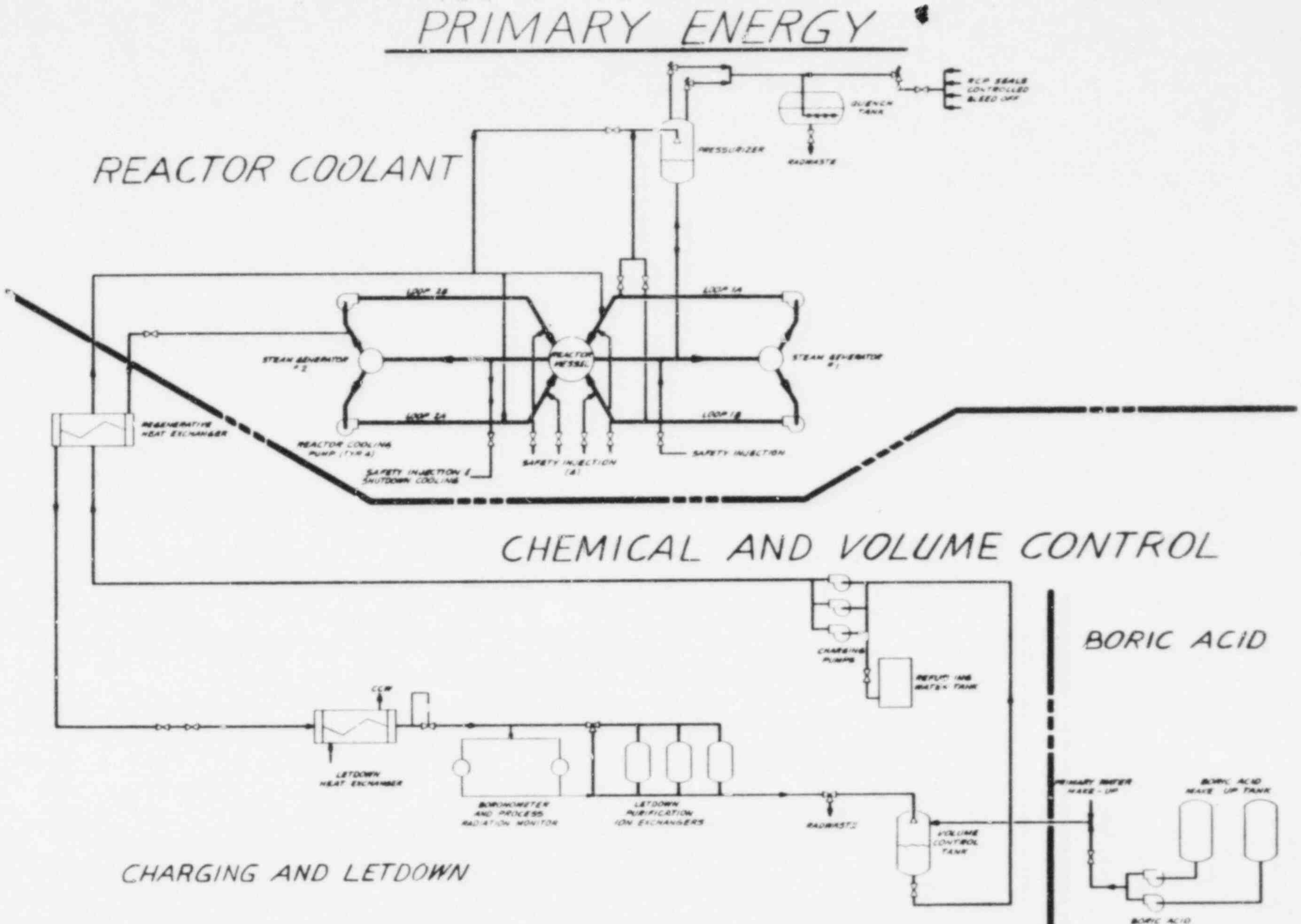

Figure 4.5-1 FUNCTIONAL GROUPING PROCESS DIAGRAM

4.6 VERIFICATION OF TASK PERFORMANCE CAPABILITIES

The objective of the task performance capabilities verification process is to assure that adequate instrumentation and controls exist in the control room to enable the performance of operator tasks with minimum potential for human error.

During the verification effort, the following aspects were investigated:

- The location of necessary controls and displays.
- Functional panel layout.
- General efficiency of the Control Panel to support operator tasks.
- Verification of instrument inventory (Availability of required instruments and controls.)

4.6.1 Instruments and Controls

A review of instruments and controls required for startup and operation was conducted on a system basis to confirm that operating needs were met. Relative locations of instruments and controls to support a good, logical operating sequence for a system were examined. (This is also discussed in subsection 5.2.1)

4.6.2 Annunciator System

Another significant element in the SONGS 2/3 CRDR control room verification of task performance capabilities was consideration of the Annunciator System. Considerable study was performed on this system, due mostly to its relatively large scale (1,250 Unit 2 + Common alarms).

For the purposes of the verification the objective was to determine if the operator could respond to an incoming alarm effectively. Specific items considered were:

- Is the alarm message meaningful or can it be confusing?
- Is the alarm physically located near the affected equipment (i.e., same panel subsection)?
- Can the operator take corrective action for the alarm?
- Is the equipment necessary to take corrective action in the control room?
- Does the operator have a sense of the relative priority/urgency of the alarm?

Following the systematic review of all annunciator functions, discrepancies were identified and recommended corrective actions provided.

4.7 CONTROL ROOM FUNCTIONS VALIDATION

4.7.1 Objective and Scope

Validation of the control room functions constitutes the final step in assuring that the actions required by the control room operators can be performed in an effective and timely manner.

The objective of this examination was to evaluate the integration of the control room operators and their resources. To the point: is the existing control room equipment and procedural configuration of sufficient quality that the operators can assess plant status, diagnose problems and take corrective actions, effectively?

To accomplish this objective, the CRDR Working Group examined two major operator task areas in the control room. Specifically, the CRDR Working Group considered normal operating procedures and emergency response tasks.

The validation philosophy attempted to ensure that all potential active areas were examined in sufficient detail so as to assure that an unusual event would not become an emergency situation due to an inappropriate and/or insufficient operator response.

4.7.2 Operating Procedures (OPs)

A subset of the OPs for SONGS 2 and 3 were examined by the CRDR Working Group. The intent of this review was to provide function validation and identify deficiencies associated with instruction format and content. This process developed criteria for reviewing and assessing other procedures. The procedures were studied and were evaluated against a standard set of criteria prepared by the CRDR Working Group (See section 5.7).

4.7.2.1 Review Criteria

The criteria used for evaluating the procedures considered:

- o Availability of instrumentation and controls required to complete procedural action
- o Technical accuracy
- o Format
- o Content
- o Consistency
- o Readability/Understandability
- o Complexity
- o Precaution/Reference statements

Deviations from the criteria were examined on an exception basis by the CRDR Working Group. All significant deviations were assessed for HED impact.

Of approximately 300 operating procedures, six representative procedures were examined. They were:

- o <u>S023-3-5.1</u> Emergency Plant Shutdown
- o <u>S023-2-4</u> Auxiliary Feedwater Pump Operation
- o <u>S023-3-2.9</u> Containment Spray System Operation
- o <u>S023-3-2.1</u> CVCS Charging and Letdown
- o <u>S023-3-5.16</u> Reactor Regulating System Failure
- o <u>S023-2-1</u> Main Feedwater Pump and Turbine Operation

4.7.3 Emergency Response Tasks

Of particular concern to the control room functions validation analysis are operator actions and needs during an unusual event. The primary emphasis for study in this area was an analysis of the emergency response capabilities of the control room and operations staff.

The functional breakdown of this area is fourfold and is summarized as follows:

1. A set of criteria for identifying the spectrum of unusual events must be developed and applied.
2. A systematic study of responses to these events must be initiated and specific mitigating functions identified.
3. An analysis of the systems and equipment necessary to accomplish these functions must be made, followed by an inventory of this equipment in the control room.
4. The operators must be given the skills and knowledge to assess any unusual event, identify the necessary mitigating actions and take control of the situation using their resources.

The activities described here were structured to meet the above mentioned breakdown. To accomplish this, SCE has employed the Combustion Engineering (CE) Emergency Procedure Guidelines (EPGs)(CEN-152) prepared for the CE owners' group. The EPGs were developed based on the Safety Function Concept which states that a nuclear power plant can be maintained in a safe condition by maintaining 10 specific safety functions. These functions, listed in table 4.7-1, were identified following an exhaustive analysis of unusual events and their consequences.

Table 4.7-1

CRITICAL SAFETY FUNCTIONS
FOR
MAINTAINING NUCLEAR POWER PLANT SAFETY

- Reactivity Control
- RCS Pressure Control
- RCS Inventory Control
- Core Heat Removal
- RCS Heat Removal
- Containment Isolation
- Containment Pressure Control
- Containment Temperature Control
- Combustible Gas Control
- Radiological Effluent Control

4.7.4 Safety Function Analysis

An analysis of the safety functions was performed to determine the flow path of unusual events, plant response, and operator actions necessary to mitigate any severe consequences.

A significant assumption used in this analysis and the resultant operational guidelines is that emergency events are readily categorized into two types. In the first type, the operator can ascertain the general type of event by recognition of the symptoms as displayed on the control panel. This gives a logical starting point in carrying out the mitigating function. However, the second type of emergency event is characterized by unrecognizable symptoms for the disturbance. In this case classical procedures can be of little or no help.

4.7.5 Recovery Methods

To address this finding the CE EPGs provide guidance for the development of two procedure types. The first is an Optimal Recovery Method (ORM) where events are recognized and specific operator actions are described. In this case, the operator knows "where to step" into the procedures and is presented with clean cut tasks to carry out. The second case, where no specific event can be recognized from the correlated symptoms the EPGs prescribe a Functional Recovery Method (FRM). The FRM offers specific tasks to maintain the previously mentioned safety functions. Use of the FRM activities is a significant departure from the previously mentioned event-oriented approach.

4.7.6 Emergency Event Classification

The CE CEN-152 classified all of the emergency events into six classes. They are:

1. Steam Line Break (SLB)
2. Loss of Coolant Accident (LOCA)
3. Steam Generator Tube Rupture (SGTR)
4. Loss of Feedwater (LOF)
5. Loss of Forced Circulation (LOFC)
6. Reactor Trip Recovery (RTR)

Each class of events bounds a group of plant specific events that are likely to occur at a nuclear facility. The results and symptoms of many events have such similarity that it is necessary to group the events as done here.

4.7.7 Event Activities Analysis

The primary emphasis of this examination was on the emergency related tasks. SCE has relied on the task analysis activities conducted by its NSSS vendor and other utilities for the bulk of the analytical analysis. An analysis of each event was conducted by an expert team consisting of senior personnel from the Design, Operations, Training, and Maintenance organizations of the NSSS vendor (CE) and the participating utilities. Each event class was analyzed by examination of plant hardware data, licensing analysis, transient analysis, incident reports, sequence of events diagrams and operating experience.

4.7.8 Event Sequence Generation and Analysis

Following the identification of the event classes, event sequences were generated for each class. The event sequence charts provide strategy for using the Optimal Recovery Procedures (ORPs) (figure 4.7-1 typical) and provide for success paths for maintaining the safety functions under the Functional Recovery Procedures (FRPs). This activity resulted in a functional system examination and a logical classification of equipment and components needed to accomplish these functions.

A major objective of the Event Sequence Generation and Analysis was to determine the general characteristics and possible causes of each event and potential effects of the event on the reactor, plant equipment, and the environment. As a product of this, key parameters were identified that should be available in the control room for monitoring, controlling and trending during the events. These items, when taken to the plant specific level, constitute the task performance parameters that are required to accomplish the emergency response function.

The generalized safety-function list is given in table 4.7-2. As part of the ongoing effort by SCE to respond to NUREG 0737, Supplement 1 (section 7), the generalized list will be incorporated into the revised Emergency Operating Procedures and the specific instrumentation and controls required will be paired against the control room drawings. Any discrepancies would then be subjected to the same criteria as applied under the program plan of this CRDR and implementation of a change will be made on a priority basis as deemed necessary.

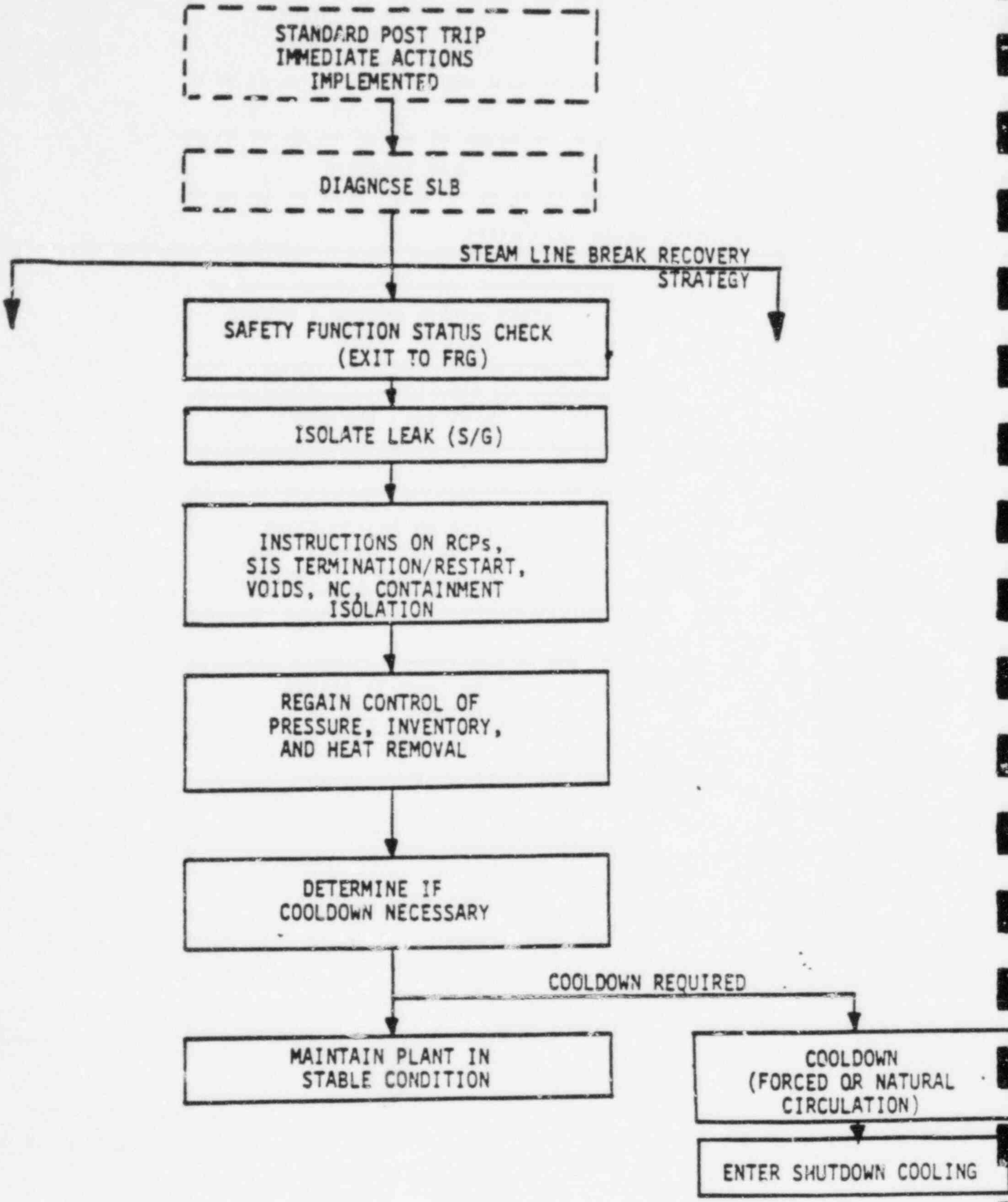

Figure 4.7-1 OPTIMUM RECOVERY PROCEDURE, STEAM LINE BREAK RECOVERY STRATEGY CHART

Table 4.7-2

SAFETY FUNCTION STATUS CHECK BASES
STEAM LINE BREAK (Sheet 1 of 4)

The safety functions listed below and their respective criteria are those used to confirm the adequacy of the SLB mitigation. Additional safety functions should be monitored as appropriate to evaluate overall plant status.

SAFETY FUNCTION	ACCEPTANCE CRITERIA	INDICATION	RANGE	BASES
Reactivity Control	Reactor Power Decreasing AND [Negative Startup Rate] AND No more than 1 CEA Bottom Light Not Lit or Borated per Tech Specs	Power Range Power Rate CEA Status Display	[0-125%] [-1→7dpm] On/Off Light for Each CEA	For all emergency events, the reactor must be shutdown. The criteria that no more than one CEA be stuck out or the RCS borated observes typical technical specification requirements.
RCS Inventory Control	If Pressurizer Level is between [35"] and [245"], charging and letdown are being operated manually or automatically to maintain or restore pressurizer level. AND RCS ≥ [20]°F subcooled OR If Pressurizer Level is < [35"], [at least one charging pump is operating and] the SIS pump(s) are injecting water into the RCS per Figure 7-9, unless SIS termination criteria are met	Pressurizer Level	[0"-350"]	A value of [245"] ([70%]) of range was chosen as an upper limit for pressurizer level to account for instrument accuracies and other uncertainties. A value of [35"] ([10%]) of range was chosen as a lower limit to account for instrument accuracy. A [20]°F subcooling margin coexisting with a pressurizer level between [34"] and [245"] indicates adequate RCS pressure control via a saturated bubble in the pressurizer.

Table 4.7-2

SAFETY FUNCTION STATUS CHECK BASES
STEAM LINE BREAK (Sheet 2 of 4)

The safety functions listed below and their respective criteria are those used to confirm the adequacy of the SLB mitigation. Additional safety functions should be monitored as appropriate to evaluate overall plant status.

SAFETY FUNCTION	ACCEPTANCE CRITERIA	INDICATION	RANGE	BASES
RCS Pressure Control	If Pressurizer Pressure > [1600 psia], heaters and pressurizer spray are being operated manually or automatically to maintain or restore pressurizer pressure within the limits of the P/T curves OR If Pressurizer Pressure < [1600 psia], [at least one charging pump is operating and] the SIS pump(s) are injecting water into the RCS per Figure 7-9, unless SIS termination criteria are met	Pressurizer Pressure	[1500-2500 psia]/ [0-1600 psia]	[1600 psia] is the SIAS setpoint. The range of the selected events are very broad, therefore the acceptance criteria is written to cover the expected range which may result from the events noted.
Core Heat Removal	Core Exit Thermocouples < [800°F]	Core Exit Thermocouples	[0°-1600°F]	[800°F] is a plant specific temperature based on engineering judgement. Best estimate analyses have shown that [800°F] CET temperature will not be exceeded for a SLB without multiple equipment failures or coincident other accidents.
	AND			
	Subcooled Margin ≥ [0°F] Subcooling	Subcooled Margin Monitor	[0°-100°F]	The value of [0°F] subcooling is based on keeping the core covered and thus ensuring adequate core cooling. If the core is covered with fluid, the RCS will not indicate superheated conditions.

Table 4.7-2

SAFETY FUNCTION STATUS CHECK BASES
STEAM LINE BREAK (Sheet 3 of 4)

The safety functions listed below and their respective criteria are those used to confirm the adequacy of the SLB mitigation. Additional safety functions should be monitored as appropriate to evaluate overall plant status.

SAFETY FUNCTION	ACCEPTANCE CRITERIA	INDICATION	RANGE	BASES
RCS Heat Removal	Level in the unaffected S/G is <u>either</u>: a) Within the zero power level band with feedwater available to maintain the level <u>OR</u> b) being restored by a feedwater flow ≥ [150] gpm <u>AND</u> RCS Tave is < [545°F] and controlled	Steam Generator Level	[+63.5" - (-)116.5"]	Decay heat levels may not be high enough to require a feedwater flow of [150] gpm. Once steam generator level is returned to the zero power level band and feedwater remains available to maintain that level, then the SIS contribution to RCS heat removal is being satisfied. [545]°F is based on not lifting a steam generator safety valve.
Containment Isolation	No containment or steam plant radiation monitors alarming <u>AND</u> Containment pressure < [4 psig] <u>OR</u> CIAS should be present or manually initiated	Containment Pressure Containment Isolation Valve Position Indication	Alarming-Not Alarming [0-60 psig] Shut/Open	During SLB, it is not expected that there will be radiation inside containment or in the steam plant. The monitors should not be alarming. [4 psig] is the CIAS setpoint. If pressure goes above [4 psig], containment isolation valves should shut (i.e. CIAS should be present).

Table 4.7-2

SAFETY FUNCTION STATUS CHECK BASES
STEAM LINE BREAK (Sheet 4 of 4)

The safety functions listed below and their respective criteria are those used to confirm the adequacy of the SLB mitigation. Additional safety functions should be monitored as appropriate to evaluate overall plant status.

SAFETY FUNCTION	ACCEPTANCE CRITERIA	INDICATION	RANGE	BASES
Containment Temperature and Pressure Control	Containment Pressure < [10 psig] AND Containment Temperature < [240^{0}F]	Containment Pressure	[0-60 psig] [0-15 psig]	[10 psig] is based on CSAS setpoint.
		Containment Temperature	[50^0-300^{0}F]	[240^{0}F] corresponds to the saturation temperature for [10 psig].
	OR Containment Spray Flow > [1500 gpm]	Containment Spray Flow	[0-5000 gpm]	During the selected event, containment temperature and pressure may exceed these limits if the break is inside containment. If this happens, a CSAS should be present and the CSP should be injected spray solution at [1500 gpm].
Containment Combustible Gas Contol	H_2 < [X]%	←	[Plant	Specific] →

4.7.9 Emergency Operating Procedures (EOPs)

The objective of reviewing the EOPs was to provide validation that the control room operator can perform those tasks using the resources in the control room.

Due to the emphasis of the CRDR task validation on assuring adequate operator response to emergency or unusual situations the walk/talk through of the EOPs is a more thorough activity.

4.7.9.1 Simulator Walk/Talk Through Activity

A simulator training program was developed for SONGS 2 and 3. The program provides exact training for operators for all plant evolutions. As with the NOPs, the EOPs are continually being used for operator training in the SONGS 2/3 simulator training and retraining programs. Any problems in procedure implementation or equipment suitability are documented by an Instruction Resolution Request (IRR) or Startup Problem Report (SPR) and are then assessed for impact on control room performance. See Section 5.7 for additional information on IRR and SPR processes.

The following table 4.7-3 lists the SONGS 2 and 3 EOPs that are walked/talked through using the simulator. Video recordings are frequently used to allow critical offline assessment of student performance during a real-time simulated event.

