BWR OWNERS GROUP

CONTROL ROOM IMPROVEMENTS COMMITTEE

HUMAN FACTORS DESIGN REVIEW

OF THE

LIMERICK 1 & 2

CONTROL ROOM

SUMMARY REPORT

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1.0 SUMMARY

In response to recently formulated regulatory requirements for design reviews of nuclear power plant control rooms (NUREG-0660, NUREG-0700), Philadelphia Electric Company has undertaken a human factors evaluation of the Limerick control panels. This one week review was performed by operations and engineering personnel from four utilities, two human factors consultants, and representatives from General Electric Company. General conclusions of the survey team are as follows:

1.1 Favorable Aspects of Control Room Design

1. Most instrumentation and hardware is located on panels within anthropometric guidelines.

2. Panels define main system operating areas.

3. Controls are generally functionally grouped.

4. Component labels are generally very explicit and consistently positioned.

5. Annunciators are generally grouped by system within panels and are placed above related controls and displays.

6. Panels are all identified by both number and system label.

7. Use has been made of both demarcation lines and mimic arrangements to organize system layouts.

1.2 General Recommendations for Enhancement

Panel Layout and Design

1. Vertical panels have controls and displays mounted above and below recommended heights. Relocation of components, where feasible, should be considered.

2. In many instances, functional groupings of controls and displays could be enhanced with demarcation lines and summary labels.

3. Some aspects of mimic layouts could be improved. Flowpaths should be readily apparent and crowding avoided.

4. A hierarchical labeling system should be instituted.

5. Large arrays of closely spaced components should be separated through the use of demarcation lines, hierarchical labeling, and spacing techniques.

Instrumentation and Hardware

1. Control room indicators and recorders should be reviewed to determine which would benefit from the addition of markings or color coding to indicate normal and abnormal ranges.

2. Non-standard indicator scales should be avoided.

3. Relocation of some instrumentation and hardware should be considered to avoid potential problems associated with glare, parallax, hand support, and general readability.

4. Multi-point recorders should be used only where such a format is applicable. Where used, consideration should be given to more widespread application of point select capability.

5. A lamp test feature should be considered.

6. Emergency switches should be clearly marked for position.

Annunciators

1. The use of a separate silence button is recommended.

2. Alarm panels should be identified by coded label.

3. Annunciator window legends should be reviewed to determine which would benefit from the use of more succinct wording.

Emergency Procedure Instrumentation

1. Indicators and recorders should be provided with range markings identifying action levels addressed in emergency procedures.

2. Certain modifications of display methods and formats could enhance the effectiveness of the control room as an operator aid during transient conditions.

3. Some information potentially useful to the operator is not available in the main operating area of the control room.

4. Some modification of instrumentation may be necessary to enable the operator to evaluate the state of the plant in accordance with certain considerations addressed in the guidelines.

2.0 INTRODUCTION

This report summarizes findings of a one week preliminary human factors review of the Limerick control panels using methodology developed by the Control Room Improvements Committee of the BWR Owners' Group. A review team comprised of operations and engineering personnel from four utilities performed the evaluation, with the assistance of two human factors specialists and representatives from General Electric Company (see Table I).

The scope of this preliminary review was defined so as to be commensurate with the current status of the control room. Because Limerick is not yet operational, it was not possible to evaluate some sections of the BWR Owners' Group Control Room Survey checklists. These have been listed in Appendix A and should be reviewed at a later phase in plant construction.

Table II lists the panels evaluated by the survey team during the review. Each panel was compared to a set of design criteria in checklist form developed from recognized human factors standards. These checklists provided detailed guidelines for panel layout, panel design, instrumentation, hardware, and annunciators.

While the control room evaluation concentrated primarily on Unit 1, both Units are essentially identical. Therefore, all conclusions discussed in this report should be considered applicable to both units.

Sections 3.0 through 5.0 provide complete lists, grouped by subject, of all checklist items for which control room modification should be considered. After each entry, the applicable checklist cross-reference has been placed in parentheses. A prioritization of potential enhancements is also included in the form of Evaluation Products. These products have been derived from two numerical rating factors, one indicating the degree to which the panel under consideration complies with the checklist criterion, the second representing the relative likelihood that non-compliance with that item could cause or contribute to operator error. The products of the two factors are then categorized as follows:

9-12 - Modification is recommended
8 - Modification should be strongly considered
6 - Modification should be considered
4 - Modification may be beneficial in some cases

Final recommendations for backfits should be determined by the utility in an item-by-item review of these concerns as part of an integrated approach to control room upgrades. This should include an analysis of the safety significance and frequency of use of the components and systems involved, the consequences of operator retraining required by the change, and the engineering practicalities of instituting the change. Inputs should be obtained from operations, engineering, training, and human factors specialists.