Table 4.7-3

EMERGENCY OPERATING PROCEDURES (Sheet 1 of 2)

Procedure No.	Procedure
S023-3-5.1	Emergency Plant Shutdown
S023-3-5.2	Turbine Shutdown with Reactor Power Below 55%
S023-3-5.3	Reactor Protection System Failure
S023-3-5.4	Complete Loss of Offsite Electrical Power
S023-3-5.5	Loss of Reactor Coolant Flow
S023-3-5.6	Loss of Coolant Accident
S023-3-5.7	Reactor Coolant Leak
S023-3-5.8	Slipped or Dropped Control Element Assembly
S023-3-5.9	Steam Line Rupture
S023-3-5.10	Emergency Boration of Reactor Coolant System
S023-3-5.11	Loss of Containment Integrity
S023-3-5.12	Loss of Shutdown Cooling
S023-3-5.13	Loss of one or more Linear Power Safety Channels
S023-3-5.14	High Activity in Reactor Coolant System
S023-3-5.15	Recovery from Inadvertent Safety Injection/Containment Isolation
S023-3-5.16	Reactor Regulating System Failure
S023-3-5.17	Pressurizer Pressure Control System Malfunction
S023-3-5.18	Shutdown from Outside Control Room
S023-3-5.19	Loss of Boron Concentration Control/ Excess Dilution
S023-3-5.20	Loss of Reactor Coolant Makeup
S023-3-5.21	Malfunction of Reactor Coolant Letdown/Purification System
S023-3-5.22	Loss of Load/Reactor - Generator Mismatch

Table 4.7-3

EMERGENCY OPERATING PROCEDURES (Sheet 2 of 2)

Procedure No.	Procedure
S023-3-5.23	Damage of Spent Fuel
S023-3-5.24	Loss of Pressurizer Pressure Control
S023-3-5.25	Loss of Offsite Power
S023-3-5.26	Reactor Coolant Pump Seal Failure
S023-3-5.27	Earthquake
S023-3-5.28	CVCS Loss of Coolant Accident
S023-3-5.29	Steam Generator Tube Rupture
S023-3-5.30	Loss of Feedwater
S023-3-5.31	Loss of Instrument Air
S023-3-5.32	Loss of Saltwater Cooling
S023-3-5.33	Loss of Component Cooling Water
S023-3-5.34	Loss of Protective System Channel
S023-3-5.35	Plant Fires
S023-3-5.36	Abnormal Release of Radioactive Liquids
S023-3-5.37	Waste Gas Accident
S023-3-5.38	Loss of Non-1E Instrument Buses

Note:

These procedures have been reviewed against the criteria established for the previous subsection 4.7.2 on NOPs.

4.7.10 Evaluation of Control Room Layout

To evaluate the adequacy of the physical control room layout during emergency events, two EOPs were walked through and operator flow paths documented. The specific procedures were:

- o Emergency Plant Shutdown, Procedure No. S023-3-5.1
- o Steam Line Rupture, Procedure No. S023-3-5.9

5.0 FINDINGS, ASSESSMENTS AND RECOMMENDATIONS

5.1 METHODOLOGY

There were several phases of human factor reviews which were accomplished by different organizational entities such as the NRC CRDR Audit Team, CRDR Working Group, and SCE Apparatus Group. As a result, there were some overlaps in scope as well as differences in the timing of the assessments of the Human Engineering Discrepancies (HEDs) and the prioritizing, scheduling and implementing the recommended modifications. As the various HEDs were identified, they were assessed and classified as to their severity and likelihood of precipitating or contributing to operator errors during various operating modes of the plant.

HEDs identified by the NRC in their audit were assessed and assigned to one of the following three categories which are defined below with the commitment period for implementation.

Category 1. Serious Concern - Human/System performance degradation with serious potential safety consequences, (implementation prior to fuel load).

Category 2. Moderate Concern - Human/System performance degradation with moderate potential safety consequences, (implementation prior to 5% power).

Category 3. Other Concerns - These HEDs require additional evaluation by licensee for future resolution. (implementation indeterminate)

HEDs which were identified by the CRDR Working Group were evaluated as to their safety aspects and were assigned to categories related to time of implementation. The principal criteria in assessing HEDs were to determine which modification could contribute more effectively to safety of the plant. Criteria to accomplish this were required to meet the following two conditions:

- o HED was associated with a safety system,

- o HED would obviously decrease the opportunity for the operator to effectively monitor and control the necessary safety system parameters.

If these two conditions existed, HEDs were classified as safety-related and would require a short-term correction. These needed to be implemented prior to fuel load. If the two conditions were not met, HEDs were considered for long-term corrective measures which, if required, could be implemented prior to completion of the first refueling outage.

In addition, there was a third group of HEDs which resulted from the CRDR Working Group assessment. These HEDs, largely in the environmental areas, needed additional evaluation dependent upon completion of the control room upgrade, operating instructions, or other developments, including operating the units, to allow empirical measurements or observations. Implementation time of corrections for these HEDs will be established after evaluation of this data.

In some cases, even though the HEDs were not significant safety items, their implementation could be accomplished in conjunction with work required for safety-related modifications. Consequently, these HEDs were recommended to be implemented concurrently with the associated changes.

5.2 CONTROL PANEL

5.2.1 Panel Arrangement

5.2.1.1 Panel Arrangement Criteria

The basic criterion for component arrangement on control boards and panels is to improve operability, i.e., man/machine interface, by proper integration of the controls and displays.

A review was made of components arrangement on panel sections CR-57, CR-56, CR-58, CR-50, CR-51, CR-52, CR-53, CR-54, CR-64, CR-61, and CR-60 for the purpose of identifying potential rearrangement which would achieve the purpose described above. Since construction was well along and the panels had already been installed in the control room, it was generally accepted to consider rearrangement only to the extent that present cutouts be utilized without the requirement for filling existing cutouts or making new cutouts. When exceptions were made, it was related to cases where:

- o A deficiency was judged to be significant as related to a safety system.
- o The control and its related display were unreasonably separated or had improper orientation.
- o Considerable improvement could be achieved in the area or section related to a functional group identified for demarcation.

- Operational sequence needs could be significantly enhanced.

5.2.1.2 Panel Arrangement Methodology

The methodology to survey the panel arrangement was to review the existing control panel in accordance with the five activities listed below.

- Identification of functional groups of components by utilizing criteria and process flow diagrams developed by the CRDR Working Group.

- Identification of component relocations considered to be supportable by criteria discussed above.

- Identification of an optimum arrangement for all components on a panel section taking into account existing provisions for safety channel separation and structural bracing.

- Identification of an optimum arrangement for all components on a panel section assuming no structural constraints.

- Charting of flow paths for operators as a part of executing immediate and subsequent actions for emergency operating instructions covering plant emergency shutdown and steam line break. See figures 5.7-1 and 5.7-2, respectively.

5.2.1.3 Panel Arrangement Findings

The result of the control room survey determined control and display locations that would increase the opportunity for the operator to effectively monitor and control process systems parameters. These fell within two major groupings.

- o Functional groups, when depicted on the control panel layout drawings with lines of demarcation revealed islands and jagged lines of demarcation. To mitigate these two undesirable aspects, a number of component relocations have been listed as HEDs.

- o Within each functional group, the location of individual controls and displays were studied in relation to one another and in relation to the sequence in which an operator would interface with an individual control and display in order to monitor and control a particular function. The results of this effort revealed that for certain operational sequences, individual component locations within a particular functional area often did not complement the flow path for the equipment being controlled. The resulting recommendations were to make the correlation between the flow path and the control panel devices more effective for the operator by panel component relocations.

A total of approximately 450 devices were evaluated for relocation.

5.2.1.4 Panel Arrangement Assessment

In assessing the components which should be relocated on the control panels, one or more of the following criteria supports moving the subject components. Figure 5.2-1 is an example of the evaluation sheet used and the criteria numbers below correspond to those in the figure.

1. Functional grouping of components within a common area or section.

2. Improved symmetry of demarcation boundaries for a functional group.

3. Left to right or top to bottom orientation for operational sequences.

4. Associated displays and controls in closer proximity.

5. Exact same relative location for identical controls and displays - Unit 2 to Unit 3.

6. Layout of redundant channels to be identical (not mirror image).

7. Adjacent location of displays which are compared to each other.

SONGS UNIT 2 AND 3 PANEL SECTION: CR-58, 50, 51 PRIMARY ENERGY

	ITEM NO	NOT CHGD	LOCATION TO WHICH MOVED	CRITERIA WHICH SUPPORTS MOVE 1	2	3	4	5	6	7	8	9	10	11	RESULTANT PHYSICAL CHANGE TO PANEL: CUT-OUT MODIFIED	CUT-OUT NEW	COVER REQ'D	NONE
1	6		8	X														X
2	7		6	X														X
3	8		7	X														X
4	11		2 Spaces Left of 11		X											X		
5	9		1 Space Left of 11		X											X	X	
6	10		11							X								X
7	32		5							X								X
8	5		10			X				X								X
9																		
10	3		32			X				X							X	
*11	443		409							X								X
*12	444		410							X							X	
13	401		403	X		X												X
14	403		401	X		X												X
15																		
*16	409		407			X	X			X								X
*17	410		654			X	X			X								X
18																		
19																		
20																		

NOTE: Short-term items are identified by (*)

Figure 5.2-1 RECOMMENDED COMPONENT RELOCATIONS (TYPICAL)

8. Most important and/or most frequently used displays and controls should be in the best viewing/use area.

9. Devices whose functions are duplicated by another device, which uses a more reliable format, should be removed and not relocated.

10. Devices should be relocated to local panels if their functions only pertain to local processes and controls.

11. Device whose relocation is dictated by another device relocation.

By comparing the P&IDs to the component arrangements on the control panel, alternate arrangements could be derived to represent the best compromise compared to the ideal rearrangement. This process is illustrated on the following sample sketch for Gland Steam. See figure 5.2-2.

It was not surprising that compromise was required in nearly every case. Frequently, the movement of one device would result in the requirement to move as many as a dozen additional devices. If each individual move is not evaluated for impact on a system basis, the correction of one problem could result in the creation of a dozen new ones. In addition, at some point, continued movement of components for optimization ceases to provide significant improvement in operational enhancement.

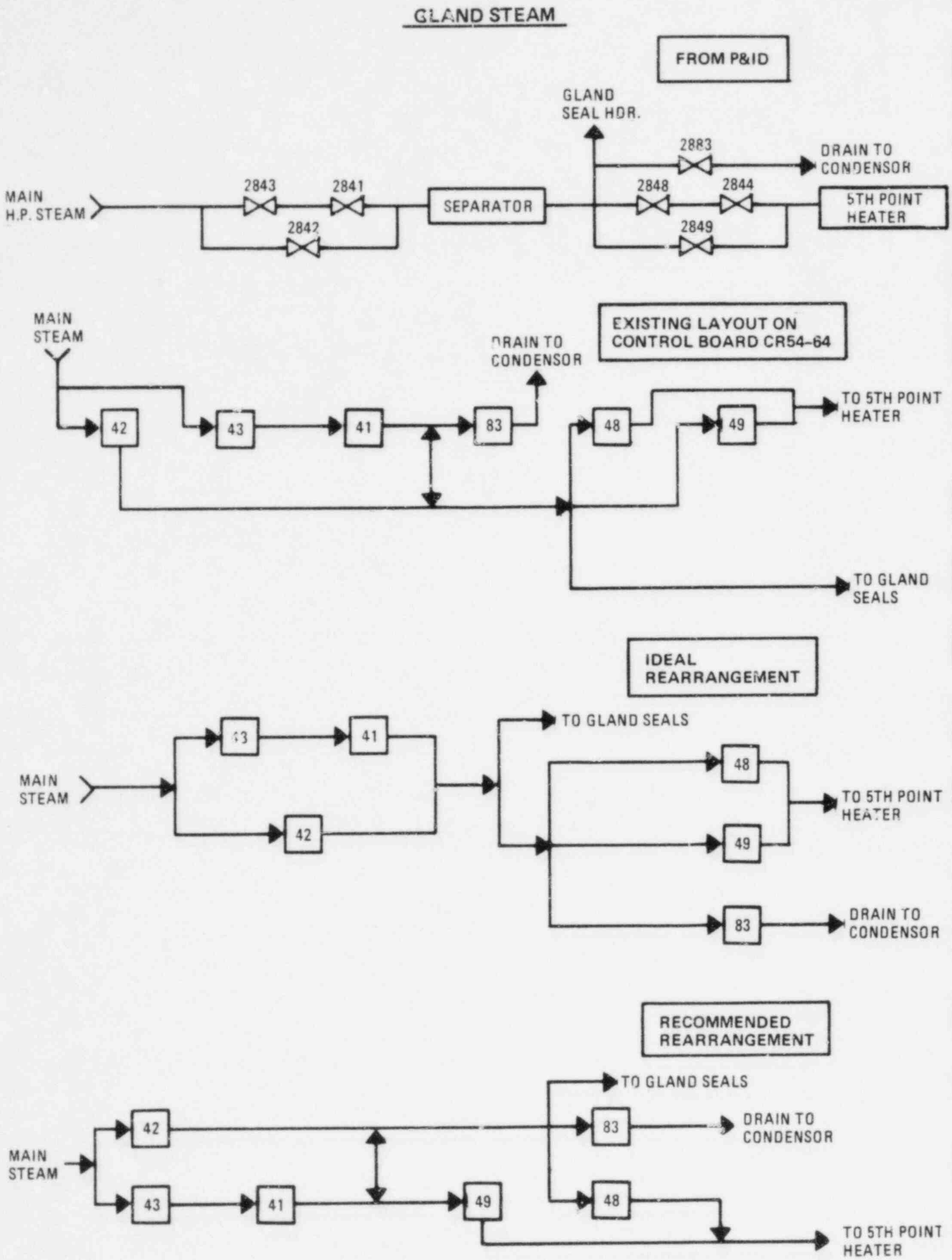

Figure 5.2-2 PANEL ARRANGEMENT ASSESSMENT, GLAND STEAM SYSTEM

The recommended relocations are, therefore, considered to be consistent with achieving the best possible control panel layouts utilizing the required components and present control panels.

However, while any given relocation can be considered to be feasible, the question remains as to whether approximately 450 relocations are, in fact, desirable to provide the appropriate operator enhancement. Beyond this, there is the question of whether change continues to be beneficial after familiarity through operating experience has been established.

Therefore, it was considered necessary to identify those relocation recommendations believed to be most contributive to enhanced safety for corrections prior to fuel load. If the answer to both of the following questions was "Yes" then the relocation recommendation was classified as a HED to be a short-term correction.

A. Was the HED associated with a safety-related system?

B. Was the HED one that would obviously (without a great deal of analysis) decrease the opportunity for the operator to effectively monitor and control the necessary safety system process parameters?

The balance of the relocations were then considered as long-term corrections requiring additional evaluation prior to recommending their relocation.

Additional relocations were assessed to determine if optimal arrangements could be made to improve operator movements in performing tasks.

To optimally rearrange the present panel to obtain straight lines of functional demarcation, massive movements of display instruments and controls were required. The assessment showed this could be accomplished without the movement of panel structural bracing.

Further optimization by providing added spacing between functional groups as well as improvements in component locations can be achieved with additional movement of display instruments and controls plus the movement of structural bracing within the panel.

Assessing these relative improvements of the additional spacing between functional groups could not justify the cost for panel structural bracing or massive movements of display instrumentation to provide minimal improvement in system demarcation and the incremental operator performance.

Further study has shown that due to the interdependence of certain systems, straight line functional demarcation could be operationally misleading. Careful consideration of these aspects resulted in CRDR Working Group acceptance of bold line demarcation utilizing straight line or grouped functions where there could be a safety concern. The remainder of the panels were functionally demarcated in accordance with the human factors consultant's recommendations described in subsection 5.2.2.

5.2.1.5 Panel Arrangement Recommendations

5.2.1.5.1 Short-Term Recommendations

The following is a summary of the recommended relocations grouped by panel number.

A. Engineered Safety Features Panel (CR-57)
Relocation of safety injection boric acid and containment purge instrumentation to provide for easier comparison of like sets of instrumentation. (33 moves, 7 new cutouts.)

B. Reactor Support Panel (CR-56)
Relocation of containment sump pump controls to an area underneath associated indicators. (2 moves, 2 new cutouts.)

C. Primary Energy Panel (CR-58, 50, 51)
Relocation of reactor coolant instrumentation to provide for easier comparison of like sets of instrumentation and eliminate a mirror image arrangement in the reactor regulating system. (15 moves, 1 new cutout.) See figure 5.2-3.

D. Secondary Energy Panel (CR-52, 53)
Rearrangement of main steam isolation controls, and auxiliary feedwater controls to achieve understandable and logical component arrangement. These relocations were also required as a result of the addition of a third auxiliary feedwater pump. (32 moves, 1 new sub panel section, plus 1 new cutout.)

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Relocation of auxiliary feedwater pump instruments to permit the operator to more readily determine that the auxiliary feedwater system is functioning properly. (4 moves, no new cutouts.)

Relocation of the steam generator level and pressure indicators to permit the operator to more readily determine the status of the steam generators. (9 moves, 8 new cutouts.)

E. Electrical Energy and Waste Heat Panel (CR-54, 64)
Relocation of the component cooling system controls and indicators to eliminate a channel A to B mirror image. Additionally, there was a movement of instrumentation to provide for easier comparison of like instruments (i.e., component cooling water heat exchanger temperature instruments.) (46 moves, 6 new cutouts, 9 modified cutouts.)

F. Emergency HV&AC (CR-60)
Relocation of heating, ventilating, and air conditioning controls to make Unit 2 and Unit 3 arrangements identical. (10 moves, 8 new cutouts.)

5.2.1.5.2 Long-Term Recommendations

There were approximately 300 long-term relocations which were initially identified for further evaluation. Further assessment has determined that implementation of any of the 300 long-term relocations will be done only if operating experience confirms that the current location is restrictive to operations.

As the plant operators gain experience, their familiarity with the various panel arrangements continues to increase. As a result, any future relocation of devices could have a negative effect on the operability of the plant and should be carefully evaluated with regards to its potential benefits.

5.2.2 Demarcation

5.2.2.1 Demarcation Criteria

To make clearly identifiable those functional groups of visual displays and control devices which provide for operability of a specific process function, the following demarcation criteria was developed:

- Each identified group should have a functionally oriented name.
- The group name should not violate accepted power industry practice, and the word "system" is considered understood and omitted.
- The group name should be included on a nameplate to clearly identify the group to which it applies.
- Where a group is a part of a larger group, the demarcation should be in a manner so as not to detract from readily identifying the larger of which it is a part.
- Visual displays and/or control devices not included in groups identified for demarcation should be given separate consideration for coding.

5.2.2.2 Demarcation Methodology

The methodology for defining the panel demarcation by identification of the functional groups of components was a two-step process. First each horseshoe panel section had a distinct orientation and hence inherent demarcation. Therefore, each was considered as an identified group, and the criteria were applied to each individual panel section. In this manner, a functionally oriented name assignment could be derived for each panel section. This was a result of the original design process which employed a full-scale mockup which was reviewed by SCE operating and engineering personnel.

Secondly, identification of functional groups within panel sections could be readily achieved for some panel sections by visual inspection of the panel section layouts.

For other panel sections, it was found that visual inspection was insufficient to achieve meaningful separation into functional groups. Therefore, a process flow diagram specific to each of these panel sections was developed as an aid to identifying the potential functional groups inherent within each of these panel sections. See figure 4.5-1 for a typical example.

These process flow diagrams were then used in conjunction with the panel section layout drawings to achieve definition of functional groups for demarcation.

In addition, Whitston Associates made a separate study to determine "how" to achieve the benefits of demarcation for the defined functional groups.

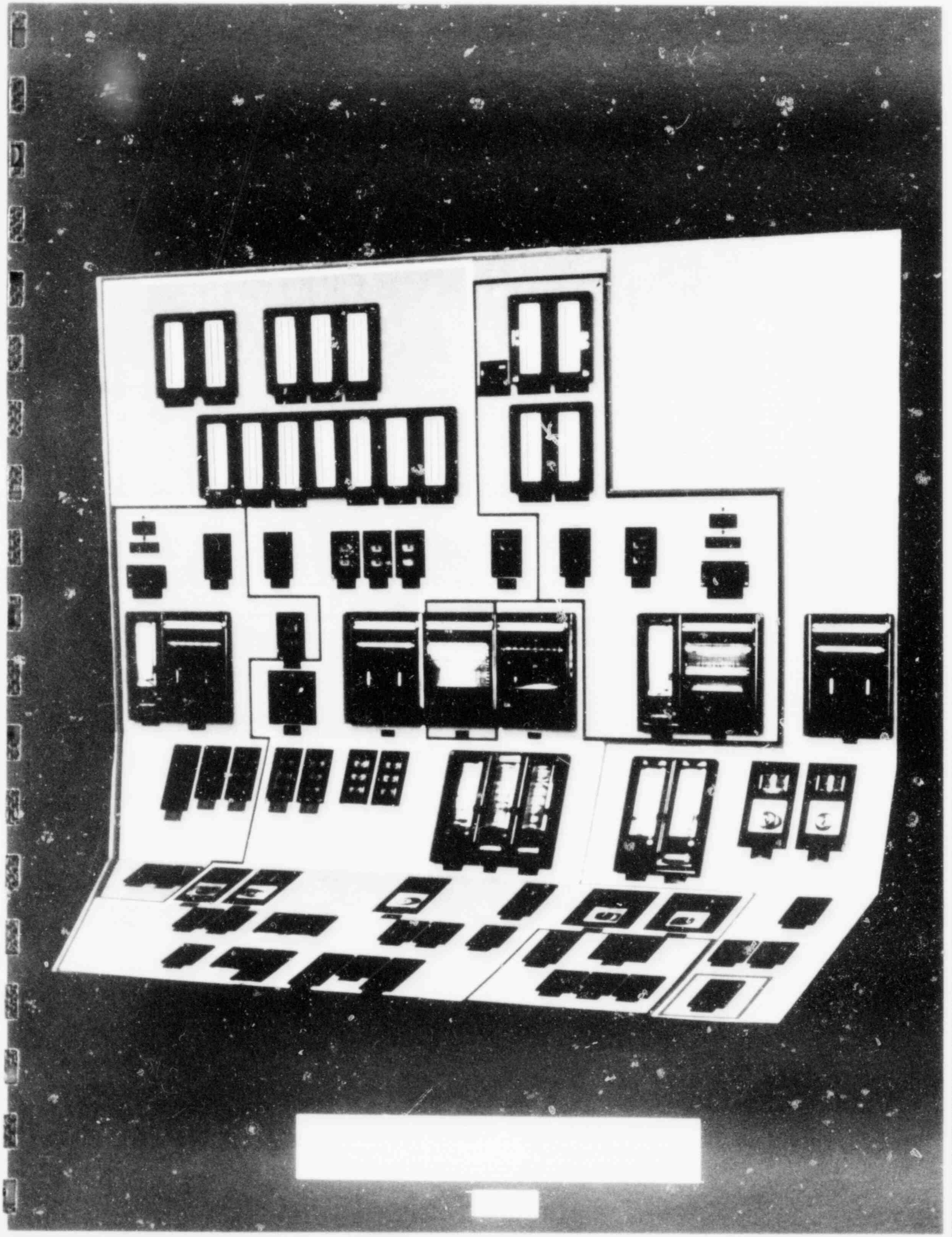
Four half-scale partial models of the Primary Energy Panel (CR-58, 50, 51) were fabricated and used to evaluate various schemes and demarcation techniques along with demonstration of hierarchical labeling. Four alternative control panel color schemes were proposed which differed from each other in the following six respects:

- Function demarcation approach
- Control and display bezel color
- Control and display nameplates
- Control panel background color
- Control/display arrangement
- Control panel titles

The four color schemes of the models are summarized as follows:

Color Scheme One: Original layout and existing background color with colored tape demarcation (figure 5.2-4),

Color Scheme Two: Original layout and existing background color with demarcation achieved by means of component bezel colors,



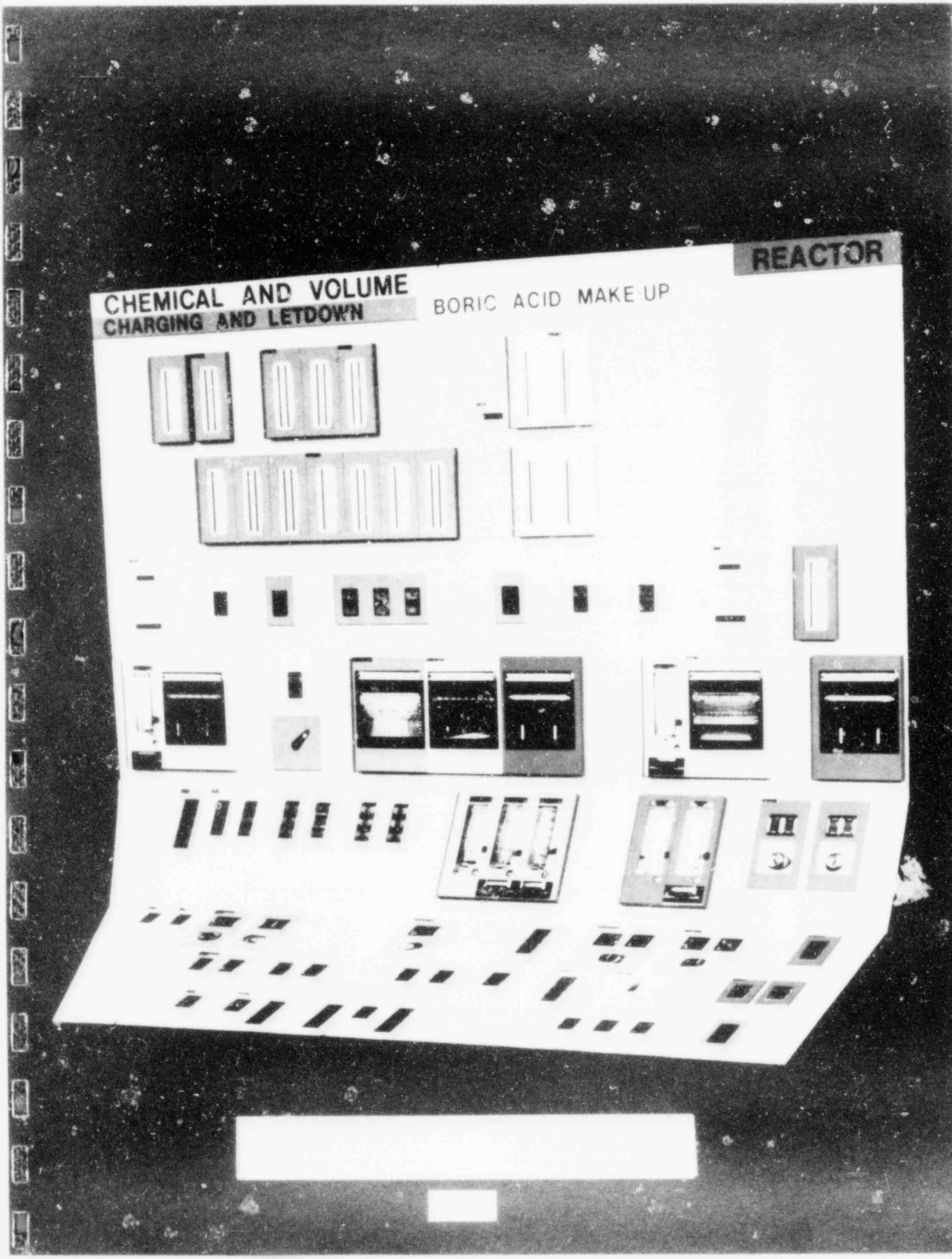
Color Scheme Three: Original layout with new background color and demarcation by means of component bezel colors modified to coordinate with the new background color (figure 5.2-5),

Color Scheme Four: Revised layout using the background and bezel colors included as a part of Color Scheme Three.

Color Schemes Two, Three, and Four also demonstrate the application of hierarchical labeling consistent with the defined functional groups.

Seven visual task variables defined below were selected to evaluate and rank the four proposed color schemes.

- o Luminance Contrast - difference in luminance of object compared to its background.
- o Illumination Type and Level - type of luminance and the level of light incident on a surface.
- o Coding - use of a particular color to convey information.
- o Esthetics - pleasantness derived from familiarity and personal experience of color patterns and combinations.


CHEMICAL AND VOLUME
CHARGING AND LETDOWN
BORIC ACID MAKE-UP
REACTOR

- Visual Noise - superfluous visual stimuli in performing visual tasks.

- Glare - sufficiently greater luminance in the field of view to which the eyes are not adapted.

- Shadows - decreased luminance caused by interception of light by opaque objects.

5.2.2.3 Demarcation Findings

The functional groups identified for demarcation within a panel section could not be effectively distinguished by use of lines except in the case of Reactor Support Panel (CR-56).

Identification of functional groups within panel sections could be readily achieved for panel sections CR-57, CR-56, CR-61, and CR-60 by visual inspection of the panel section layouts.

For panel sections CR-58, 50, 51, (figure 5.2-3) CR-52, 53, and CR-54, 64, it was found that visual inspection was insufficient to achieve meaningful separation into functional groups.

The Electrical Mimic Panel, CR-63, did not have hierarchical demarcation of systems and a different set of demarcation colors than the other panels.

Color Scheme One (figure 5.2-4), which used existing control and display bezels, nameplates, background color, arrangement, and titles, was found to have poor demarcation characteristics.

5.2.2.4 Demarcation Assessment

Using the demarcation criteria given in paragraph 5.2.2.1, demarcation by functional groups could be assessed for panel sections CR-57, CR-56, CR-58, 50, 51, CR-52, 53, CR-54, 64, CR-61, and CR-60.

To assess panel sections CR-58, 50, 51, CR-52, 53, and CR-54, 64, a process flow diagram specific to each of these three panel sections was required to identify functional groups inherent within each of these panel sections. See figures 4.5-1 and 5.2-6 for a typical example of the process flow diagram and functional description.

The decision for group definition was influenced by considerations of past practice, impact on panel section layout, the desirability of having approximately equal numbers of visual displays and control devices in each group, ability to clearly define the functions, and the ability to identify the means by which the functional status is determined.

The functional groups defined for demarcation were identified by panel section as shown in figure 5.2-7 using the same panel (CR-58, 50, 51) as a typical example. Given are the assigned names for each of the functional groups diagrammed to depict the hierarchy.

Figure 5.2-6

FUNCTIONAL DESCRIPTION

PRIMARY ENERGY

1. Chemical and Volume Control

   Charging and Letdown
   Function -- Maintain reactor coolant system inventory
   How Measured -- Pressurizer level

   Boric Acid
   Function -- Maintain proper boron concentration
   How Measured -- Boron Concentration

2. Reactor Coolant

   Function -- Heat Removal
   Maintain fluid system in proper state, i.e., pressure control
   How Measured -- Δ_t Inferred from T_h and T_c

3. Reactivity Control

   Function -- Control Heat Production
   How Measured -- Power Level
   Temperature

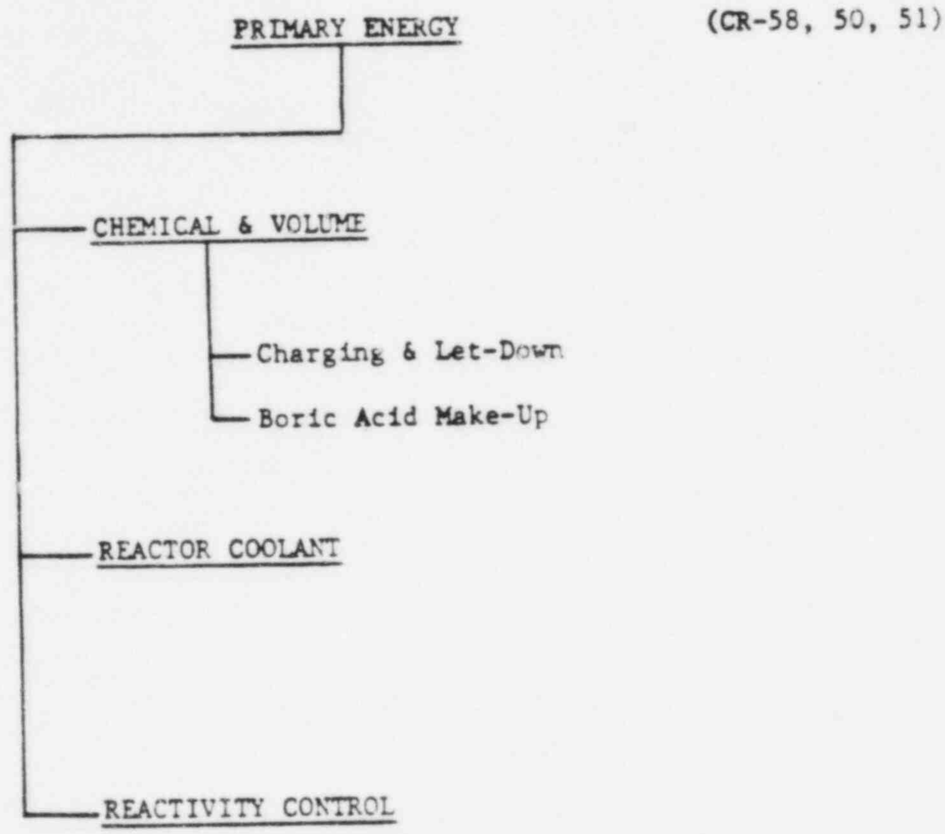


Figure 5.2-7 FUNCTIONAL GROUP DEMARCATION (TYPICAL) (CR-58, 50, 51)

The four color schemes were evaluated to yield the following results: Color Scheme Four attained the highest score, closely followed by Color Scheme Three (figure 5.2-5). Both schemes scored high in visual task variables such as coding and visual noise absence which are needed for quick, accurate discrimination of demarcated systems. Color Schemes Two and One were judged to be low in these variables. However, it was observed that there was an insignificant improvement from Color Scheme Three to Color Scheme Four for the variables required for demarcation. The complexity of implementing Color Scheme Four could not be justified by the slight incremental benefit that would be derived.

5.2.2.5 Demarcation Recommendations

Recommendations resulting from the assessment were to implement the following modifications prior to fuel load.

- o Demarcate the panel sections by functional groups showing the hierarchy developed during the review.

- o Demarcate control panels using Color Scheme Three.

5.2.3 Labeling

5.2.3.1 Labeling Criteria

The principal criterion in control panel labeling is to optimize the operator's ability to easily locate and identify the displays and controls within the control room. The labeling should be consistent and uniform from panel to panel throughout the control room. Identification of various systems and components should be achieved easily and quickly by the operators to guide them in sorting from the general to the specific within any panel. To assist the operator, the hierarchical labeling should be graduated in decreasing size from the system to the component level.

5.2.3.2 Labeling Methodology

The main effort of the CRDR Working Group was to develop a systematic approach for labeling the panels rather than evaluating the existing labeling for good human factors practices. To perform this task, the CRDR Working Group developed criteria to be used in providing a complete hierarchical approach to labeling the existing control panels. This hierarchy resulted in the following five discrete levels of identification to assist the operator in going from the general to the specific.

- Panel section
- System
- Subsystem
- Component group
- Component

5.2.3.3 Labeling Findings

A. Good Features

The review showed that the existing labels generally used good lettering and character size, and in general, the color contrast provided good readability.

The existing lamacoid labels utilized white lettering on a black background and channel or train associated components which have color-coded labels using a contrasting background (i.e., white on red, black on yellow, white on blue, and white on green). The use of colors to identify the channels and trains is a desirable feature.

B. Undesirable Features

The following is a listing of areas of the criteria that were not met with the existing labels:

- Use of hierarchical approach was inconsistent. For example, no effort was made to take advantage of component groupings serving a common function to provide a shared label with single identification of function.
- Most of the nameplates were mounted below the components. Preferred placement of component labels is above rather than below.
- Inconsistent and redundant information existed on nameplates and lens legends.

- Use of abbreviations was inconsistent.
- Some "Dymo" tape labeling was being used to augment operational instructions which is unsatisfactory for permanent labeling.
- Nameplate lettering and lens legend engraving were easily obscured by reflected light (glare) due to lamacoid material.
- Labels did not take into account component bezel thickness and were "shadowed" in some cases.
- Yellow coded labels with white lettering had poor readability.

5.2.3.4 Labeling Assessment

During the assessment phase, the following application criteria for labeling were developed to be used in correcting the existing findings of hierarchical labeling plus nameplate locations, size, shape, and lettering inconsistencies.

5.2.3.4.1 Hierarchical Labeling Nameplates and Locations

Each panel section should be labeled using the following guidelines as illustrated by figure 5.2-8.

Level 1: Panel section title nameplates should be located at the top portion above the annunciator window boxes of each major panel section. The title should represent the system(s) monitored and controlled from the specific panel section.

Level 2: System process nameplates should be located at the top of the vertical panel sections but under the annunciator window boxes.

Level 3: Subsystem process nameplates, if applicable, will be located under the system process nameplate.

Level 4: Process component group nameplates, where used, should be located above the related component nameplates.

Where possible, Level 4 nameplates will overlap the nameplates of related devices (Level 5) as an aid in identifying devices belonging to the same group.

Level 5: Component Nameplates, preferrably, will be located directly above the control, display, or other device.

5.2.3.4.2 Nameplate Characteristics

A. General

Nameplates should be rectangular in shape and oriented on the panels so that they are read from left to right. If the nameplate length is less than the width of the area to which it applies, it should be centered. Nameplate lettering may be centered or left-oriented on the nameplate. The approach chosen should be consistently applied.

LEVEL 1 - PANEL SECTION TITLE

LEVEL 2 - SYSTEM PROCESS

LEVEL 3 - SUBSYSTEM PROCESS (where applicable)

LEVEL 4 - PROCESS COMPONENT GROUPS (where applicable)

LEVEL 5 - COMPONENT

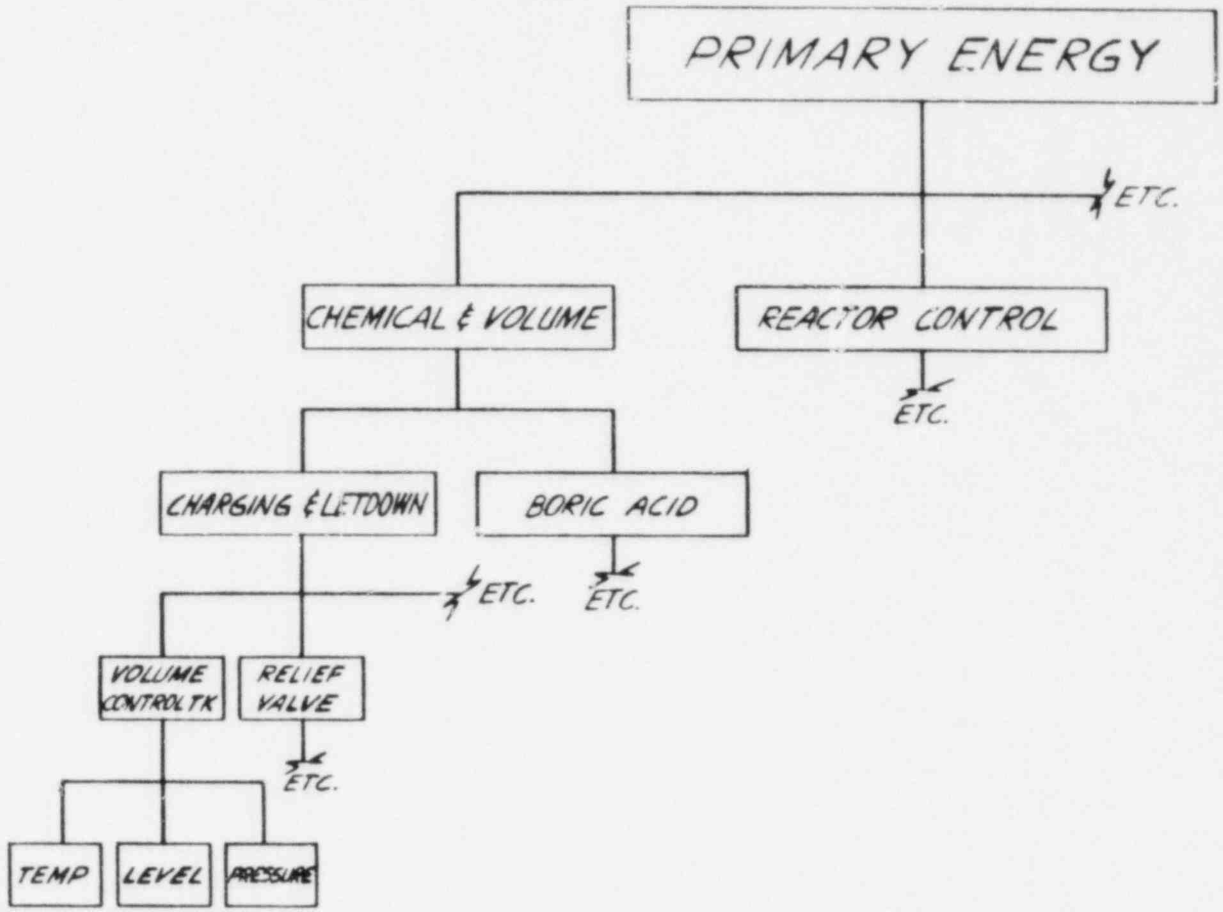


Figure 5.2-8 HIERARCHICAL NAMEPLATES (TYPICAL)

Nameplate size and nameplate letter size should vary according to hierarchical level. Within any given level, nameplates should be the same height. The largest size is assigned to level one (panel section title). Only capital letters designated "Helvetica Bold Condensed" should be used.

Component nameplates should be flush with the adjacent bezel surface. The nameplates should extend as far as, but not beyond, the extremities of the frame of the indicator, control, or other device.

Trade names on large vendor nameplates and other irrelevant information should not appear in the control room.

When unusual and/or critical operational control modes are required, special instructions will be placed on or adjacent to the control.

B. Panel/rack/console identification labels should not detract from the operational labeling.

C. Function labeling on vendor equipmpment (meters, recorders, etc.) will be legible. Vendor labeling duplicating the hierarchy described herein should be removed or made not visible to the operators during operations.

Nameplate material should be a non-glare plastic and be obtainable in the designated demarcation colors. Lamacoid plastic will not be used since it is not obtainable in required demarcation colors, not engravable in the required type of lettering and produces glare.

5.2.3.4.3 Nameplate Lines of Lettered Information

Lines of information will not exceed the following numbers:

Nameplate	Max. Lines of Info.	Character Size
Panel Section Title (Level-1)	1	1.5"
System Process (Level-2)	1	1"
Subsystem Processes (Level-3)	1	1/2"
Process Components Group (Level-4)	2	5/16"
Component (Level-5)	3*	1/8"

*5 for Dual Indicating Meters

Where applicable, nameplates for dual indicating meters, Level 5, will clearly identify each indicator scale by its related instrument "Tag Number".

5.2.3.4.4 Nameplate Content

A. The process component group nameplates, Level 4, should identify the equipment or process.

B. Nameplates for grouped components, Level 5, should only identify the displayed parameter or control function. Also, the instrument "Tag Number" shall be included. Below is a typical example.

DISCHARGE PRESSURE
2PI-4703

C. Nameplates for non-grouped components, Level 5, should identify the following:

- o Related equipment or process on the first line,
- o The displayed parameters or control functions on the second line, and
- o The instrument "Tag Number" on the third line.

5.2.3.4.5 <u>Lens Legend</u>

Lens legends for back-lighted pushbuttons and status indicators should contain not more than two lines of information on each lens. Where practical, the information should be limited to identify the control action or the status.

Lens legends for back-lighted push buttons and status indicators should be visible and legible whether or not the back-light is energized.

5.2.3.5 Labeling Recommendations

The conclusions reached from the assessment of control panel labeling were that the numerous labeling deficiencies and inconsistencies should be corrected in an orderly modification effort that includes the following actions.

- Implement a hierarchical system of labeling to the component level.

- Correct errors, inconsistencies, shadowing, and missing labels.

- Eliminate redundancy of information wherever possible.

- Relocate labels from present bottom locations to top of the components.

5.2.4 Scale Coding

5.2.4.1 Scale Coding Criteria

The following criteria contain those factors that, when properly applied to the face of scale indicators, will provide a means of facilitating the operator's role of verifying correct system performance. Information to be conveyed includes desirable operating range, dangerous operating range, cautions, undesirable and inefficient conditions.

- Normal ranges should be identified and coded by a marking scheme.

- Abnormal ranges should be identified and coded by a marking scheme.

- Meters having ranges with technical specification limits require a set point marker on the scale, capable of being repositioned upon removal of the meter lens.

- o Pump motor ammeters should have adjustable markers for indicating the most restrictive limit of motor and pump performance.

- o Dial gauges, should employ the same code marking scheme as required for the horizontal and vertical straight-scaled meters.

- o Where control is initiated automatically as a consequence of a variable limit (level, temperature, pressure) having been reached, the meter (for such measured variables) should have a marker capable of being repositioned upon removal of the instrument lens.

- o Recorders should employ, where practicable, the same code marking scheme for ranges as required for the horizontal and vertical straight-scaled meters.

- o Coding and markings must be applied in such a fashion that
  - the meter scales and parameter legends will not be obscured, and
  - parallax will be reduced to an acceptable level.

5.2.4.2 Scale Coding Methodology

The purpose of this review was to improve control panel operability by the coding of quantitative visual displays. This effort consisted of reviewing the various types of scales associated with panel mounted devices and preparation of applicable criteria for follow-on analysis and implementation.

In general, indicating and recording instruments need to be "customized" to reflect their application to the specific role they serve for the process function as defined by the P&ID. "Customizing" takes into account the identification of normal operating values, technical specification limits, or initiation of automatic control as applicable to devices displaying a quantitative value.

The means to achieve such "customizing" must be independently derived for each specific variation of manufacturers products used to display quantitative data. The approach used to distinguish normal operating range, technical specification limit and point of automatic control initiation should be similar among product variations. The physical design of the instrument will influence how best to achieve the needed contrast while avoiding clutter.

The examples made as a part of the scale coding criteria are intended to demonstrate the principles and offer suggestions as to the techniques that might be employed in implementing fixes for scale coding.

5.2.4.3 Scale Coding Findings

With the exception of some Sigma indicators, the analog indicator scales were generally without coding to indicate normal and abnormal operating ranges for the following types of instrument indicators:

- Linear fixed-scale meters
- Circular fixed-scale gages
- Recorders.

Also deficient was a means for indicating technical specification limits and points of automatic control initiation.

5.2.4.4 Scale Coding Assessment

In general, the lack of scale coding for meters, gages, and recorders was assessed during the NRC audit to be Category 2, moderate concern. Because only some Sigma indicators and some safety-related indicators with makeshift normal ranges had existing scale coding, it was concluded that there could be potential safety consequences or operator error due to these HEDs.

5.2.4.5 Scale Coding Recommendations

Based on the assessment, the CRDR Working Group recommended the implementation should be done in two stages.

In general, bar/band marking should be used to identify normal versus abnormal operating ranges, a red pointer for technical specification limits, and a black pointer for points of automatic control initiation.