This report identifies areas of control room design for which modifications should be considered, stated as general suggestions with the understanding that corrective action should be considered on a control room wide basis. While specific examples have been provided wherever possible, this document is not designed to serve as an all inclusive list of every piece of hardware for which modification may be beneficial. Nor is it intended to recommend specific improvements for the concerns discussed. Topics such as control panel layout should be given very careful review prior to instituting a change as these concerns involve many interrelated factors which must be considered in parallel.

TABLE I

SURVEY TEAM MEMBERS

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Gerald Rainey, Philadelphia Electric Company

Wallace Colvin, Cleveland Electric Illuminating Company

Byron Thibodeaux, Gulf States Utilities

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TABLE II

CONTROL ROOM PANELS REVIEWED

10C-600	10C-654
10C-601	10C-655
10C-602	00C-656
10C-603	00C-660
10C-607	10C-661
10C-610	00C-667
10C-614	10C-668
00C-624	10C-669
10C-626	10C-670
10C-647	00C-671
10C-648	00C-681
10C-649	10C-681
00C-650	00C-693
10C-651	10C-696
10C-652	Emergency Shutdown
10C-653	

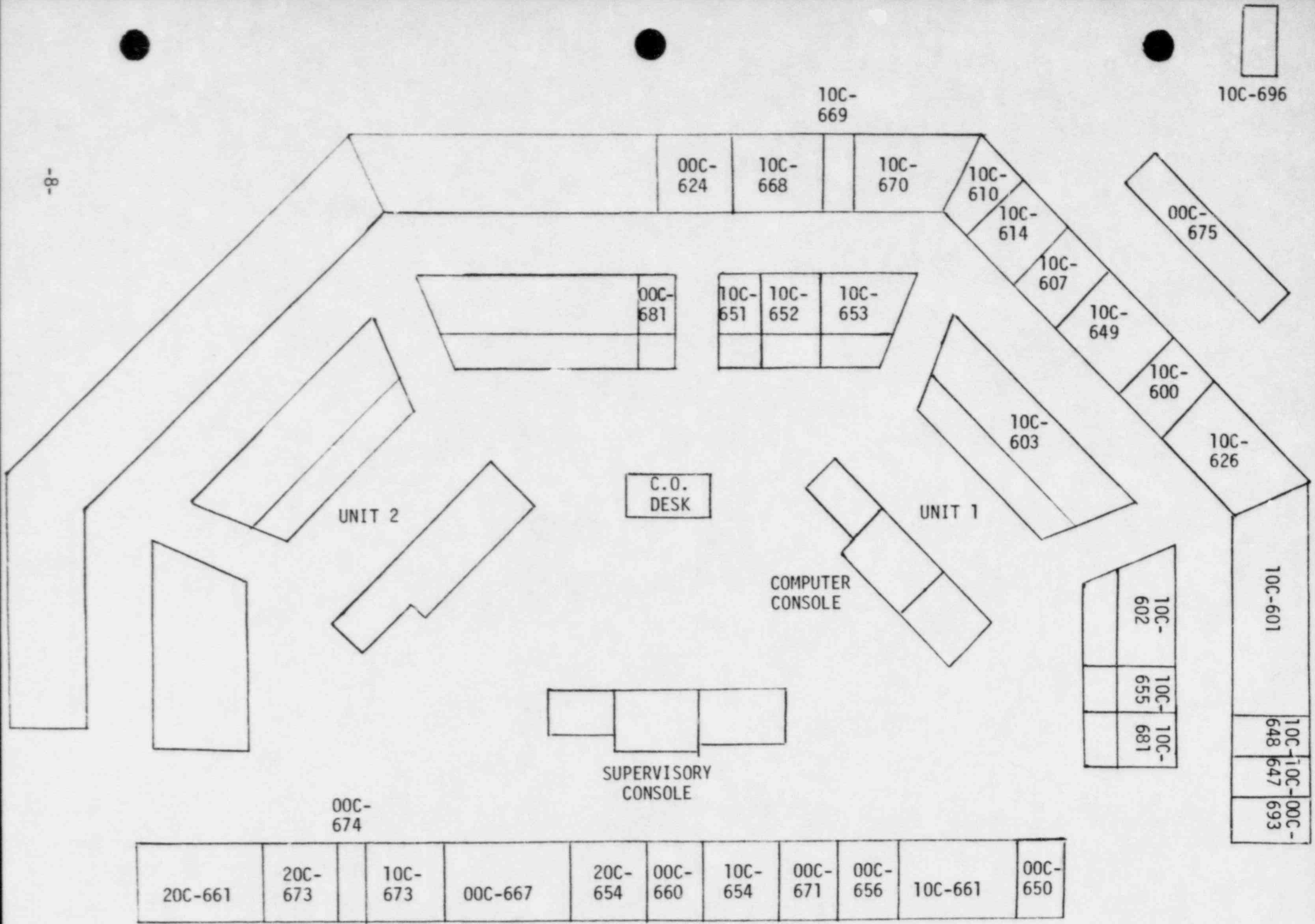


FIGURE 1. CONTROL ROOM ARRANGEMENT

3.0 CONTROL PANEL LAYOUT AND DESIGN

Control panels were evaluated against checklist standards covering anthropometrics, panel arrangements, mimic and demarcation lines, control/display grouping, color codes, and labeling systems.

Several positive aspects of panel design were evident, suggesting that considerable attention has already been paid to human factors engineering in the Limerick control room. Overall panel dimensions generally conform to recommended standards, controls and displays are functionally grouped, demarcation lines are used to define system operating areas and mimic lines have been added to some system layouts. However, several areas were noted in which control room design could be further enhanced, resulting in a still more effective man-machine interface.

While overall panel dimensions are in close compliance with checklist standards, controls and indicators were often found mounted above and below recommended heights on most vertical panels. Indicators were found as high as 92" and as low as 22", and controls were found as high as 80" and as low as 20". (The recommended range for vertical panel indicators is 48" to 68"; for controls, 42" to 60".) Also, all annunciators in the primary operating area exceed the maximum recommended height of 88" (top row is 118" high).