A. Prior to Fuel Load

Add scale coding and set points in accordance with the applicable criteria included in subsection 5.2.4.1.

B. Prior to Commercial Operation

Correct scale coding based on operating results for determination of normal versus abnormal ranges and adjust automatic control initiation point as necessary.

5.2.5 <u>Component Suitability</u>

5.2.5.1 Component Suitability Criteria

Instruments and panel mounted visual display/control devices selected for control room utilization must be suitable for the operational use intended and the operational environment expected.

From an instrument suitability point of view, visual display/control devices should be consistent in their meaning and function in an acceptable and expected manner, i.e., "cultural responses". For example, switches performing a similar function should, in general, "look" the same and "feel" the same. Also, displays indicating identical pressure ranges and requiring the same degree of precision, should have identically graduated scales.

Visual display/control devices should perform to or fulfill generally accepted "cultural response" criteria such as the following.

- o Control devices which appear to be identical should have identical tactile sensed responses when activated.

- o For control devices which are (or appear to be) identical, their actuation procedure and their control response to actuation should be identical.

- o Controllers should produce a variable response directly proportional to a change in controller output: that is, not inversely proportional.

- o Priority alarm status conditions (red or yellow) should have the capability of being assessed immediately by operating personnel with direct verification by control room instrumentation.

- o Panel control devices should be readily distinguishable from visual display devices.

- o A form of coding (color or symbol) should be provided to distinguish between control devices for different types of equipment.

5.2.5.2 Component Suitability Methodology

Component deficiencies that appear to be not suitable when compared to "cultural responses" or standard human factors practices were identified during the control room survey. Several situations were identified, listed, and if required, criteria for correcting the descrepancies were developed.

5.2.5.3 Component Suitability Findings

A significant outcome of the component review of the CRDR was that no instruments were replaced because of unsuitability. This means that scale sizes were appropriate for their use, the proper type of instrument (indicator, recorder, controller, etc.) was available, and, with few exceptions, scale factors and ranges satisfied human factors criteria. However, there were six areas which were investigated to determine if they could be potential problems.

A. Nearly all pushbuttons exhibit a snap-into-position when pressed and a second snap to the restored position when released. However, there are a few which snap when pressed but not when released. The difference in feel can be misleading to the operator causing distraction and introducing concern as to possible malfunction.

B. In nearly all cases, the function controlled by a pushbutton carries through to completion automatically once the pushbutton is momentarily depressed. However, an exception is the auxiliary feedwater valve which moves only when the pushbutton is maintained in the depressed position.

C. The orientation of control systems design to the process is to provide for proportional response in a direct acting mode when possible. However, there are cases which, of necessity, result in an inversely proportional response. A typical example is that of back-pressure controllers wherein an increase in controller output signal opens the control valve which in turn causes the back pressure to decrease.

D. Annunciator alarms designated as having priority status, (red or yellow) by definition require immediate operator response. Yet, there are 89 priority alarms which cannot be directly verified by instrumentation provided in the control room.

E. Differentiation between Master Specialties control pushbuttons and status indicators is accomplished by use of narrow black bars on each side of the indicator. This present means of providing distinguishing coding may be overlooked by the operators.

F. Aside from the device legend, there is no distinction between control pushbuttons which start or stop motor-driven equipment and pushbuttons which open or close valves.

5.2.5.4 Component Suitability Assessment

In assessing these component suitability HEDs, any proposed modifications or improvements had to be evaluated for positive gain versus deleterious effects on other aspects of human factor engineering.

A. Dependent on the switch action, e.g., a momentary contact versus a maintained contact type, a different tactile response recognition is acquired by the user. As the result of the operator's training, conditioning, and familiarity with these few switches, susequent evaluation did not indicate the need to modify them.

B. For those pushbuttons controlling the auxiliary feedwater valve, the requirement for modulating the valve is the overriding consideration and all operators are aware of this requirement.

C. The assessment of controllers with inversely proportional outputs resulted in recommending that special instructions in accordance with labeling criteria in paragraph 5.2.3.4.2 be provided.

D. The annunciator warning system review had identified 89 priority alarms that could not be verified in the control room. By definition these alarms should be verifiable in the control room. However, subsequent review has determined that none of these alarms have any safety consequence potential and for the most part they merely affect the efficiency of the plant.

Since control room indication does not provide for direct verification, the operators approach should be to:

- o Employ assistance of the roving operating personnel to provide direct verification.
- o Interrogate available readings for data which infers the existence of the conditions.

Operations personnel have been made aware, through procedural guides, of the need to implement these less direct methods of assessment. Based on this, no modification of these alarms is required.

E. An assessment of the panel control devices and visual display devices resulted in the determination that the black bars on the Master Specialties pushbuttons were adequate in distinguishing between the two devices for a trained operator who, in addition, had become accustomed to using them in actual operations.

F. In assessing if a form of coding to distinguish between actuation of different equipment would be beneficial, it was felt that implementing additional color or symbol coding could increase visual noise or clutter on the control room panels. It was concluded that the improved hierarchical labeling with its simplified labels at the component level (fifth level) would best serve to assist the operator in recognizing the type of equipment which is controlled by a particular switch.

5.2.5.5 Component Suitability Recommendations

Based on the preceding assessments, the HEDs related to component suitability are acceptable as is, and that human factors requirements are satisfied without modifications. Also, since operating familiarity had been established with the existing components, it was felt with that additional changes would not be beneficial.

5.2.6 Annunciator/Alarm System

5.2.6.1 Annunciator/Alarm System Description

The original annunciator system was a unitized system with approximately 1,250 windows in use for Unit 2 and common and approximately 900 windows in use for Unit 3.

The annunciator system employs contacts which are closed in the normal process condition and which open to alarm. At the time of the CRDR, the existing basic functional sequence operated as follows:

- A field contact opened to initiate an alarm which is signaled by its flashing window and an audible chime.

- The operator could silence the chime from any annunciator control station "Silence" switchlight.

- The operator could convert the flashing window to a "steady on" condition by operating the "Acknowledge" switchlight of the annunciator control station at the same control panel section as the box containing the alarm window.

- When the alarm contact returned to normal (closed), there was no indication of status change. (There was no "Ringback" feature.)

- o Periodically, the operator could check to see if any of the existing alarms in a control panel section had returned to normal by depressing the "Reset" switchlight of the annunciator control station in the same control panel section as the alarm window. Following a return to normal, the alarm window would go dark when its "Reset" switchlight was depressed.

- o Each unit's annunciator system had two master control switchlight stations, each with a "Silence", "Acknowledge", and "Reset" pushbutton. Any window in a unit's annunciator system could be controlled from that unit's master station.

The annunciator system has no "first-out" feature. This function is provided, as required, by the unit's plant computer sequence-of-events capability. The annunciator system has reflash capability (ability to annunciate subsequent alarms on a single window) on approximately 17 percent of its windows.

5.2.6.2 Annunciator/Alarm System Criteria

There are several basic human factors criteria for annunicator/alarm systems to improve operability by the operator.

- o Annunciator windows should identify various priorities of operator response.

- The switchlight control stations should only control annunciator lights in their immediate vicinity.

- All status changes, e.g., return to normal, should be indicated.

- Annunciator windows should not be ambiguous and should have a means to differentiate and verify multiple input alarms.

- Annunciator windows should be arranged with respect to each other to reflect functionally related groups, vertical relationships to other functionally related visual displays, and groups related to coding priority.

5.2.6.3 Annunciator/Alarm System Methodology

The review process involved the evaluation of individual alarm windows to assign a priority classification, briefly stated below, to each alarm window based on priority application criteria developed during the review.

- All alarm windows were first classified as (1) priority, or (2) low-priority in accordance with the application criteria.
- Priority alarms were then classified as (1) system-oriented or (2) equipment-oriented in accordance with the criteria.

- Low-priority alarms were classified as to whether verification and assessment would take place (1) within the control room, or (2) outside the control room, in accordance with the criteria.

Also reviewed were the suitability of relative window locations within each box and whether a window had been assigned to the appropriate window box.

5.2.6.4 Annunciator/Alarm System Findings

The review of the annunciator/alarm systems revealed both good features and potential HEDs.

5.2.6.4.1 Good Features

- Abbreviations used were quite consistent and, in general, were used only when space limitations in the message engraving required it. Readability at a distance was excellent.
- Specific alarm windows were located in a window box in the panel section containing the related controls required to initiate corrective action and, in most cases, directly over the related subsystems.
- Panel design and window box locations permitted visual observation of all alarms by the operator from any location within the central control room area.

5.2.6.4.2 Potential Problem Areas or HEDs

- No means existed to identify the relative importance (prioritization) of individual alarms competing for the operator's attention.

- Alarms were randomly located throughout the individual window boxes. (More consistency in relative locations of related alarms could be employed.)

- Two master "Acknowledge" and two master "Reset" switchlights existed which contributed to the possibility of the operator's missing a simultaneous alarm status change in another window box.

- Quantity of windows may be excessive.

- Annunciator control switchlights were not easily distinguishable from other switchlights.

- No means existed to identify multiple input windows or to differentiate multiple windows with and without reflash capability.

- There was no indication on the window showing a Plant Monitoring System (PMS) interface where additional time-related hard copy information might be available to the operator.

- o There appeared to be inconsistent use of the multiple, with and without reflash, inputs and retransmissions to the PMS.

- o The annunciator list is a living document that is incomplete and there were inconsistencies with P&IDs, elementary diagrams, and alarm response procedures.

5.2.6.5 Annunciator/Alarm System Assessment

5.2.6.5.1 <u>Alarm Window Prioritization and Associated Color Coding.</u> During the evaluation of the annunciator/alarm system, criteria were applied to each alarm window to determine its priority. Red, yellow, blue, or white color coding was recommended for each window based upon its priority classification. The criteria applied is as follows:

A. A priority classification (Priority 1 or 2) was given to status alarm windows indicative of a condition which requires operator intervention and may require the operator to:

1. Interrupt other activity
2. Analyze the extent and rate of change of process degradation
3. Take corrective action as necessary to stabilize, and if possible, restore the process.

B. A low-priority classification (Priority 3 or 4) was given to status alarm windows indicative of a condition which introduces some degree of constraint to total systems capability but does not, in itself, introduce process degradation. The operator response is:

1. Assess the degree to which the constraint is a limit to present and projected process operation.
2. If applicable, take action to alleviate the constraint.
3. If the constraint will necessarily continue for some period of time, allow for it as a part of planning for continued process operation.

C. All status alarm windows were classified as priority or low-priority in accordance with criteria stated in A and B, above.

D. All priority alarm windows were categorized as systems priority or equipment priority alarms in accordance with criteria stated in F and G, below.

E. All low-priority alarm windows were categorized as control room assessment low-priority alarms, or delegated assessment low-priority alarms in accordance with criteria stated in H and I, below.

F. System Priority Alarms (Red - Priority 1)

Red alarms are those priority alarms indicative of a degradation to systems functional capability sufficient to challenge safety, unit availability, or the acceptable performance of a major system.

G. Equipment Priority Alarms (Yellow - Priority 2)

Yellow alarms are those priority alarms indicative of degradation to equipment functional capability sufficient to introduce the potential for, and, in some cases, high probability of a resulting system priority alarm.

H. Control Room Assessment - Low-Priority Alarms (White - Priority 3)

White alarms are those low-priority alarms for which the condition can be verified and assessed from visual displays within the control room.

I. Delegated Assessment - Low-Priority Alarms (Blue - Priority 4)

Blue alarms are those low-priority alarms for which there are no control room visual displays available to verify and assess the alarmed condition. The control room operator must, therefore, delegate to operating personnel outside the control room the responsibility for condition verification and assessment which is then to be conveyed back to the control room operator.

J. Although a number of low-priority alarm conditions are available for verification through the PMS Computer CRT, the CRT is not considered to be a viable means for alarm verification in and of itself since time required for access and display may be imcompatible with need depending upon operating conditions.

5.2.6.5.2 Alarm Window Rearrangement. In evaluating the arrangement of the windows in the annunciator system, the following criteria were applied to assess if operability could be improved by rearranging the windows with respect to each other to reflect functionally related groups, vertical relationship to other functionally related visual displays, and groups related to color coding priority.

A. Annunciator windows associated with a functional group identified for demarcation should be located within an area vertically above the associated visual displays and control devices.

B. If the number of windows associated with a function exceed the capacity of window box or the space available in a box after accommodating some other function(s), the remaining windows should be located in the adjacent box on the same panel section such that they are not separated beyond the unavoidable distance between boxes.

C. Within each functional group, red and yellow windows should be located in the higher portions of the box unless in conflict with criterion D below.

D. When a functional group has equipment priority (yellow) windows together with a system priority (red) window, the equipment priority windows should be located directly below the system priority window.

E. White windows for a process function should be in the same relative positions as their associated controls and indicators.

F. Relative locations of identical windows within redundant subsystems should be identical.

The overall assessment of the annunciator windows revealed that in general the alarms meet the above criteria and consequently no windows are required to be moved.

5.2.6.5.3 Master Switchlights

The evaluation of the two annunciator master "Acknowledge" and "Reset" control switchlights determined that a possibility existed for an operator to miss an additional alarm simultaneously occurring in another panel section. In addition, an annunciator master indicating light mimic should be added to a centrally located panel to preclude the possibility of operators missing simultaneously occurring alarms.

5.2.6.5.4 Other Assessments

Review of the quantity of annunciator windows indicated that the number is approximately equivalent to similar sized plants. In addition, any reduction in the quantity could result in an increase of multiple input windows.

The problem of the annunciator control switchlights not being easily distinguishable from other switchlights should be resolved by color demarcation per subsection 5.2.2.

Inconsistencies between the annunciator list and other engineering documents will be resolved as the details of the plant design are completed.

A review concentrating mainly in the area of multiple input windows, with and without reflash capability, and retransmission of the alarms to the PMS was performed to determine the extent and the necessity of modifying these alarms. Subsequently, an extensive effort by a task group was undertaken to reduce the number of nuisance alarms. As a result of this effort, many multiple inputs which were ambiguous have been eliminated. Additionally, operational experience has not concluded that identifying those alarms retransmitted to the PMS will be beneficial to operators.

5.2.6.6 Annunciator/Alarm System Recommendations

As the result of the assessment, the following recommendations were proposed:

5.2.6.6.1 <u>Short Term Recommendations</u>

A. Prioritize individual windows in each box by color, as follows:

   - o Red - Priority 1 Alarms - indicative of a degradation to system functional capability sufficient to challenge safety, unit availability, or the acceptable performance of a major system.

   - o Yellow - Priority 2 Alarms - indicative of a degradation to equipment functional capability sufficient to introduce the potential for and, in some cases, high probability of a Priority 1 alarm.

   - o White - Priority 3 Alarms (Low-Priority) - indicative of an operating constraint for which the condition can be verified and assessed from visual displays within the control room.

   - o Blue - Priority 4 Alarms (Low-priority) -indicative of an operating constraint for which there are no control room visual displays available to verify and assess the alarmed condition.

   Refer to figure 5.2-9 for a typical annunciator functional group color coded per the above criteria.

2-7/8

2-5/8

SIAS ACTUATION TRAIN A 1	CIAS ACTUATION TRAIN A 2	CSAS ACTUATION TRAIN A 3	MSIS ACTUATION TRAIN A 4	EFAS 1 ACTUATION TRAIN A 5	EFAS 2 ACTUATION TRAIN A 6	CCAS ACTUATION TRAIN A 7	RAS ACTUATION TRAIN A 8	SAFETY INJ TANK T007 (SW) LEVEL HI-HI/LO-LO 9	SAFETY INJ TANK T009 (NW) LEVEL HI-HI/LO-LO 10
CHEM STORAGE TANK LEVEL HI/LO 11	CHEM STORAGE TANK PRESS HI/LO 12	CHEM STORAGE TANK TEMP HI/LO 13	SHUT ON EQUIP TRANS SW IN LOCAL TRAIN A 14	CONTAINMENT EMERGENCY SUMP LEVEL HI 15	REFUELING WATER TANK T006 (W) LEVEL LO 16	17	LOOP 2 HOT LEG INJ CHECK VALVE LEAKAGE PRESS HI 18	SAFETY INJ TANK T007 (SW) PRESSURE HI-HI/LO-LO 19	SAFETY INJ TANK T009 (NW) PRESSURE HI-HI/LO-LO 20
SAFETY INJ PUMPS TRAIN A OC/GND 21	LPSI PUMP P015 (SW) OVERRIDE 22	CONTAINMENT SPRAY PUMP P012 (S) OC/GND 23	SPRAY CHEM ADD PUMP P020 OVERRIDE 24	CNTMT EMER SUMP OUTLET VV 2HV-9303 OVERRIDE 25	ANNUNCIATOR GROUND 26	PZR PRESS ABOVE SETPNT 2HV-9339 NOT CLOSED 27	PZR PRESS ABOVE SETPNT 2HV-9337 NOT CLOSED 28	SAFETY INJ TANK T007 (SW) LEVEL HI/LO 29	SAFETY INJ TANK T009 (NW) LEVEL HI/LO 30
HPSI PUMP P017 (E) OVERRIDE 31	HPSI PUMP P018 (W) OVERRIDE TRAIN A 32	CONTAINMENT SPRAY PUMP P012 (S) OVERRIDE 33	SPRAY CHEM ADDITION VALVE OVERRIDE 34	CNTMT SPRAY HEADER ISO VV 2HV-9367 OVERRIDE 35	REFUELING WATER TANK T006 TEMP LO 36	ESSENTIAL CNTMT ISO VALVES OVERRIDE 37	PSR PRESS ABOVE 700 PSI TKS T007/T009 BELOW 600 38	SAFETY INJ TANK T007 (SW) PRESSURE HI/LO 39	SAFETY INJ TANK T009 (NW) PRESSURE HI/LO 40
HPSI TO LOOP 1A (SE) VV 2HV-9324 OVERRIDE 41	HPSI TO LOOP 1B (SW) VV 2HV-9327 OVERRIDE 42	HPSI TO LOOP 2A (NW) VV 2HV-9330 OVERRIDE 43	HPSI TO LOOP 2B (NE) VV 2HV-9333 OVERRIDE 44	LPSI TO LOOP 1B (SW) VV 2HV-9325 OVERRIDE 45	LPSI TO LOOP 2A (NW) VV 2HV-9328 OVERRIDE 46	PZR PRESS ABOVE SETPNT 2HV-9360 NOT OPEN 47	PZR PRESS ABOVE SETPNT 2HV-9350 NOT OPEN 48	SAFETY INJ TANK T007 (SW) PRESSURE LO-LO 49	SAFETY INJ TANK T009 (NW) PRESSURE LO-LO 50
SAFETY INJ SYSTEM TRAIN A INOPERABLE 51	CONTAINMENT SPRAY SYSTEM TRN A INOPERABLE 52	CONTAINMENT ISOLATION SYSTEM TRN A INOPERABLE 53	RECIRCULATION SYSTEM TRAIN A INOPERABLE 54	STANDBY POWER SYSTEM TRAIN A INOPERABLE 55	CONTAINMENT COOLING SYSTEM TRN A INOPERABLE 56	MAIN STEAM ISOLATION SYSTEM TRN A INOPERABLE 57	EMERGENCY FEEDWATER SYSTEM TRN A INOPERABLE 58	LOOP 1B SAFETY INJ CHECK VV LKG PRESS HI 59	LOOP 2A SAFETY INJ CHECK VV LKG PRESS HI 60

PRIORITY 1 ALARMS

PRIORITY 2 ALARMS

PRIORITY 3 ALARMS

PRIORITY 4 ALARMS

Figure 5.2-9 ANNUNCIATOR WINDOW ENGRAVING WINDOW CABINET NO. 2UA-0057A (TYPICAL)

B. Delete the two annunciator master "Acknowledge" and "Reset" control switchlights (per unit) to keep the operator from missing an additional alarm simultaneously occurring in another control panel section. The master "Silence" capability is to be retained.

C. Add a master indicating light mimic array on the center section of the main control panel to identify and direct operator attention to the control panel section with the newly activated alarm.

5.2.6.6.2 Long Term Recommendations

A. Revise the annunciator internal circuitry to provide "ringback" feature to notify the operator when an alarm has returned to normal. Limit the ringback audible feature to a two-second duration.

B. Annunciator window messages should be reviewed by Engineering for clarity and for consistency and acceptability of abbreviations.

C. Complete upgrading the information on elementary wiring diagrams, P&IDs, alarm response procedures, and annunciator lists to provide missing information and eliminate inconsistencies.

5.2.7 Color Usage

5.2.7.1 Color Usage Criteria

Control room design makes use of color to provide coding and to aid in providing an effective work environment.

Furthermore, the use of color as a part of coding needs to be added for demarcation, annunciator prioritization, and normal operating range, specification limit, or point of automatic control initiation as applicable to the scales for quantitative measurements. These usages have been discussed in subsections 5.2.2, 5.2.3, and 5.2.4.

When used as a part of coding, the intent of color is to aid pattern recognition wherein items sharing a commonality of purpose, use, function, status, meaning, etc., are thereby associated together.

In the power industry, red and green have come to be associated with status meanings:

Red - In-service or valve open
Green - Not In Service or valve closed

In addition, red generally has been used for the following meanings:

Red - Out of limits, emergency, danger, priority.

Other common color color meanings are:

Yellow - Caution or ready for automatic use.
Blue - Ready for manual use.

San Onofre 2 and 3 makes use of red, green, yellow, and blue for all of the above meanings. In addition, these colors are used to provide component assignments to safety channels.

The second aspect of color usage is to provide a work environment that allows the operators to perform visual tasks quickly and accurately with a minimum of visual fatigue. In order to perform these visual tasks without errors, seven variables, described in paragraph 5.2.2.2, can affect the operators' performance.

5.2.7.2 Color Usage Methodology

Due to the complex interrelationships, a separate study was ordered undertaken by Whitston Associates to evaluate the overall color coding effect on control panels. Four half-scale partial models of the Primary Energy Panel (CR-58, 50, 51) were fabricated and used to evaluate various schemes and demarcation techniques along with demonstration of hierarchical labeling. Four alternative control panel color schemes were proposed which differed from each other in the six respects which are listed in paragraph 5.2.2.2.

To rank the four proposed color schemes, seven visual task variables defined in paragraph 5.2.2.2 were selected to evaluate and rank the schemes.

5.2.7.3 Color Usage Findings

There were no HEDs identifed for color usage of equipment coding status as described by the criteria in paragraph 5.2.7.1.

The Color Scheme One, which used original control and display bezels, nameplates, background color, arrangement, and titles, was judged to be unacceptable. Color Scheme Two using some original features such as background color and arrangement was also unacceptable. For Color Schemes Three and Four, those visual task variables which tend to decrease operator's fatigue and provide an effective work environment, e.g., esthetics and absence of visual noise, glare and shadows, had significantly higher scores than Color Schemes One and Two.

In summary, the original panel paint colors, materials, and combinations of these were judged to be an inadequate use of color in the effective performing of visual tasks.

5.2.7.4 Color Usage Assessment

The four proposed alternative control panel color schemes were evaluated by assigning scores from one to ten to each of the seven visual task variables. An overall score for each of the four color schemes was obtained using weighted values for each of the seven variables. Color Scheme Four attained the highest score, closely followed by Color Scheme Three. Both were judged to be conducive to successful visual task performance. A sizeable gap separated Color Scheme Three from Color Schemes Two and One, which were judged to be unacceptable.

The evaluation indicated a small increment of improvement from Color Scheme Three and Four which could not be justified by the large additional expense involved with implementing Color Scheme Four.

5.2.7.5 Color Usage Recommendations

Based on the evaluation of the color consultant study, it was recommended that Color Scheme Three be implemented prior to fuel load. Refer to subsection 6.2.7 for implementation of this recommendation.

5.2.8 Miscellaneous Related Items

The following items were considered to have relevance to the man/machine interface and, therefore, were surveyed for compliance with human factors criteria during the CRDR.

5.2.8.1 Guard Rails for Operating Panels

5.2.8.1.1 Methodology. The survey reviewed the design change of adding guard rails to the operating panels to determine what human factors benefits would be gained.

5.2.8.1.2 Assessment of Guard Rail on the Operating Panels. In their assessment, the CRDR Working Group concluded that the addition of a guard rail on the operating panel would provide the following benefits:

- A barrier structure to prevent visiting personnel from leaning or resting on the control surfaces,

- A work surface by accommodating a properly designed clip board for use in conjunction with operating instructions, maintenance data, etc., which might otherwise be placed on the control surface,

- Further minimize the chance of inadvertent controls activation.

5.2.8.1.3 Recommendation for Guard Rail. It was recommended that a guard rail approximately 1 in. OD, of ribbed tubular chrome or stainless steel, extending approximately 6 inches from the control surface of the operating panels be installed on the panels prior to fuel load.

5.2.8.2 Dislocation of Control Feedback

5.2.8.2.1 Criteria and Methodology. For components which were functionally located correctly to best accommodate normal operating requirements, dislocation of control feedback components required for execution of a particular instruction were identified and reviewed for acceptability.

5.2.8.2.2 Finding Regarding a Dislocated Control Feedback. A review of operating instruction S023-3-2.1 revealed the need for adjustment of component cooling water flow control valve TV0223 to increase the rate of flow of component cooling water a finite amount. Component cooling water flowrate indicators FI6243 or FI6248 are located on the Waste Heat Panel Section while the control station for valve TV0223 is located one and one-half panel sections to the left on the Primary Energy panel.

5.2.8.2.3 Assessment of the Dislocated Control Feedback. The magnitude and acceptability of such dislocated control feedback was evaluated as a part of the "walk through" of operating instructions by the CRDR Working Group.

5.2.8.2.4 Recommendation for Correction of the Dislocated Control Feedback. The recommendation resulting from the "walk through" assessment of the operating instructions was to leave the indicators and the valve control in their present locations. (See section 5.6.1)

5.2.8.3 Use of Indicating Graphics Panel

5.2.8.3.1 Criteria for Indicating Graphics Panels. The use of indicating graphics panels for systems such as NSSS, CCW Loops, etc., should improve the operators performance and effectiveness in controlling the plant under all conditions. Any mimic arrangement should be similar to the Electrical Panel (CR-63).

5.2.8.3.2 Methodology for Indicating Graphics Panels. The CRDR Working Group evaluated the extended use of mimic, or graphics arrangements and markings on the panels in the control room.

The evaluation addressed the subject on a system and subsystem basis from the standpoint of improving the operators ability to control the plant under all conditions. Each system was reviewed with respect to the instruments used (recorders, indicators, controllers, status lights, and switches) and their locations on the panel as well as the operators' use of the instruments in the system.

5.2.8.3.3 Findings for Indicating Graphics Panels.

As a result of this review, it was found that some systems might benefit from a mimic arrangement to assist the operator.

A separate review of the Electrical Mimic Panel (CR-63) found several HEDs including widths of mimic lines, their color, use of symbols and the placement of symbols.

5.2.8.3.4 Assessment of Indicating Graphics Panels.

It was concluded that a mimic would be of marginal benefit to the the operator in most of these systems because of the recommendation to relocate instruments in addition to employing color for system demarcation. Furthermore, extensive modifications to the panels and replacement of some instruments with different types would be required to implement a mimic arrangement. In other systems it was concluded that because of varying operating modes, the use of a mimic could add significantly to operator confusion during the stress of an emergency situation.

It should be noted that as a part of post TMI requirements, a Critical Functions Monitoring System (CFMS) was implemented and includes extensive use of graphics on CRTs as an operator and engineering tool to evaluate and respond to emergency conditions. These graphics provide a much greater benefit to the operator than changes to the panels would accomplish.

For the Electrical Mimic Panel (CR-63), the evaluation concluded that some modifications should be implemented.

5.2.8.3.5 Recommendations for Indicating Graphics Panels. For the reasons given in the assessment, the CRDR Working Group recommended no additional use of mimics or graphics on the control panels in the main control room area except for those identified on the Electrical Mimic Panel (CR-63).

5.2.8.4 Valve Position Feedback

5.2.8.4.1 Criteria for Valve Position Feedback. Positive indication requires that control room indication of a valve open or closed position be unambiguous so that the operator is not confused about the valve status. The signal source for the indication should be derived from the valve stem position by means of limit switches, reed switches, or acoustic sensors associated with the flow path.

A review of various regulating documents (Reg. Guide 1.97, NUREG-694, NUREG-660, NUREG-712, etc.) broadly implies a requirement for furnishing position indication (positive indication or direct indication) of the following categories of valves:

- Containment Isolation Valves except check valves.
- Primary System Safety Relief Valves.
- Accumulator Isolation Valves.
- Main Steam Relief Valves.
- Reactor Coolant System Vents.
- Other valves actuated by safety signals.
- Other safety-related valves not actuated by safety signals.

5.2.8.4.2 Methodology for Valve Position Feedback. Safety-related valves (excluding check valves and manually-operated valves) were reviewed for their positive or direct indication in the control room. Valves to be reviewed were compiled on the basis of the project criteria, design documents such as P&IDs, elementary diagrams, vendor diagrams, specifications, instrument index, FSAR, data sheets, and DCPs.

5.2.8.4.3 Findings of Valve Position Feedback. Most of the valves reviewed have positive indication in the control room or acoustic pickup of signals with control room annunciation. The position indication (positive indication or direct indication) is furnished for the following categories of the valves (manually-operated valves are excluded):

- Containment isolation, except check valves (stop-check valves are included).
- Actuated by a safety signal.
- Power locked-out.
- Other valves operated by handswitch from the control room.
- Valves required by NRC.

The only valves that do not have such indication in the control room, but require control indication in accordance with the criteria, are the Main Steam Relief Valves.

5.2.8.4.4 Assessment of Valve Position Feedback. Subsequent evaluation of the valve position feedback HED was that the Main Steam Relief valves position would be known to the operators except in cases when they don't reseat properly.

5.2.8.4.5 Recommendation of Valve Position Feedback. Based on the above assessment, position-indicating lights for the Main Steam Relief valves will not be added in the Control Room.

5.2.8.5 Remote Shutdown Panel (RSP)

5.2.8.5.1 Criteria and Methodology

The evaluation of the Remote Shutdown Panel (L-42) was accomplished using the human factors criteria developed by the CRDR Working Group. The review addressed:

- o Identification of component relocations required;
- o Identification and demarcation of functional systems;
- o Labeling requirements.

5.2.8.5.2 Findings for Remote Shutdown Panel

For optimal arrangement of the RSP, moves for sixteen devices were identified. The review indicated that line demarcation could be used rather than color coding of instruments to provide the necessary identification of the function systems. No specific labeling HEDs other than hierarchical labeling were identified.

5.2.8.5.3 Assessment of the Remote Shutdown Panel

The remote shutdown panel is designed to be used only in the event the control room is unavailable and is required to permit the operator to bring the plant to hot shutdown. For this reason, there is a minimal number of devices required on this panel and the panel arrangement is relatively simple and straightforward. Although the CRDR

Working Group identified HEDs for rearrangement and demarcation for potential improvement, the existing RSP was evaluated to be adequate. Subsequent evaluation during startup testing did not indicate that resulting operational benefits would warrant rearrangement or demarcation modifications.

Furthermore, the existing panel is used for periodic operator training, on a 30 day basis, and modification could lead to potential operator errors resulting from lack of familiarity with a revised RSP.

5.2.8.5.4 Recommendations for the Remote Shutdown Panel

The existing design of the RSP was reviewed for clarity and ease of operation. Assessment of the component suitability and operability has determined that any additional rearrangement or demarcation would be of little benefit. This is due to the simplicity of the panel design layout. Based on this, no modifications of the RSP are currently planned.

5.3 COMPUTER SYSTEMS

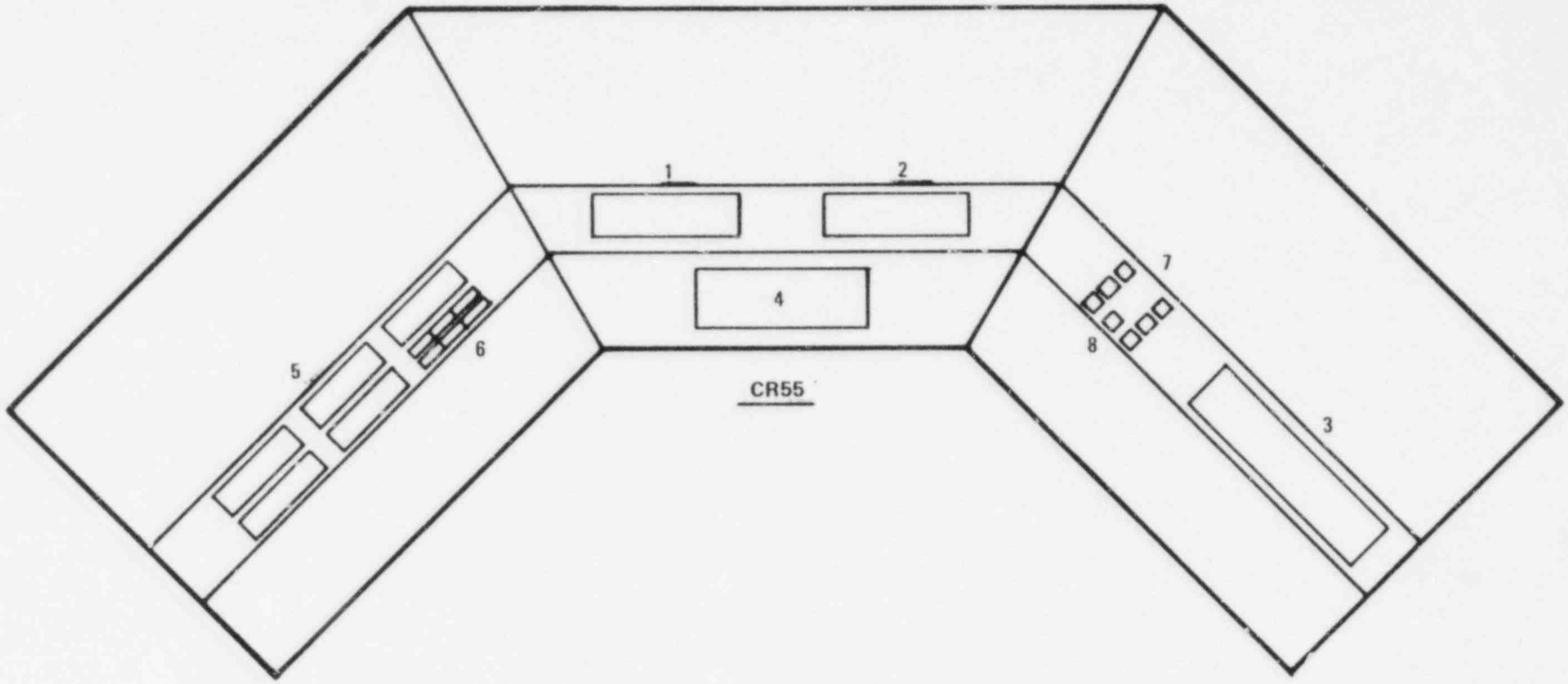
5.3.1 Introduction/Overview

Plant operators make use of three computer systems that are located in the control room.

Plant Monitoring System - PMS
Critical Function Monitoring System - CFMS
Qualified Safety Parameter Display System - QSPDS

A. The Plant Monitoring System (PMS) is a computer data acquisition, processing, and display system provided as a part of the NSSS. The unit Computer Console 2CR-55 in the control room contains three CRTs, a keyboard, five 2-pen trend recorders, system alarm indicators, and system control switches. Two printers for each unit are located behind the common Electrical Mimic Bus Panel (CR-63). See figures 1.2-2 and 5.3-1.

The PMS monitors NSSS and BOP system performance and provides alpha-numeric displays on the monochrome CRTs and hard copy on the printers. The PMS functions include reactor core operating limit supervision, alarm status, sequence of events, post trip review, trend recording, logging, and plant system status monitoring. The PMS functions provide operators with information that allows more convenient and efficient plant opera n. Plant control and protection functions re not performed. The PMS is not required to permit plant operation or to ensure plant safety.



LEGEND

1 PMS DISPLAY
2 PMS DISPLAY
3 PMS DISPLAY
4 PMS KEYBOARD
5 RECORDERS (5)
6 PMS FAILURE INDICATORS
7 PMS ALARM PUSHBUTTONS
8 PMS KEY SWITCH

Figure 5.3-1 PLANT MONITORING SYSTEM CONSOLE (CR-55) SONGS 2 & 3

B. <u>The Critical Function Monitoring System (CFMS)</u> is a computer data acquisition, processing, and display system provided to satisfy the requirements of NUREGs 069C and 0737. It displays critical plant safety parameters in a concise and integrated manner. The Operators Console for Unit 3 (3CR-65) includes one CRT and a keyboard. The CRT and keyboard for Unit 2 are presently located on a temporary stand, but will be installed in a new Unit 2 Operators Console (2CR-65) prior to startup following first refueling. One CRT and a keyboard for Unit 3 are installed at one end of the Common Operators Console (2/3CR-66). The Unit 2 CRT and keyboard will be installed at the other end of this console during the prior to startup following first refueling. See figures 1.2-2, 5.3-2, and 5.3-3.

The CFMS monitors reactor and steam generator control, core heat removal, coolant system, and containment parameters that include the Safety Parameter Display System (SPDS) requirements. The CRT displays are organized and make use of color and graphics to optimize comprehension by plant operators. The CFMS provides critical function algorithms, historical data storage and retrieval, real time trends, and alarm status. The CRTs, keyboards, and printers in the Technical Support Center (TSC) and the Emergency Operations Facility (EOF) also operate from the CFMS. To a large

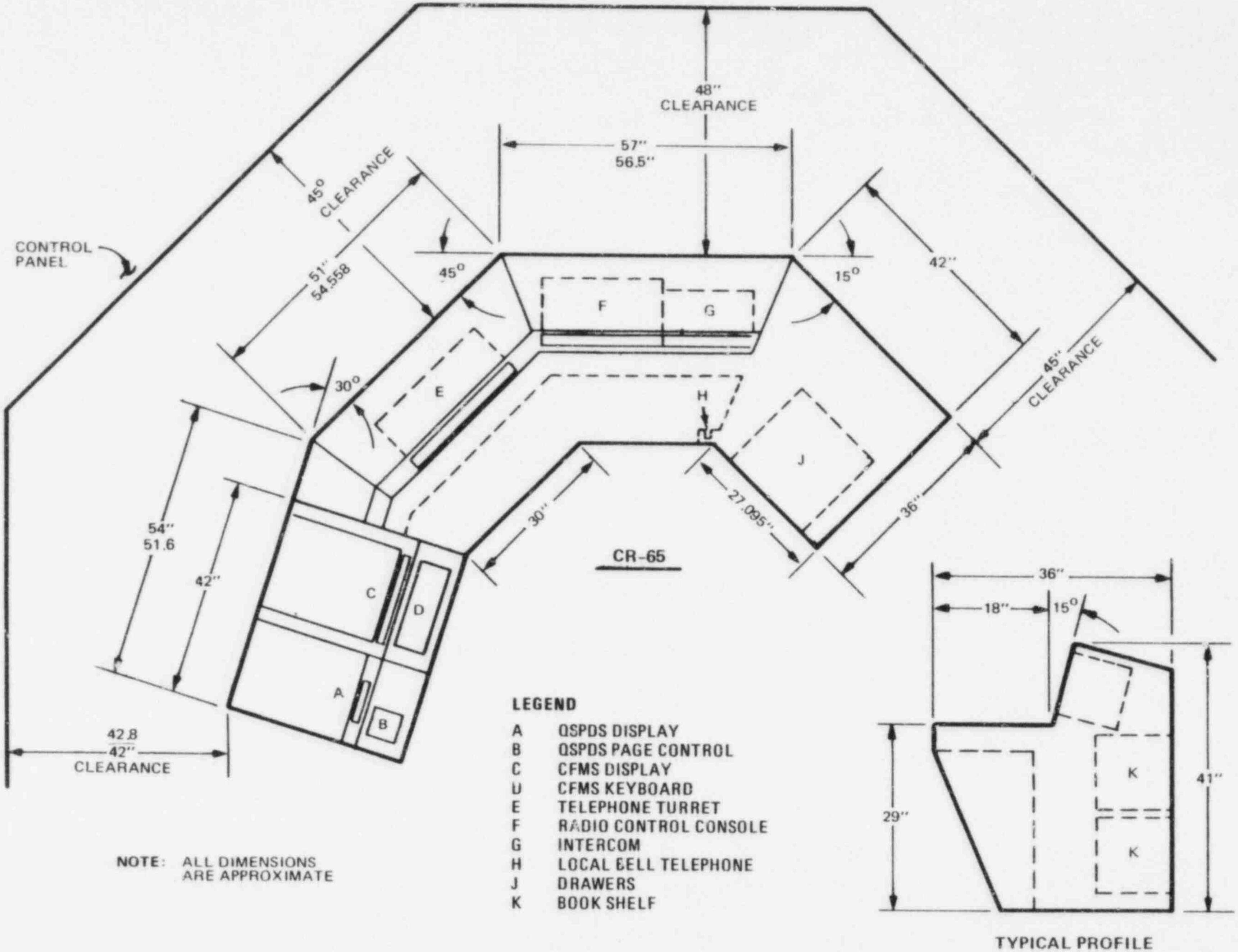


Figure 5.3-2 OPERATOR'S CONSOLE (CR-65)
SONGS 2 & 3

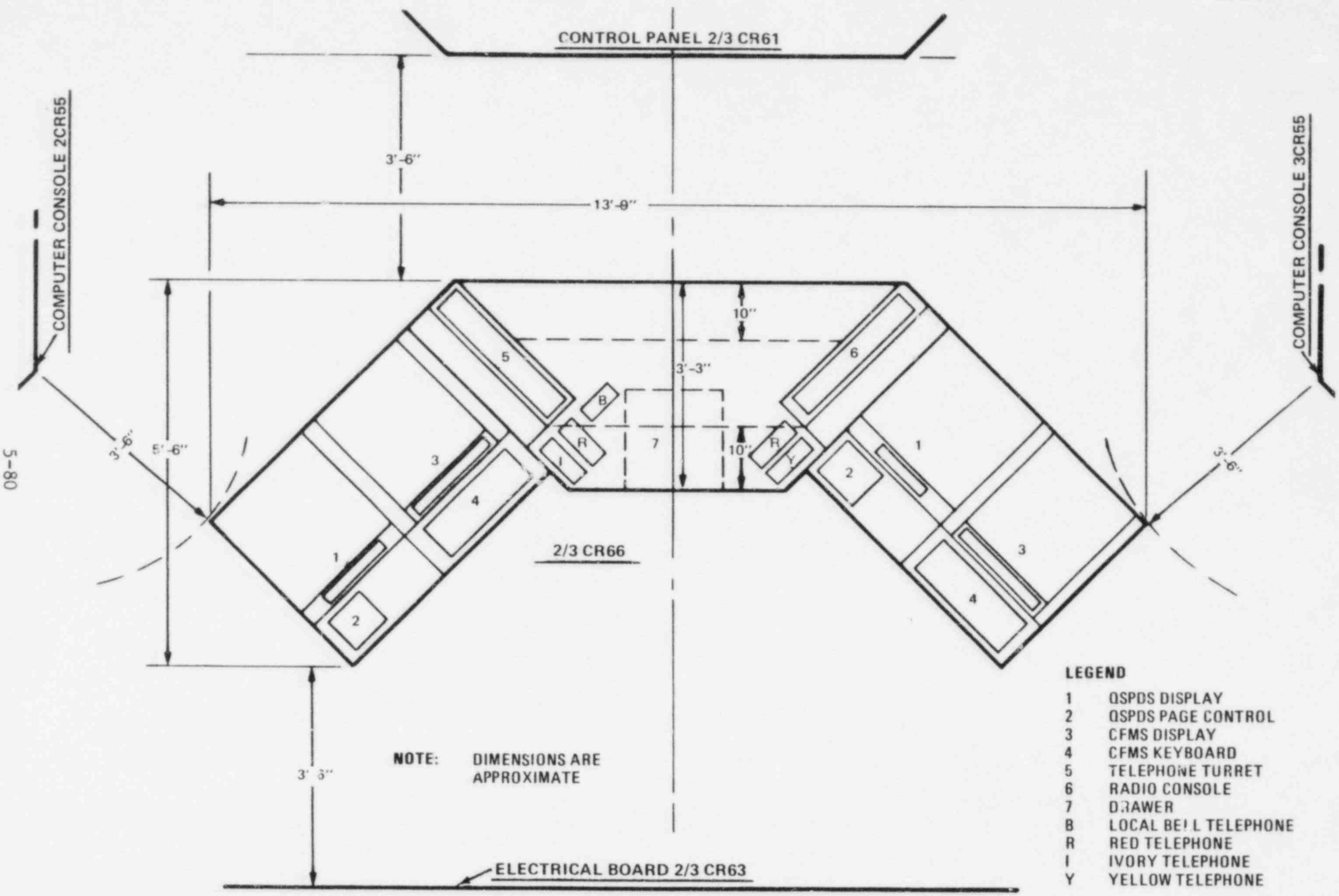


Figure 5.3-3 COMMON OPERATING PANEL (2/3 CR-66)
SONGS 2 & 3

extent, CFMS inputs are also monitored by the PMS. While designed for high reliability for use during both normal and abnormal plant conditions, the CFMS does not perform control or protection functions and is not required for plant operation or safety.

C. The Qualified Safety Parameter Display System (QSPDS) is a microprocessor data acquisition and display system provided to satisfy the requirements of NUREGs 0696 and 0737 and Reg. Guide 1.97. It displays critical plant safety parameters and uses redundant components that are qualified to nuclear Class 1E safety standards. The Operators Console for Unit 3 (3CR-65) includes the Channel A plasma display and page control unit. The Channel B plasma display and page control unit are installed at one end of the Common Operators Console (2/3CR-66). The Unit 2 devices will be installed on a new Operators Console (2CR-65) and on the other end of the Common Operators Console (2/3CR-66) prior to startup following first refueling. See figures 1.2-2, 5.3-2, and 5.3-3.

The QSPDS meets the Safety Parameter Display System (SPDS) requirements and provides a reliable backup to the CFMS. The plasma displays provide monochrome displays of alpha-numeric data that is organized to optimize comprehension by plant operators. The QSPDS does not perform control or protection functions and is not required for plant operation or safety.