Controls and displays have generally been functionally grouped by system on each panel. However, these groupings could be made more discernible through the use of spacing techniques, demarcation lines, mimics and a hierarchical labeling system. On many panels controls and displays have been spaced to define system operating areas, but this technique could be extended to arrays of components such as the many switches on panel 10C-668. Demarcation lines have been used to define system areas. Demarcation lines could also be used to enhance some subsystems of components, to further separate systems on some vertical panels, and to clearly offset components such as trip, manual isolation, and annunciator response buttons. Mimic layouts have been used to organize the ECCS system and electrical system components. The ECCS mimics could be further organized to eliminate congestion and simplify flow paths. The use of mimics could also be extended to other systems in the control room such as the ESW system. System summary labels have been provided in many locations, however, the existence of repetitive labels is still apparent. Incorporating a hierarchical labeling system would eliminate much of this redundancy, result in more succinct labels, and enhance functional groupings of controls and displays.

Two panels, OOC-681 and OOC-667, were noted which, besides the use of enhancement techniques previously mentioned, could benefit from the rearrangement of components into functional and easily recognizable systems. The Heating and Ventilating Console, OOC-681, is rather disorganized and, for the most part, mirror-imaged. The ESW control panel, OOC-667, was noted by operators interviewed to be very confusing to operate.

The mimics used on the ECCS panels could be improved with respect to both materials and installation. Coloring of mimic bars could be brighter, arrangements simplified, and mimic lines made straight.

3.1 Anthropometrics

	Evaluation Product[1]
1. The design of benchboard panels generally conforms closely to anthropometric measurement standards. The majority of vertical panels however, do not meet the measurement standards. Also, annunciators are located above 88", with the top row at a height of 118" (except panels 675 and 696). (A1.1)	6

[1]See Section 2.C for explanation of Evaluation Products.