5.3.2 Computer Systems Methodology

The PMS design review was implemented in several phases. HEDs related to the PMS were developed by the NRC Control Room Design Review Audit Team during the NRC control room audit in 1980. The Control Room Design Review Working Group reviewed the PMS as a part of the overall Control Room Design Review. These reviews took place prior to the issue of NUREG CR-1580 and NUREG-0700. At a later date, a report was prepared evaluating the PMS reliability, maintainability, and suitability for continued operation over the life of the plant. The hardware obsolescence identified in this report may lead to an eventual upgrade of the PMS computer using current technology. The functional shortcomings identified by the evaluation have been offset by the recent installation of the CFMS and QSPDS capabilities.

A computer system design review was performed after the CFMS and QSPDS were installed in the Unit 3 control room and the CFMS was in use in a temporary location in the Unit 2 control room. This comprehensive review of all computer systems in the control room assumed that the Unit 2 installation will be the same as the present arrangement for Unit 2. This review included PMS, CFMS, and QSPDS components in the control room and compared features of the three systems for consistency.

The methods used in this review included an engineering survey of available drawings and specifications, a physical survey of computer system features and workspace, an operator survey to identify problem areas relating to both normal and upset plant conditions, and an operating history survey of Startup Problem Reports (SPRs).

The computer system review was simplified for several reasons. The CFMS is the only system of the three that makes use of color and graphic displays. The CFMS and QSPDS were both designed using human factors techniques developed in recent years. The designs and workspace arrangement of these two systems were reviewed for human factors in design meetings that included the participation of an independent consultant. The human engineering guidelines for control room workspace and process computers from NUREG-0700 were used in this review. The functional features of the CFMS and QSPDS to meet the requirements of NUREG-0835 were conducted by the CFMS and QSPDS supplier.

5.3.3 <u>Computer Systems HED Identification Assessment and Recommendations</u>

- General Conclusions

  The survey of the Computer, Operator, and Common Operator Consoles indicated adequate operator accessibility and compliance with anthropometric requirements for work station design. The shelf added above the Computer Console for laying out drawings does not create an obstruction for plant operators since this console faces away from panels used for unit operations. While checked primarily for seated operation, the three consoles provided satisfactory display positioning for viewing from standing positions in nearby areas.

In addition to HEDs that were identified, the NRC Audit Team noted favorably that the PMS CRT displays were clear and readable with some glare evident, PMS cleared alarms are displayed in reverse video, the PMS can trend up to 10 parameters on strip chart recorders, and that PMS alarms actuate an annunciator system window.

The CRDR did not concentrate on the PMS, but did determine that the system lacks features available with current technology, the PMS is not considered useful for annunciator alarm verification because of delayed response, and that the PMS should be reviewed further in relation to computer/ operator relationships.

The PMS Evaluation report indicates the considerable value of the PMS to plant operators and also indicates in detail how this value is limited by significant reliability, maintainability, and suitability problems. The problems that relate to plant operators have been developed into HEDs. The report suggests that any replacement for the PMS should include CRTs on the Common Operators Console (2/3CR-66) and should use human factors methods that are consistent with those used elsewhere in the control room.

Software security is ensured by administrative control. Computer system database changes are accomplished at a location away from the control room. Formal Engineering Procedures have been established to control the development and review of changes. One copy of the current software is stored in a remote secure location.

HEDs related to the PMS printers are not considered to be significant since the plant operating criteria indicates use of the printers for later analysis of important data and alarms only. While several HEDs were identified relating to consistency of operation of the three systems, plant operators did not mention these items when questioned about operating deficiencies.

The more important of the HEDs identified by the several reviews of the PMS are related to technical limitations of the present system. Replacement of the PMS would be required to allow improvement in these areas.

- Specific HED Identification and Assessments

The following are the HEDs identified during computer system design reviews and the assessment response for each HED. The abreviations below are used to identify the source of each HED.

NRC - NRC Control Room Design Review Audit

CRDR - Control Room Design Review

PMS - Evaluation of the Plant Monitoring System Reliability, Maintainability, and Suitability

CSR - Computer System Design Review

1. The PMS computer data base is not up-to-date. (NRC)

   Response: Cat. 1 - To be updated prior to fuel load revising nomenclature for consistency with new control panel legends and to be updated periodically as required.

2. The PMS data point IDs are not cross-indexed by name, system/subsystem or functionally grouped. (NRC)

   Response: Cat. 2 - A cross-index by name, system/subsystem, and functional grouping was proposed in the form of a notebook available in the control room prior to fuel load. On later analysis it was determined that the notebook was not required, since operators first locate the desired measurement instrument on the P&ID and the related data point ID is made up of the instrument number, loop number and the measurement type.

3. Glare on PMS CRT displays causes degradation in readability. (NRC, CRDR)

   Response: Cat. 1 - A glare shield will be provided prior to fuel load.

4. A window fan is used to cool the PMS console to prevent overheating caused by use of the top of the console to lay out drawings. (NRC)

   Response: Cat. 1 - Provisions will be made prior to fuel load for laying out drawings that will not impede air circulation by installing a shelf above the console.

5. The PMS operator training is not completed. (NRC)

   Response: Cat. 1 - PMS trained personnel will be available on each shift prior to fuel load.

6. PMS CRTs do not utilize color-coded displays. (NRC)

   Response: Cat. 3 - Cleared alarms are displayed in reverse video. Replacement of the PMS will be studied to provide color CRT displays.

7. The PMS has no graphic trending capability. (NRC, CRDR)

   Response: Cat. 3 - Five 2-pen trend recorders are provided on the Computer Consoles to indicate and record PMS data. Replacement of the PMS will be studied to provide CRT graphic trend displays.

8. PMS alarm displays are not prioritized. (NRC, CRDR, PMS)

   Response: Cat. 3 - The PMS alarm point ID designation will be revised to include letters, R, Y, W and B to correspond to the red, yellow, white, and blue colors used to prioritize individual annunciator windows.

9. PMS alarm displays are not grouped by priority. (NRC)

   Response: Cat. 3 - Replacement of the PMS will be studied to provide grouping of alarm displays by priority.

10. PMS alarm displays are not grouped by system/subsystem. (PMS, CSR)

    Response: Cat. 3 - Replacement of the PMS will be studied to provide grouping of alarm displays by system/ subsystem.

11. PMS alarms displays are delayed during upset conditions because of the number of alarms and the display method. (CRDR, PMS, CSR)

Response: Cat. 3 - Replacement of the PMS will be studied to provide display of alarms in real time.

12. PMS printers do not utilize color coded printing (NRC)

Response: Cat. 3 - Replacement of the PMS will be studied to provide color coded printing.

13. PMS printers do not record all annunciator alarms. (CSR)

Response: Cat. 3 - The annunciator system is the primary plant alarm system. Many alarms are also displayed and logged on PMS CRTs and printers. It is not considered necessary to display and log on the PMS the low priority alarms that are not related to safety, unit availability, or performance of major systems. Additional system inputs will be available if the PMS is replaced.

14. PMS printers do not provide alarm printouts grouped by system/subsystem upon operator request. (CSR)

Response: Cat. 3 - Grouped alarm printouts would not be useful to plant operators since the printers are located outside of the primary operating area and are used to log alarm status for later analysis only.

15. PMS printers are not in the primary operating area. (CSR)

Response: Cat. 3 - The printers provide alarm status, sequence of events, post trip review, and logging data for later analysis only. They are located behind the Electrical Mimic Bus Panel (2/3 CR-63) to avoid noise and obstructions in the primary operating area. Information required by plant operators is displayed on PMS CRTs.

16. PMS printers do not provide hard copy of CRT displays upon operator request. (CSR)

Response: Cat. 3 - Replacement of the PMS will be studied to provide CRT display hard copy upon operator request.

17. The PMS is out-of-service frequently. (PMS, CSR)

Response: Cat. 3 - Replacement of the PMS will be studied to provide more reliable operation.

18. The PMS program to cut out nuisance alarms based on plant operating condition does not work. (CSR)

Response: Cat. 3 - Many nuisance alarms have been eliminated by modifications to alarm logic circuits connected to the annunciator and repeated to the PMS. The PMS alarm cutout program will be studied to determine whether putting it in service is practicable.

19. The CFMS and QSPDS numeric keyboard numeral arrangements are not consistent. (CSR)

Response: Cat. 3 - the effect of the different numeral arrangements on operator performance will be studied to determine if replacement of one of the two numeric keyboards is required.

20. The PMS and CFMS alpha-numeric keyboard auxiliary key arrangements are not consistent. (CSR)

Response: Cat. 3 - the difference in the location of the auxiliary keys is not considered to affect operator performance in a significant way. A more consistent arrangement will be investigated when the replacement of the PMS is studied.

21. The PMS and CFMS alarm display, acknowledge, and reset methods are not consistent. (CSR)

    Response: Cat. 3 - The effect of the different alarm methods is not considered to affect operator performance in a significant way. A more consistent method will be obtained when the replacement of the PMS is studied.

22. PMS and CFMS points operating from the same analog inputs do not display the same digital values and do not alarm at the same time. (CSR)

    Response: Cat. 3 - The differences are inherent when redundant measurement systems are used. Differences in calibration of the PMS and CFMS A/D converters will produce slightly different digital values. Uniformity can be achieved if a replacement computer system includes both PMS and CFMS functions.

23. Subcooled margin monitor (SMM) displays are not provided. (NRC)

Response: Cat. 1 - Displays to be installed prior to fuel load. A dedicated instrument display will be provided on Unit 2 until the CFMS and QSPDS are installed. Both the CFMS and the QSPDS display the subcooled margin.

5.4 CONTROL ROOM

5.4.1 Communications Survey

5.4.1.1 Communications Survey Criteria and Methodology

The Communication Survey of the control room consisted of measurement and collection of data and its evaluation. In each segment, survey principles were addressed in the communication systems review as follows:

1. Data required for each system were collected;

2. The data were recorded on the appropriate data form;

3. Checklists were completed using the recorded communication survey data;

4. HEDs were identified on the checklist.

Communication system adequacy was examined in relation to specific task requirements. The survey addressed the six kinds of voice communication equipment that are used in the control room.

Communication systems guidelines were established for the survey of each system, as applicable, from a component perspective. Performance tests were developed to establish compliance with the various guidelines.

Six types of voice communications equipment systems are used in the control room:

- o Conventional-powered telephones
- o Walkie-talkie radio transceivers
- o Fixed-band UHF transceivers
- o Announcing systems
- o Sound-powered telephone
- o Point-to-point intercom systems.

Human factors requirements were applied to each of the classes involved.

5.4.1.2 Communications Survey Findings and Assessments

All six systems were found to be in adequate compliance with the established guidelines. Therefore, no recommendations were made concerning needed improvements.

5.4.2 <u>Lighting System</u>

5.4.2.1 Lighting System Survey Criteria and Methodology

A lighting survey was done following control room modifications which helped reduce glare, reflections and shadows by repainting the control room walls and panels with flat paint and utilizing anti-glare materials and lenses.

Control room lighting was evaluated with consideration to the guidelines for normal and emergency lighting discussed in NUREG-0700, Section 6.1.5.3, on "Illumination", which recommends the following illumination levels:

	Task Illuminance, Footcandles		
1. Normal Lighting	Min.	Recommended	Max.
Panel Area	20	30	50
Seated Operator Stations	50	75	100
Reading & Writing Areas	50	75	100

2. Emergency Lighting — Minimum illumination level of 10 footcandles at all work stations in the primary operating area.

Based on the control room layout drawing, figure 5.4-1, used to select and identify locations, several types of readings were taken to ensure that every relevant aspect of the lighting environment was recorded and available for analysis. Readings were taken both for normal AC lighting, and emergency DC lighting with the following types of readings.

A. Eye-level (66 inches from the floor) with meter facing out from panel held flat against panel. These readings show the level of light actually incident on the panel at eye-level.

B. At eye-level, one inch from panel with meter facing the panel. These readings were taken as a measure of the light reflected by the panels at eye-level.

C. Meter held flat against panels at transition section, position B in figure 5.4-1, section B-B. These measurements show the value of light incident on the panels at position B on the Main Control panels.

D. Meter held flat on the handrail at position C, figure 5.4-1, section B-B.

E. Meter held at eye-level six inches from Main Control Panels, pointing up.

F. Meter at the seated operator station areas (z on figure 5.4-1). The central location of the operator stations gathers light over a 180° hemisphere from a large number of overhead fixtures contributing to the total integrated light intensity readings.

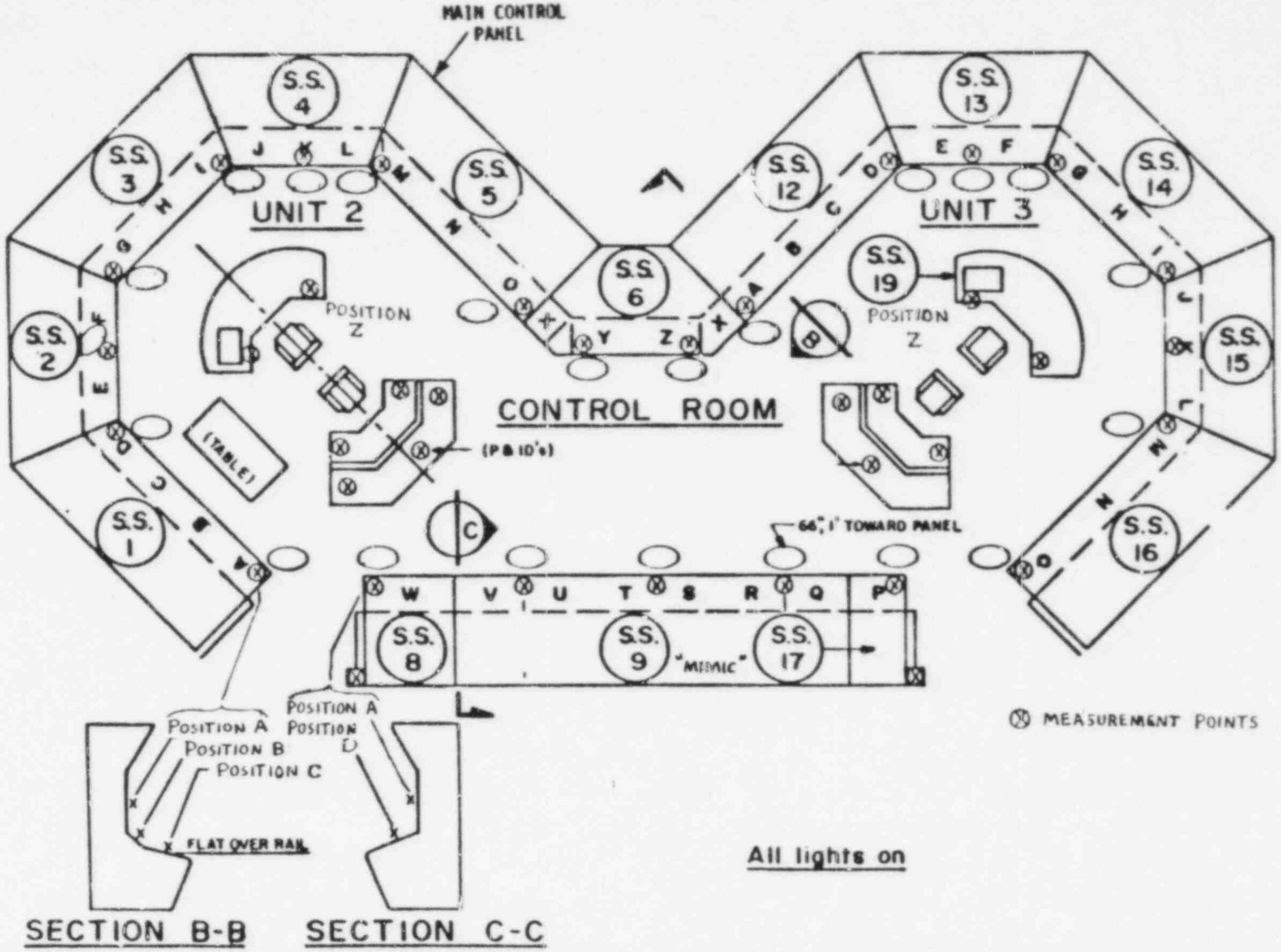


Figure 5.4-1 SONGS UNITS 2 & 3 NORMAL LIGHTING, 8/19/82

G. Same type of readings as A; these readings were taken on the "Mimic" panel.

H. Same type of readings as B; these readings were taken on the "Mimic" panel.

I. Same type of readings as E; these readings were taken on the "Mimic" panel.

J. Meter held flat on the "Mimic" panel handrails at position D in figure 5.4-1 section C-C.

5.4.2.2 Lighting System Survey Findings

The results of the San Onofre Units 2 and 3 Control Room lighting system survey for the normal lighting levels summarized in table 5.4-1. The results of the lighting survey for vertical section position A of both the main control panel and mimic panel showed an average lighting level of 42.9 footcandles consistent with the guidelines of NUREG-0700 for panel areas. The results of the lighting survey for inclined sections positions B and C of the main control panel and inclined section position D of the mimic panel showed average lighting levels of 57.4, 69.5, and 77.5 footcandles respectively. These higher lighting levels are a direct result of the increase in incident light on the panels due to the orientation of the inclined panels. The results for these inclined areas are also considered to be consistent with the guidelines of NUREG-0700 since the illumination levels fall between the recommended guidelines for vertical

Table 5.4-1

LIGHTING SURVEY RESULTS

Light Measured At	Location of Meter/Sensor	Normal Lighting *Average	Normal Lighting *Range	Emergency Lighting *Average/	Emergency Lighting *Range
Main Control Panels	a. 66" from floor, flat against vertical panel	42	34.8-50.5	6.5	5.5-7.2
	b. 66" from floor, 1' from panel facing panel (Measure reflected light)	17.6	13.7-24.5	2.9	2.3-3.9
	c. Flat on panel at (B) on Enclosures 1 and 2, Section B-B	56.3	45.0-76.2	8.5	7.3-9.8
	d. Flat on handrail at (C) on Enclosures 1 and 2, Section B-B	69.5	57.3-96.5	10.2	8.7-11.9
	e. 66" from floor, 6" from panel pointing up	62.2	44.3-90.1	9.2	7.9-10.9
Seated Operator Station Areas "Z" on Enclosure	f. Flat on surface (See Enclosures 2 and 3 for actual readings)	100	83.6-115	14.6	13.8-17.6
Mimic Panels Only	g. 66" from floor, flat against vertical panels	45.9	41.9-49	7.5	6.7-8.3
	h. 66" from floor, 1' from panel facing panel (Measure reflected light)	18.5	15.5-22.2	2.8	2.4-3.3
	i. 66" from floor 6" from panel facing up	68.4	65.9-71.4	12.2	10.4-14.1
	j. Flat on handrail at (D) on Enclosures 1 and 2, Section C-C.	77.5	73.7-80.1	11.9	10.6-13.5

Notes: (1) All lights were functioning normally for both normal and emergency surveys.
(2) *All values in footcandles.

section (panel areas) and sit-stand sections (seated operator stations). The results for reading and writing areas, position Z, showed an average lighting level of 96.9 footcandles consistent with the guidelines of NUREG-0700.

The results of the San Onofre Units 2 and 3 Control Room lighting survey for the emergency lighting level are summarized in table 5.4-1. The results of the lighting survey for reading and writing areas, position Z, (work stations in the primary working area) showed an average lighting level of 13.8 footcandles consistent with the guidelines of NUREG-0700 for emergency lighting. The average lighting levels for the panel areas are also identified in table 5.4-1. The emergency lighting levels in the panel areas did not impair the capability of the operators to obtain clear and discernable readings.

To satisfy requirements related to Fire Hazards Analysis and subsequent to the control room lighting survey conducted for the CRDR, five inspections and walkdowns of the emergency lighting system for the safe shutdown areas were conducted by the NRC. As a result of those inspections a number of emergency lighting improvements were implemented by DCP procedures.

In summary, with these improvements, the NRC has accepted, as adequate, the 8-hour emergency lighting system for the safe shutdown areas.

5.4.2.3 Lighting System Assessment

To reduce the reflected glare, the following corrective actions were considered for reducing glare, reflections and shadows.

1. Replacement of pushbutton switch lenses with anti-glare lenses.

2. Replacement of all Lamicoid legend plates with antiglare plate material.

3. Evaluation of anti-glare sprays and optical films for, or replacement of lens covers, instrument windows, etc.

4. Treatment of glossy surfaces with flat paint.

5. Addition of hood covers for CRTs.

Based on the results of the lighting survey, subsequent to the anti-glare modifications, it was concluded that the normal and emergency lighting levels in the control room are consistent with the guidelines of NUREG-0700 and that no further lighting modifications are necessary.

5.4.2.4 Lighting System Recommendations

The glare conditions existing in the control room were derived from a combination of lighting, equipment paint, glossy surfaces, and location of instruments. In order to alleviate these conditions, it was recommended that the following modifications be performed prior to fuel load:

1. Replace Master Specialties pushbuttons switch lenses with anti-glare lenses.

2. Substitute Lamicoid legend plates with anti-glare plate materials.

3. Repaint instrument bezels with flat paint as recommended by the Whitston Associates reports.

4. Provide hood covers for existing CRTs.

5. Replacement and/or optical coat the indicator lenses as determined by engineering and degree of acceptability.

Based on the lumination levels of the survey, additional lighting modifications are not considered necessary to meet the requirements of NUREG-0700.

5.4.3 Sound Survey

5.4.3.1 Sound Survey Basis

The intent of the review of acoustic conditions was to ensure that, under "worst case" situations in the control room, ambient background noise and acoustic reverberation would not significantly impair voice communication between personnel within the control room.

There are a number of acoustic sources, including speaking, with their distinctive spectral, temporal and spatial characteristics, which interact with the room volume and boundaries to produce the composite acoustic signal to the listener's ears. The interfering noise sources, which together made up the background noise in the control room, are located both outside the control room (line printers and other equipment) and inside (ventilating duct outlets, cooling fans in equipment cabinets, etc.). The signal (spoken message) level and the noise (all other acoustic sources) level, and also the sentence intelligibility, are influenced by parameters of the room such as volume and acoustic absorption at the boundaries.

5.4.3.2 Sound Survey Methodology

The following locations, where sound survey measurements were to be taken, were selected and marked on a control room layout drawing:

- Senior reactor operator's desk,
- Reactor operator's desk,
- Operator work stations, or at points near the center of each panel or console,
- Back panel areas requiring communication with the primary area.

The acoustic design of the control room was evaluated to insure that verbal communications between operators are not impaired. The following measurements were taken:

- Background noise,
- Maximum levels of background noise,
- Reverberation time.

From these measurements, estimates of Speech Interference Level (SIL) and Speech Transmission Index (STI) were made.

5.4.3.3 Sound Survey Findings

Since the control room had not been completed when measurements were first made, it was necessary to estimate the reverberation time for the room in its final configuration.

Following this procedure, the following results were obtained, first for the control room in the as-measured condition, then for the recommended final configuration. Quantities in parenthesis are measured values. All other quantities are estimated.

Parameter	As-Measured Conditions	Estimated Final Configuration
Reverberation Time, sec	0.41 (0.42)	0.25
Average Absorption Coefficient	0.36 (0.34)	0.51
Speech Level at 13 feet, dBA	63.2	61.5
Noise Level, dBA	(60)	57
Allowable Noise Level, dBA	56	56.5
Allowable SIL, dB	58	58.5
STI	0.5	0.6
Sentence Intelligibility	90%	98%

5.4.3.4 Sound Survey Recommendations

Recommendations are to add carpeting to the control room and do a final survey of the acoustical parameters after the carpeting has been installed. From these measurements, new SIL and STI values will be estimated. This final survey will be performed following the guidelines as outlined in NUREG 0700, after both units 2 and 3 are fully commercial and are at full power. Addtional sound panel and control room doors may be required to meet NUREG 0700 standards.

5.4.4 Heating, Ventilating and Air Conditioning System

A survey of the Control Room HVAC Systems and any modifications required will be accomplished prior to completion of first refueling.

In order to verify acceptable operation of the control room HVAC systems, testing will be performed as stated in section 6.4.4.

5.5 SYSTEM FUNCTION IDENTIFICATION AND ANALYSIS FINDINGS

The objective of the System Function Identification and Analysis review activity was to establish and quantify the function of each major system and subsystem in the plant. In meeting this objective functional grouping of components and systems was performed. Process flow diagrams were developed based on the functional grouping activity.

The functional grouping and process flow diagrams were compared to the layout of the instruments and controls on the various main control panels to determine the relationship between the system functions, process flow, and panel layout. In keeping with the recommendations of the human factors consultant, the control panel instruments were relocated on a photo mosaic mockup. Various instrument layouts were examined and an analysis of each conducted.

Several cases were noted where the functional grouping was somewhat disorganized and less than optimal. These occurences were recorded and subjected to assessment of impact on operator/plant performance. In summary, however, most of the disorganized groupings were corrected by instrument relocation.

5.6 VERIFICATION OF TASK PERFORMANCE CAPABILITY FINDINGS

The objective of the task performance capabilities verification process is to assure that adequate instrumentation and controls exist in the control room to enable the performance of operator tasks with minimum potential for human error.

5.6.1 Instruments and Controls

This activity, in conjunction with system function identification, resulted in the recommendation for the relocation on the control panels of approximately 150 instruments. (For additional discussion of this refer to subsection 5.2.) Additionally, it was determined that the existing control board contained the necessary instrumentation and control required to monitor, operate, and control the plant processes. The detailed component by component evaluation was conducted during the panel review.

This review activity also defined several cases where operations personnel are required to get information external to the control room proper. In most cases, the function analysis confirmed the existence of these requirements rather than discovering them.

It was also found that for a given operating task a Flow Controller and relative indicators were 1-1/2 panel sections apart. This, at first, appeared to require relocation but further investigation determined that for all other normal and emergency activities the components were located properly and functionally. Based on this, no implementation was performed.

The remaining element of this activity will be performed during the verification and validation of the plant specific parameter list to be generated from the function oriented Emergency Operating Procedure Generation.

5.6.2 Annunciator System

The examination of the annunciator system showed that the annunciator windows needed prioritization by color, to be most effective. Also, the alarm messages were meaningful, the operator could take corrective action given the existing instrumentation and controls, and all windows were located on the proper respective panels. Further discussion of the annunciator system is made in subsection 5.2.6 of this report. No annunciator windows needed panel relocation which compliments the original Control Room Design criteria as it affects the annunciators.

In responding to the objectives of this aspect of the annunciator study, it became clear that overall the alarm meanings were well understood and that corrective or mitigating actions could be taken on the control board adjacent to the alarm window.

5.7 CONTROL ROOM FUNCTIONS VALIDATION FINDINGS

The objective of the Control Room Functions Validation Analysis was to identify and evaluate the necessary tasks in the control room that are required to operate the plant efficiently and maintain the plant in a safe condition and to evaluate the integration of the control room operator with his/her resources.

To meet this objective, two major areas of operator tasks were examined: normal operating tasks and emergency operating tasks. The emphasis of this review was on the emergency or off-normal tasks.

A significant portion of the emergency response analysis was performed by the NSSS Vendor and supplied to the NSSS owners' group. This analysis is documented in the Combustion Engineering Emergency Procedure Guidelines (CEN-152). SCE has not generated the plant specific procedures from the generic procedures. This activity will be performed in responding to section 7 of NUREG 0737 Supplement No. 1.

Further study of the specific parameter list generated as part of the Emergency Operating Procedure (EOP) verification and validation will be conducted and CRDR criteria, developed as part of this review, will be applied to identify any needed revisions.

The review of the Generic Guidelines has shown that adequate instrumentation and controls to support maintenance of the safety functions is available in the control room. Specific attributes of the instrumentation are discussed in subsection 5.2.5.

The walk-through of the current EOPs has shown no inadequate or misplaced controls or instrumentation. The operators work stations support the activities necessary to perform normal and emergency operating tasks.

The walk-through conducted on the normal operating procedure subset was considered acceptable and supported the functional grouping activities.

In summary, the review of these procedures determined that:

1. The instrumentation and controls required to accomplish these procedures are available in the control room and they are of sufficient adequacy to allow the operator to perform the required function.

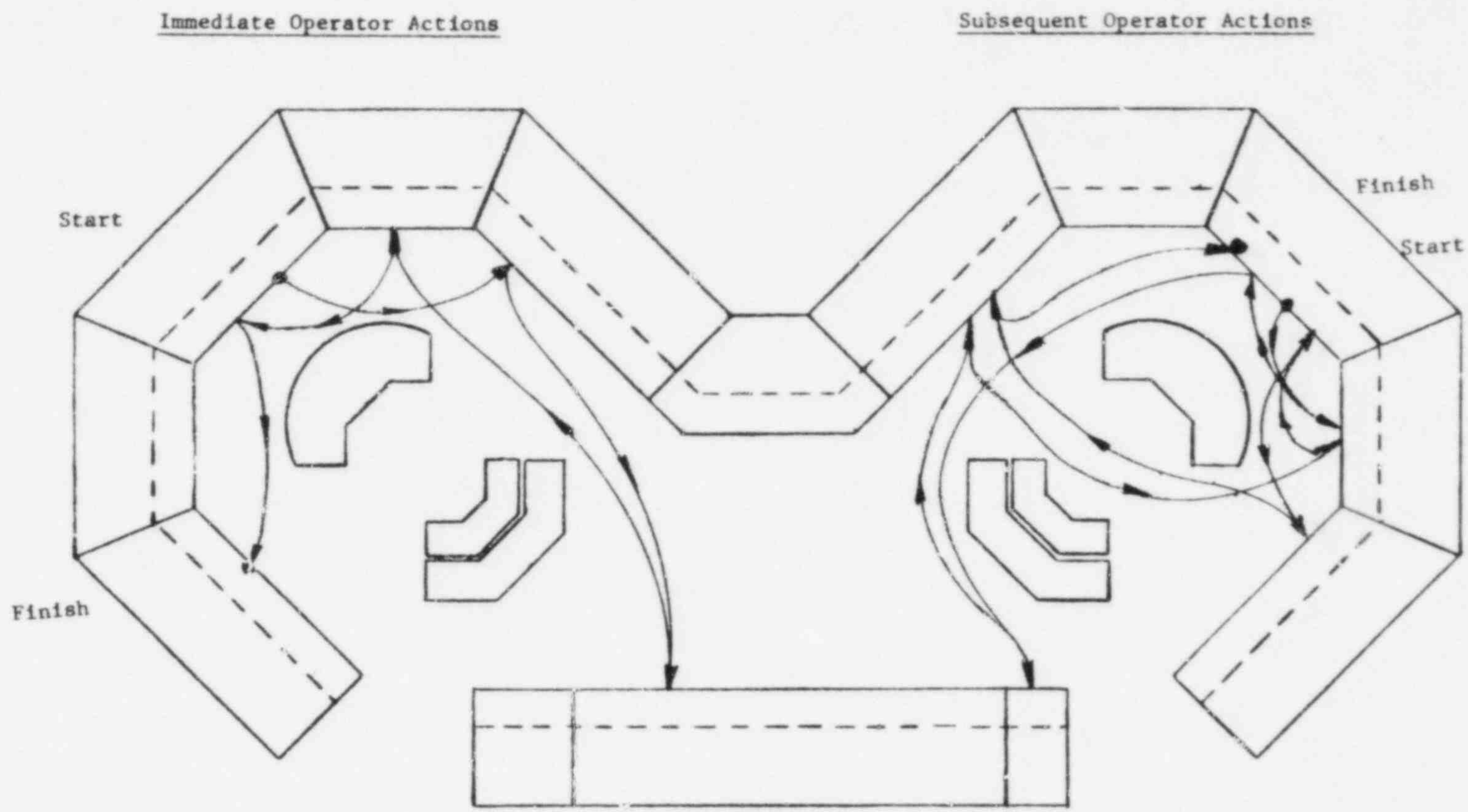
2. A consistent format was not evident in the NOPs and all NOPs should be reworked.

With regard to Finding No. 1 it was expected that no significant deficiencies would be discovered as these procedures are constantly walked-through in the operator training program on the SONGS Simulator. As part of this program, any problems, deficiencies, discrepancies or improvements to the operator functions are conveyed to the station engineering staff by means of an Instruction Resolution Request (IRR). The IRR is a forum for operators to air requests and has proved to be an outstanding tool for identifying weaknesses in the procedures and equipment in the control room. Additionally, the Startup Problem Reports (SPRs) also provide direct means for the operations staff to correct deficiencies of equipment in the control room.

The evolution of the IRR and SPR process constitutes a major portion of the ongoing commitment for continued control room design improvements.

Figures 5.7-1 and 5.7-2 depict the operator flow paths during the walk-through of the emergency procedures for Emergency Plant Shutdown and Steam Line Rupture.

The results of this study are acceptable to the CRDR working group and to the actual operators. Clearly instruments could be relocated to best suit a particular procedure but a thorough study on the impact of moving instruments on all procedural activities would require a best-fit computer model and would probably result in a non-functionally grouped panel layout. This would, of course, defeat a major Human Factors Engineering accomplishment by degrouping functional areas and, therefore, was not considered.



Note: All Actions occur @
Unit 2 Control Board.
Units 2 & 3 Control
Board used for clarity.

REFERENCE: OP SO23-3-5.1
Rev. 01

Figure 5.7-1 OPERATOR FLOW PATH DURING AN
EMERGENCY PLANT SHUTDOWN

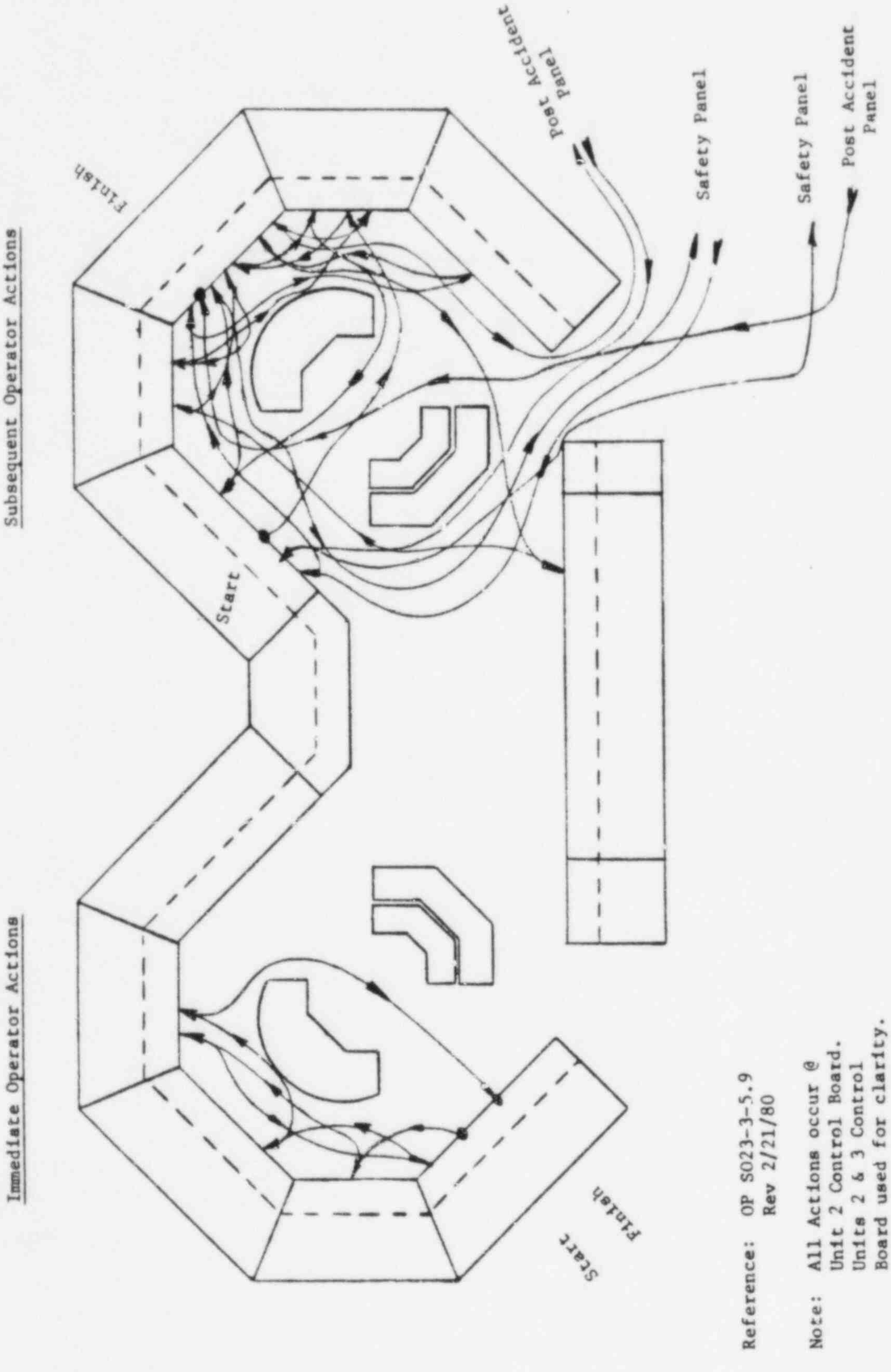


Figure 5.7-2 OPERATOR FLOW PATH DURING A STEAM LINE RUPTURE

Reference: OP S023-3-5.9
Rev 2/21/80

Note: All Actions occur @ Unit 2 Control Board. Units 2 & 3 Control Board used for clarity.

5.8 NRC AUDIT FINDINGS

The NRC Human Factors Engineering Staff conducted a 4-day audit of the SONGS Unit 2 Control Room during the week of August 4-8, 1980. The evaluation focused on the following:

- o Control and display design and location
- o Work station layout, including visibility and reach
- o Control room environment, specifically noise and illumination

The NRC Audit resulted in findings in the following control room design review evaluation criteria areas: Process Computer, Labeling Errors, General, Annunciators, Control Room Environment, Labels, Lamp Test, Communications, Minor Deficiencies, and Incore Thermocouple Instrument Display.

The NRC August 4-8, 1980 Audit findings were additionally documented by the NRC in Item 1.D.1 of Supplement No. 1 to the Safety Evaluation Report (SER) for SONGS 2 and 3, dated February 1981. The NRC concluded in the SER that in general:

> "...the control room was designed to promote effective and efficient operator actions. The controls and displays are, in most cases, functionally grouped and generally well integrated. Alarm displays have good visibility and are easily readable from the main control area. Alarm displays are located over appropriate system controls and displays. The physical design of the vertical

boards and the control console reflects considera-
tion of human anthropometry. Alarm panels are tilted down for normal visual access and all controls on bench boards are accessible to operators. In many cases the deficiencies identified by the staff had been previously identified by SCE during their control-room review, and plans are in process to rectify many of these deficiencies."

Furthermore, many of the deficiencies identified in the SER were included by the NRC in License Condition 2.C(19)f of the SONGS 2 Operating License (paragraph 5.7.1). Also, License Condition 2.C(17)c of the SONGS 3 Operating License requires implementation of the corrective actions specified in the SER (paragraph 5.7.2). SCE's letter of August 19, 1982 informed the NRC that all activity associated with the 17 corrective actions specified in the SONGS 2 license condition had been satisfied. As a result of SCE's review of the corrective actions specified in the SER, it is concluded that all corrective actions required for the SONGS 2 and 3 control room have been completed.

5.8.1 SONGS 2 License Conditions

The deficiencies identified in the SER that were included in License Condition 2.C(19)f of the SONGS 2 Operating License are summarized below.

Prior to exceeding five percent power, SCE shall:

1. Prioritize the control room annunciator windows.

2. Delete master acknowledge capabilities of the annunciator system.

3. Incorporate a second flash note/audible scheme into the annunciator system to alert the operator of an alarm returned to normal.

4. Identify changes required to correct control room lighting for optimum operator performance.

5. Revise control room labeling according to a hierarchical scheme.

6. Label Foxboro containment spray controller.

7. Replace RC loop hot leg temperature scales with appropriate scale divisions.

8. Eliminate 10X multiplier from RC loop hot leg and cold leg temperature.

9. Make all labels flush with the face of the instrument bezel.

10. Incorporate normal and abnormal operating range indications on applicable instruments.

11. Replace Dymo tape with permanent labels or markers.

12. Color code all component bezels.

13. Add channel identification to emergency feedwater controls.

14. Label dual function vertical scales to identify each scale.

15. Provide increase/decrease labels for the containment spray chemical controllers.

16. Incorporate the requirement to replace burned-out lamps in the procedures.

17. Add phone jacks to the control room back-panel areas.

5.8.2 SONGS 3 License Conditions

The deficiencies identified in the SER that were included in License Condition 2.C(17)c of the SONGS 3 Operating License are summarized below. (The item numbering of these deficiencies is derived from the SER and does not correspond to the rest of the CRDR report.)

SER Section B:

Deficiencies to be Corrected prior to Fuel Loading

1.0 Process Computer

a. The process computer data base is not up-to-date.

b. Operator training is not completed.

c. A window fan is used to cool the process computer console (operators use the top of the console to lay out drawings, causing reduction in air circulation).

d. Data point addresses are not cross indexed by name, system/subsystem or functionally grouped.

e. Glare on the CRT display causes degradation in readability.

2.0 Labeling Errors

a. Containment spray actuation system (CSAS) is mislabeled CCAS.

b. Refueling water flow controller and recorder is mislabeled. Should be primary makeup pump.

c. HPSI and LPSI modulating valves are not labeled as to open/close.

d. Legend for hydrogen purge control on HVAC panel are reversed (open is over the closed position).

3.0 General

a. Verification that safety injection (SI) has occurred is by pattern recognition, primarily strings of red and some green lights. There is no cue on the panel or in procedures to aid operators in reading what the pattern should be.

b. Operator guides to the core protection calculators were not available to the operators in the control room.

Deficiencies to be Corrected prior to Exceeding 5% Power

4.0 Annunciators

a. The annunciators were not priortized.

b. The master acknowledge allows operators to acknowledge alarms from a distant location (without identifying alarms).

c. The lack of an alarm clear signal requires operators to periodically reset annunciators to clear alarms that are back within limits in order for operators to receive current plant status information.

5.0 Control Room Environment

a. It appears that the lighting was arranged without regard for specific task lighting needs for optimum operator performance, readability is impaired on displays due to excessive glare.

6.0 Labels

a. In general, labeling is incomplete and inconsistent. However, the applicants will redo the labeling according to a hierarchical scheme. The examples already in place are clearly an improvement.

b. Foxboro controller for containment spray is not labeled for control (increase, decrease).

c. Scales for reactor coolant (RC) loops hot leg temperature on plant protection panel are not optimally marked (e.g., major numbers are 54, 60, 66).

d. Scales for RC loop hot leg temperature and cold leg temperature on reactor coolant system panel are different from those on plant protection for same parameter (one has an X10 multiplier).

e. SIGMA vertical meters protrude from the board and shadow or obscure labeling below 5 feet and the "White on Red" (Train A) labels.

f. There are some makeshift techniques for indicating normal operating ranges (e.g., pressurizer pressure and setpoint).

g. There is considerable use of Dymo tape and some other temporary labeling.

h. There is no demarcation or color coding of systems or functions.

i. Emergency feedwater system activation controls are not labeled by channel.

j. Dual function vertical scales are not clearly labeled to identify the function of each scale (e.g., RC loops 1-2 temperatures).

k. Containment spray chemical addition (Foxboro controller). The increase or decrease manual position level is labeled where you cannot see it. Also, flow scale does not identify units of measure.

7.0 Lamp Test

There is no separate lamp test for legend switch pushbuttons. These normally have two bulbs and depend on the operator observing the change in intensity to indicate the need for a new bulb.

8.0 Communications

There are no back-panel phone jacks for communications with the main control room area.

SER Section C:

Minor Deficiencies

Our review identified a number of minor deficiencies, which we belive offer no significant risk to full-power operation. However, to ensure that the additional modifications are made to the control room in the most effective and efficient manner, the staff will not require implementation of the minor design deficiencies until SCE has completed the detailed control-room design review to be required of all operating reactors. As a part of this design review, we will require

SCE to evaluate the benefits of installing data recording and logging equipment in the control room to correct the deficiencies associated with trending of important parameters on strip chart recorders in use at most nuclear power plants.

SER Section D:

Incore Thermocouple Instrumentation Display

There are 56 groups of incore detectors, each group having 6 or more detectors (1 detector in each group is a thermocouple). Individual readouts (one group of 5 detectors) or group trending, utilizing 35 predetermined groups, can be provided via the process computer and CRT display. One group at a time can be displayed; from this each of the 5 individual detectors can be read. For the group-trending capabilities, 35 groups are monitored and any 12 detectors can be displayed. The computer provides thermocouple readouts up to 1650°F. The incore thermocouple system is not consistent with the requirements of Item II.F.2 of NUREG-0737, "Clarification of TMI Action Plan Requirements." SCE is evaluating the requirements of NUREG-0737, which requires, among other things, a display of temperature to 1800°F and a backup display to be implemented by January 1, 1982 as required by NUREG-0737.

6.0 IMPLEMENTATION OF CORRECTIVE ACTIONS

6.1 OBJECTIVES

The objective of the Implementation Phase is to remedy the significant HED's identified in the CRDR Assessment Phase and accepted by SCE Management for implementation. An effort was made to give the most important items priority for corrective action. Prioritization was based upon safety considerations, degree of difficulty imposed upon the operator if not corrected, consequences of potential operating errors, cost effectiveness, difficulties in making the modification, plant construction and startup schedules, and equipment availability for outages.

6.1.1 Implementation Methodology

The control room and control panel modifications recommended by the CRDR Working Group and accepted by SCE Management were implemented by an established, closely controlled and scheduled procedure employing the Design Change Package (DCP). The DCP procedure is defined in section 22 of the Bechtel Project Internal Procedures Manual (PIPM). Basically, the DCP contains all the engineering design information required to make the revision, including the description of the change, the reason for it, the initiating document, and all related design drawing change notices or drawing revisions. In addition, the DCP identifies any other plant documents, such as the FSAR, that require revision. Field Construction and Startup install and test the revised design disclosure defined in the DCP in accordance with the established procedures and in coordination with SCE Plant Operations. Upon completion (implementation) of the work, a signed DCP completion sheet is returned to project engineering via the documentation control procedures.

The SONGS Simulator, which duplicates the Unit 2 and common areas of the control room has been maintained in a current configuration through implementation of Simulator Work Orders (SWO) by SCE. These SWOs duplicate the modifications made to the actual plant by the DCP process.

6.2 CONTROL PANEL

Implementation of corrective actions to resolve the control panel HED's are in the following major areas: arrangement, demarcation, labeling, scale coding, component suitability, annunciator, and miscellaneous.

6.2.1 Arrangement

The control panel arrangement recommendations, summarized in paragraph 5.2.1.5, that are identified as Short Term have all been implemented and were completed prior to fuel load.

Following is a summary of the implementation of the Short-Term corrective actions grouped by control room panel:

A. Engineered Safety Features Panel (CR-57)

Relocation of safety injection boric acid and containment purge instrumentation to provide for easier comparison of like sets of instrumentation (25 moves, 7 new cutouts). This implementation was completed by DCPs-77J, 78J, and 79J, prior to fuel load.

B. Reactor Support Panel (CR-56)

Relocation of containment sump pump controls to an area underneath associated indicators (2 moves, 2 new cutouts). This implementation was completed by DCP-80J, prior to fuel load.

C. Primary Energy Panel (CR-58, 50, 51)

Relocation of reactor coolant instrumentation to provide for easier comparison of like sets of instrumentation and eliminate a mirror image arrangement in the reactor regulating system (14 moves, 1 new cutout). This implementation was completed by DCPs-73J, 74J, 75J, and 76J, prior to fuel load.

D. Secondary Energy Panel (CR-52, 53)

Rearrangement of main steam isolation controls, and auxiliary feedwater controls to achieve understandable and logical component arrangement. These relocations were also required as a result of the addition of a third auxiliary feedwater pump (32 moves, 1 new sub panel section). This implementation was completed by DCP-71J, prior to fuel load.

Relocation of auxiliary feedwater pump instruments to permit the operator to more readily determine the status of the steam generators (9 moves, 8 new cutouts). This implementation was completed by DCP-80J, prior to fuel load.

E. Electrical Energy and Waste Heat Panel (CR-54, 64)

Relocation of the component cooling system controls and indicators to eliminate a channel A to B mirror image. Additionally, there was a movement of instrumentation to provide for easier comparison of like instruments (i.e., component cooling water heat exchanger temperature instruments) (46 moves, 6 new cutouts, 9 modified cutouts). This implementation was completed by DCPs-69J and 70J, prior to fuel load.

F. Emergency HV&AC (CR-60)

Relocation of heating, ventilating, and air conditioning controls to make Unit 2 and Unit 3 arrangements identical (10 moves, 8 new cutouts). This implementation was completed by DCP-81J, prior to fuel load.

G. Optimal Arrangement - Present Panels

To obtain straight lines of functional demarcation would require massive movements of display instruments and controls, but could be accomplished without the relocation of panel structural bracing. This arrangement will not be implemented because operating experience to date indicates that there are not sufficient benefits to warrant the implementation of this modification.

H. Optimal Arrangement - By Fabricating New Panels

Additional spacing between functional groups as well as improvements in component locations can be achieved beyond that described in paragraph G, above. Typically, to achieve this type of arrangement and spacing would require the movement of structural bracing within the panel and the fabrication of new panels. These arrangements will not be implemented because operating experience to date indicates that there are not sufficient significant benefits to warrant the implementation of this modification.

6.2.2 Demarcation

The control room panel demarcation recommendations summarized in paragraph 5.2.2.5 have been implemented and were completed prior to initial criticality of the reactor. These panels were demarcated by functional groups to identify the hierarchy by using color Scheme Three with flat paint utilized on the panel and instrument bezels. Demarcation was implemented by DCP to the following control panels: Engineered Safety Features Panel (CR-57)(DCP-109J), Reactor Support Panel (CR-56)(DC-108J), Primary Energy Panel (CR-58, 50, and 51)(DCP-110J), Secondary Energy Panel (CR-52, 53)(DCP-106J), Electrical Energy and Waste Heat Panel (CR-54, 64)(DC-107J), Emergency HV & AC (CR-60)(DCP-111J), Electrical Mimic Panel (CR-63) (DCP-113J), Plant Services Panel (CR-61)(DCP-112J), and Computer Console (CR-55) (DCP-167J).

Painting of the Operators Desk (CR-65) was completed by DCP-168J, prior to fuel load.

6.2.3 Labeling

The control panel labeling recommendations summarized in Paragraph 5.2.3.5 were completed prior to fuel load and a slightly modified approach was utilized to combine the recommendations into meaningful work packages. The two basic work packages to accomplish the recommendations were defined as follows:

6.2.3.1 Labeling (Legend Hierarchy)

A. Implement a hierarchical system of labeling to the component level.

B. Correct errors, inconsistencies, shadowing and missing labels.

C. Relocate labels from present bottom locations to top of the components.

D. Eliminate redundancy of information wherever possible; labels that duplicated the information on the pushbutton switchlight (Master Specialties) stations were deleted. The new or replacement labels (legend plates) were fabricated with anti-glare material.

6.2.3.2 Labeling (Nomenclature and Glare Reduction)

A. Clarification of the information contained on the pushbutton switchlight (Master Specialties) stations.

B. Utilization of non-glare lenses on all the pushbutton switchlight stations in the control room panels.

The following is a summary of the implementation of the labeling recommendations listed by control room panel with the legend hierarchy DCP listed first and the nomenclature and glare reduction DCP listed last; Engineered Safety Features Panel (CR-57)(DCPs-117J, 209J, and 125J), Reactor Suport Panel (CR-56)(DCPs-116J and 124J), Primary Energy Panel (CR-58, 50, and 51)(DCPs-118J, 209J, and 126J), Secondary Energy Panel (CR-52, 53)(DCPs-114J, 209J, and 122J), Electrical Energy and Waste Heat Panel (CR-54, 64)(DCPs-115J, 209J, and 123J), Emergency HV&AC (CR-60)(DCPs-119J, 209J, and 127J), Electrical Mimic Panel (CR-63)(DCPs-121J and 129J), and Plant Services Panel (CR-61)(DCPs-120J and 128J).

6.2.4 Scale Coding

The control panel scale coding recommendations, summarized in paragraph 5.2.4.5 have all been implemented in accordance with the recommendations. DCP-130J was completed to implement the installation of scale codings on 214 instruments located on the control room panels. Five additional DCPs-286J, 290J, 277J, 219J, and 278J were implemented to correct and revise the scale coding based upon operating experience. These five DCPs revised the scale coding of 157 instruments on the various control room panels. Scale coding was applied to the applicable instruments on the following control panels; Engineered Safety Features Panel (CR-57), Reactor Support Panel (CR-56), Primary Energy Panel (CR-58, 50, and 51), Secondary Energy Panel (CR-52, 53), Electrical Energy and Waste Heat Panel (CR-54, 64), Emergency HV&AC Panel (CR-60), Electrical Mimic Panel (CR-63), and Plant Services Panel (CR-61).

6.2.5 Component Suitability

The component suitability review summarized in paragraph 5.2.5.5 indicated that the instrument components satisfy the human factors requirements and no recommendations for corrective action were made.

6.2.6 Annunciator

The annunciator recommendations, summarized in paragraph 5.2.6.6, have been identified as short term implementations, paragraph 5.2.6.6.1, and long term implementations, paragraph 5.2.6.6.2. Certain short term and long term recommendations have been implemented and are discussed in the following sections.

6.2.6.1 Short Term Recommendations and Implementation

A. Prioritize the annunciator by color. Implementation of this recommendation for a four color prioritization of the control room annunciators on main control room panels CR-57, CR-56, CR-58, 50 and 51, CR-52, 53, CR-54, 64, CR-60, CR-63, and CR-61 was completed by DCP-96J, prior to fuel load.

B. Delete the two annunciator master "Acknowledge" and "Reset" control switchlights. Implementation of this recommendation was completed by DCP-65J, prior to fuel load.

C. Add an annunciator master indicating light mimic. Implementation of this recommendation was completed by DCP-89J, prior to initial criticality of the reactor.

6.2.6.2 Long Term Recommendations and Implementation

A. Revise the annunciator internal circuitry to provide "ringback" feature to notify operator when an alarm has returned to normal. Limit the ringback audible feature to 2-seconds duration. Implementation of this recommendation was completed by DCP-67J, prior to fuel load.

B. Annunciator window messages should be reviewed by Engineering for clarity, consistency and acceptability of abbreviations. Implementation of this recommendation was completed by DCP-213J, DCP-270J, and DCP-1211J. Additional work was implemented by the Annunciator Nuisance Alarm Task Force described in subsection 6.8.1 of this document.

C. Complete upgrading the information on elementary wiring diagrams, P&IDs, alarm response procedures, and annunciator lists to provide missing information and eliminate inconsistencies. Upgrading of the information contained on these engineering documents has been completed and these documents continue to be revised on an as needed basis.

6.2.7 Color Usage

The Scheme Three color usage recommendation summarized in paragraph 5.2.7.5 was implemented for all the control room panels. Implementation of color Scheme Three was accomplished by the same DCPs that accomplished the demarcation of the control room panels and are as follows: Engineered Safety Features Panel (CR-57)(DCP-109J), Reactor Support Panel (CR-56)(DCP-108J), Primary Energy Panel (CR-58, 50, and 51)(DCP-110J), Secondary Energy Panel (CR-52, 53)(DCP-106J), Electrical Energy and Waste Heat Panel (CR-54, 64)(DCP-107J), Emergency HV & AC (CR-60)(DCP-111J), Electrical Mimic Panel (CR-63)(DCP-113J), Plant Services Panel (CR-61)(DCP-112J), Computer Console (CR-55)(DCP-167J), and Operators Desk (CR-65)(DCP-168J).

6.2.8 Miscellaneous

Recommendations made by the CRDR Working Group to correct certain miscellaneous related findings are summarized in subsection 5.2.8. Furthermore, several findings of the NRC Audit team fall into this category. Implementation of both the CRDR and NRC audit findings are discussed below:

6.2.8.1 Guard Rails for Operating Panels

The guard rail recommendation, summarized in paragraph 5.2.8.1.3 was implemented for control panels CR-56; CR-57; CR-58, 50, and 51; CR-52 and 53; CR-54 and 64, and CR-61. This was completed by DCP-5A, prior to operation at 5% power level.

6.2.8.2 Indicating Graphics Panels

The indicating graphics panel recommendation, summarized in paragraph 5.2.8.3.5 indicated that no additional use of mimics or graphics on the control panels and therefore no implementation action is required.

6.2.8.3 Process Computer Cooling

The process computer cooling recommendation as discussed in the SCE Response to NRC Audit Finding No. 3.3.g was implemented in accordance with the recommendation. Installation of a drawing shelf on the computer console (panel CR-55) to allow air circulation was completed by DCP-165J, prior to fuel load.

6.2.8.4 Process Computer CRT Glare

The process computer CRT glare recommendation as discussed in the SCE Response to NRC Audit Finding No. 3.3.e was implemented in accordance with the recommendation. Installation of glare filter on the computer CRT (panel CR-55) was completed by DCP-166J, prior to fuel load.

6.2.8.5 ESF Pattern Recognition

The ESF pattern recognition recommendation as discussed in the SCE Response to NRC Audit Finding No. 3.5.k was implemented in accordance with the recommendation. Drawing No. 90024 was issued prior to fuel load. Color coded drawings of control panel CR-57 are provided to aid the plant operator in the recognition and identification of ESF system components required for correct operation of an ESF system (Containment Isolation, Safety Injection, and etc.)

6.3 COMPUTER SYSTEMS

The modifications and training necessary to resolve the five Category 1 computer system HEDs were completed prior to fuel load. The single Category 2 HED relating to the PMS data point ID cross-index was resolved by analysis without modification.

The remaining computer system HEDs are all in Category 3. Two of these will not require modifications since the PMS printers are for later analysis only and not primary operating devices. Prioritization of the PMS alarm displays, a Category 3 HED, was implemented by revising the alarm point ID designations.

Ongoing studies, which address the availability and potential obsolescence of the existing computer system, may result in replacement of the PMS at which time discrepancies in the existing system would be considered during development of the design criteria for the replacement PMS. Additionally, with the installation of the CFMS and QSPDS capabilities, the majority of the previously identified HEDs have been significantly reduced or eliminated.

6.4 CONTROL ROOM

6.4.1 Communications Survey

The communications survey indicated that the communications systems were adequate and no recommendations were made for improvements, paragraph 5.4.1.2. In response to the NRC Audit (NRC 3.8a) twelve additional sound-powered phone jacks were installed in the back area of the Main Control Room. The implementation of this task was accomplished by DCP-259E.

6.4.2 Lighting System

The lighting system recommendations summarized in paragraph 5.4.2.4 and listed below were implemented and completed as required. Details about the work that was accomplished are described in the paragraphs cited.

A. Replace Master Specialties pushbutton switch lenses with anti-glare lenses, paragraph 6.2.3.

B. Substitute Lamicoid legend plates with anti-glare plate materials, paragraph 6.2.3.

C. Repaint control panels and instrument bezels with flat paint as recommended by the Whitston Associates reports, paragraph 6.2.7.

D. Provide hood covers for existing CRTs, paragraph 6.2.8.4.

E. Replacement and/or optical coat the indicator lenses as determined by engineering and degree of acceptability, paragraph 6.2.3.2.

6.4.3 Sound Survey

Sound survey recommendation to add carpeting will be implemented by SCE DCPs 2-1500SA and 3-1500SA as the material is available, presently forecast for implementation prior to startup following the refueling outage.

Possible addition of sound panels and control room doors will be delayed until sound level measurements are taken after both Units 2 and 3 achieve commercial operating status. Data to date indicates no additional changes will be required to the control room to meet the sound survey criteria.

6.4.4 Heating, Ventilating and Air Conditioning

The temperature, humidity and air velocity survey will be based on measurements taken by an environmental survey team consisting of SCE employees familiar with the station and its equipment. These personnel will consist of the following:

- Instrument and Control Engineer
- Industrial Hygienist
- Station operating personnel

Other SCE personnel to assist in data collection and recording as needed.

The survey will consist of two parts: Measurement and collection of data and evaluation. The control room will be segmented using the following approach:

- The segmented areas will correspond to the primary operator work stations.
- Data will be collected in each area.
- Data will be recorded on the appropriate data record form.

For the temperature-humidity part of the survey readings in each area will be taken at:

- Floor level
- Six (6) feet above floor level

Readings will be taken every hour over a 24-hour period. It is expected that the results of the temperature-humidity survey will show that the climate control system will maintain the control room, under normal conditions within the ASHRAE comfort zone of 55-74, with air movement of less than 45FPM. Temperature differential is expected to be not more than 10^{o}F between floor level and six feet above the floor.

For the ventilating part of the survey, measurements will be taken at the principal operator stations.

Readings will be taken at elevations of:

- Six feet above the floor
- Four feet above the floor

It is expected that the results of the ventilation survey will show that the ventilation system is capable of introducing outside air into the control room at a rate of at least 15CFM per occupant and that air velocity will not exceed 45FPM at the six foot above the floor level.

The survey for temperature, humidity and ventilation will be completed subsequent to commercial power date and all aspects of the Environmental Survey will be completed by first refueling.

6.5 SYSTEM FUNCTION IDENTIFICATION AND ANALYSIS (IMPLEMENTATION)

Based on the findings of the System Function Identification and Analysis Activities several improvements were made in the control room.

Process flow diagrams were generated for all systems and now provide an integral part of the operator training and system diagnostic exercises.

The Functional Grouping Activity has been subjected to the analyses previously described and the approximately 150 instrument relocations (Category 1) cited in subsection 6.6 have also contributed to a better defined functional grouping which allowed clean demarcation and hierarchical labeling on the Control Panels.

6.6 VERIFICATION OF TASK PERFORMANCE CAPABILITIES (IMPLEMENTATION)

6.6.1 Instruments and Controls

Based upon the findings for this activity approximately 150 instruments were relocated in the control room panels. (For further discussion of this see subsection 6.2.1.)

The cases where it was necessary for operating personnel to get information external to the control room were evaluated by the staff, and operating procedural guides have been implemented.

6.6.2 Annunciator System

All annunciator control room windows (1,250 Unit 2 + Common) were reviewed and assigned a priority class (see subsection 5.2.6). Implementation of a four level prioritization was completed by addition of color film to the windows.

6.7 CONTROL ROOM FUNCTIONS VALIDATION (IMPLEMENTATION)

The Control Room Functions Validation examined two specific areas of Control Room functions. Those were:

- o Normal Operations
- o Emergency Operations

Based on the findings of this activity, the complete set of normal operating instructions were reformatted and rewritten to be consistent. This resulted in improved operation response and understanding.

Since the normal operating procedures are continually being used during everyday control room operation it is certain that inconsistencies in the implementation of these operation tasks and functions have been identified and corrected.

The need for Drawing Files and Technical Manual Files was illustrated clearly, and to accommodate this, specific file areas were assigned and supplied as well as layout areas for these documents.

6.8 ONGOING EFFORTS TO UPGRADE THE CONTROL ROOM

Ongoing efforts to eliminate Human Engineering Deficiencies (HEDs) and upgrade the control room and panels continue, following the intial CRDR efforts. These ongoing efforts have been generally concentrated in the following areas:

- Implementation of the Annunciator Nuisance Alarm Task Force recommendations.
- Resolution of Startup Problem Reports (SPRs) that are applicable to the HEDs related to the control room and panels.
- Continued implementation of the original CRDR design criteria as applied to instruments and controls not previously addressed.

The annunciator nuisance alarm DCPs are summarized in paragraph 6.8.1 but all findings were developed after the original CRDR activities had been completed. Implementation of the DCPs to resolve the SPRs are summarized in paragraph 6.8.2.1. Implementation of the DCPs for continued implementation of the original CRDR design criteria are summarized in paragraph 6.8.2.2.

6.8.1 Elimination of Annunciator Nuisance Alarms

A. In September 1982, after starting operation at the 5% power level, it became apparent that there were spurious or nuisance alarms displayed on the Unit 2 control room annunciator. A program was initiated at this time to identify and resolve all problems associated with the alarms. The specific task was to:

1. Review all annunciator alarms and resolve which alarms were valid and which were non-valid (spurious or nuisance).
2. Determine the problem associated with the non-valid alarms.
3. Resolve the problems identified.

B. A list was prepared of the Unit 2 and common alarms that were believed to be non-valid and in need of investigation. A similar program was initiated on Unit 3 and a list of the Unit 3 alarms that merited investigation was added to the Unit 2 and common list for a total 243 windows. As the review of the Units 2, 3, and common annunciator windows progressed, the design problems were classified into four areas:

1. Windows alarm with equipment out of service, 60%.
2. Windows alarm because of low process conditions present at low power levels (Plant mode), 20%.
3. High/low alarm windows that have no means for operator to determine if alarm is high or low, 16%.
4. Inappropriate control logic, 4%.

Implementation of the recommended corrective action has resulted in the preparation of 79 DCPs, affecting 224 windows, for the Units 2, 3, and common annunciators. These DCPs have been completed by Engineering and are in various stages of implementation. Another group of 16 DCPs, affecting 61 windows for the Units 2, 3, and common annunciator have been identified and are pending completion of the engineering analysis. It should be noted that this total of 285 windows reviewed in the ongoing effort to eliminate nuisance alarms represents approximately 11 percent of the total annunciator windows available to the operator.

6.8.2 Other Improvements

As previously noted, other improvements resulted from SPRs and continued implementation of the CRDR design criteria to other instrumentation and controls not previously addressed. These are summarized in the sections that follow.

6.8.2.1 Startup Problem Reports (SPRs)

SPR 909 resulted in DCP-132J to connect three retransmitted alarms and delete one alarm from the plant monitoring system. Implementation of this DCP is complete.

SPRs 2351, 2597, 2763, and 2884 resulted in DCP-270J to revise six annunciator window engravings, drawings, and input wiring. Implementation of this DCP is complete.

SPRs 4252 and 4260 resulted in DCP-911.3N to revise two annunciator windows to provide separate alarms for the high range in-containment radiation monitors. Implementation of this DCP is complete.

SPR 4817 resulted in DCP-1211J to revise 17 annunciator window engravings to satisfy SCE Operations requirements and for conformance to issued drawings. Implementation of this DCP is complete.

SPR 4780 resulted in DCP-1242J to relocate two handswitches on the Secondary Energy Panel (CR-52) to correct a labeling error. Engineering has been completed on this DCP, and it is presently at site awaiting implementation.

SPRs 2588, 2589, and 2621 resulted in DCP-255J to install six revised nameplates on the main control panels, CR-50, CR-52, CR-61, EFAS-1, and EFAS-2. Implementation of this DCP is complete.

SPRs 2631, and 2666 resulted in DCP-256J to replace four pushbutton light lenses on the Engineered Safety Features Panel (CR-57) and install two revised nameplates on the Primary Energy Panel (CR-58, 50 and 51). Implementation of this DCP is complete.

SPRs 2480 and 2775 resulted in DCP-278J to revise the instrument scales on four instruments on the Engineered Safety Features Panel (CR-57), one instrument on the Recorder Panel (CR-59), and one instrument on the Electrical Mimic Panel (CR-63). Implementation of this DCP is complete.

SPRs 3358, 3772, and 4185 resulted in DCP-886J to replace the scales on five instruments on the Electrical Energy and Waste Heat Panel (CR-54, 64), three instruments on the Engineered Safety Features Panel (CR-57) and one instrument on the Plant Services Panel (CR-61). Engineering was completed on this DCP, and it is presently at the site awaiting implementation.

6.8.2.2 Continued Implementation of CRDR Design Criteria

DCP-213J was issued to; revise the annunciator prioritization, revise annunciator window engraving, add new windows, and replace revised annunciator windows all resulting from revised system requirements. Implementation of this DCP is complete.

DCP-285J was issued to implement the control room legend, nomenclature, and demarcation modifications requested by SCE for the Engineered Safety Features Panel (CR-57) (12 instrument bezels repainted, and 43 nameplates changed), Reactor Support Panel (CR-56) (three nameplates changed), Primary Energy Panel (CR-58, 50, and 51) (25 nameplates changed), Secondary Energy Panel (CR-52, 53) (four pushbutton light lenses, and 14 nameplates changed), Electrical Energy and Waste Heat Panel (CR-54, 64) (one pushbutton light lense and 77 nameplates changed), Emergency HV and AC (CR-60) (nine nameplates changed), and Plant Services Panel (CR-61) (one nameplate changed). Implementation of this DCP is complete.

DCP-982.0J was issued to implement the human factors improvements to the Secondary Energy Panel (CR-52, 53) (two instrument relocations) per SCE request. Engineering was completed on this DCP, and it is presently at the site awaiting implementation.

DCP-1086N is in preparation to implement labeling and nomenclature revisions to the Reactor Support Panel (CR-56) (one annunciator window, four instrument nameplates and four pushbutton switchlight lenses). Preparation of the DCP to implement these revisions is in work.

DCP-219J was issued to implement installation of scale coding on level indicators on the Emergency HV and AC Panel (CR-60) (tab indicators) and the Electrical Mimic Panel (CR-63) (one indicator). Implementation of this DCP is complete.

DCP-279J was issued to change one instrument scale on the Essential Plant Protection Monitoring System Panel (L-411) from narrow range to wide range. Implementation of this DCP is complete.

DCP-161J was issued to provide backup display for the core exit thermocouples in addition to the computer inputs for the CFMS on the Primary Energy Panel (CR-58, 50, and 51) (added TI-0926). Implementation of this DCP is complete.

DCP-1090J implemented separate controls and audible alarms for the annunciator system on a unitized basis. Separate "Acknowledge" and "Reset" pushbuttons in addition to individual audible alarms now exist for each unit and for the common alarms.