	Evaluation Product
2. The Generator and Auxiliary Power panels, 10C-654 and 20C-654, are mirror imaged. (A1.2)	8
3. The path to and view of vertical panels located behind the benchboards is obstructed by the benchboards. This is especially of concern for the ECCS panels. In addition, the view of the ESW panel is somewhat obstructed. (A7.1, A7.2)	9
4. Annunciator windows for the meteorological alarms, panel 00C-675, and for the post LOCA hydrogen recombiner panels, 696, are not visible from the primary control area. (A7.3)	6

3.2 **Demarcation Lines and Mimics**

1. The Heating and Ventilating Common Console 00C-681 is not distinguished from panel 20C-681 by demarcation lines or other graphic display (Photo #1). (A2.1)	8
2. Part of the demarcation line which distinguishes the common panel 00C-656 is missing. (A2.1)	4

3. Extensive use has been made of demarcation lines on benchboards and some vertical panels. In conjunction with mimics such as those used on the ECCS and electrical panels and spacing techniques, controls and displays have been generally grouped per system and separated between systems. Areas where the use of demarcation lines (and hierarchical labeling) could provide further distinction of system operating areas include: (A2.2) 6

Enclose sets of related indicators, panel 652

Enclose related turbine and main steam displays and selector switches, panel 653

Separate RFPT controls and IRM/APRM range switches and indicating lights, panel 603

Separate and highlight reactor manual scram buttons, panel 603 (Photo #2)

Continue demarcation lines to vertical portion of panel 655

Highlight annunciator response buttons on applicable panels

Enclose related displays and controls, panel 00C-681 (Photos # 1, 3)

	Evaluation Product
Enclose related displays, panels 647 and 648	6
Enclose related electrical meter displays and synchroscopes, panels 654 and 00C-660	
Enclose fire pump displays and controls, panel 00C-650	
Separate and enclose related sets of small indicators, pushbuttons, and switches on panel 670	
Separate MSIV inboard division 1 and outboard division 2 and ADS division 1 and 3, panel 626 (Photo #4)	
4. Graphical aids and/or hierarchical labeling techniques have generally not been used to separate similar subgroups of components within system groupings on all benchboards.	12 HIGH PRIORITY
These techniques could also be used on vertical panels such as: (A2.3)	6
Distinguish main steam line inboard and outboard isolation switches, panel 601	
Separate meters for safeguard transformers, auxiliary switchgear, and start-up buses, panel 00C-660	

Divide motor and diesel driven remote start switches and indicators for fire pumps, panel 00C-650

Within switch arrays of panel 668 (Photo #5)

Separate systems within divisions of MSIV inboard and outboard leakage control, panel 626 (Photo #4)

5. Mimics used in the LPCS, RHR, and containment control systems, panel 601, use two different widths of bars. In most instances the wide mimic bars refer to the primary flow path while the narrow mimic bars refer to secondary flow paths. A few places exist where primary width bars have been utilized for secondary flow paths. These include: (A2.4) 4

Flow paths from the core spray pumps to the minimum flow bypass valve (Photo #6)

Main steam drain lines from the main steam lines to the equalizer valve

Bypass line through the RHR pump minimum flow valve

Also, the flow paths through the steam line warmup bypass valves in the RCIC and HPCI mimics of panels 648 and 647, are shown as primary rather than secondary.

6. Red, dark green and dark blue mimics are used on panel 601. Each of these mimics is visually distinctive against the panel background. However, the contrast between dark green, dark blue and black demarcation lines is of a lower quality. The corresponding mimics used on the simulator are much brighter and provide good visual contrast. (A2.5) 4

7. Mimics used on panels 601, 647, and 648 appear to be of low quality and to have been installed without the proper care. (A2.6) 8

8. Pieces of mimics or demarcation lines are missing in the following cases: (A2.6) 4

   From the HPCI pump discharge valve, panel 647

   Steam trap to the steam line drain inboard isolation valve, panel 647

   Discharge of the barometric condenser vacuum pump, panel 647

Demarcation line between RHR A and B systems, panel 00C-667

Extension of demarcation line on panel 00C-656

A piece of the 13.2 KV bus mimic, panel 10C-654

9. Flow paths and arrangements on panel 601 are not orderly nor easily recognized. In core spray system A, the mimic bar from pump 1C to the minimum flow bypass valve should not connect with the pump 1A line. Likewise, the mimic bar from the pump 1A line to the bypass valve should connect. 12

RHR 1A mimic lines for minimum flow bypass and suppression pool sparger flow appear to connect, but should not.

Some flow arrows are misplaced such as that to the A containment hydrogen recombiner cooling water inlet valve.

Main steam drain lines appear to flow into the main steam lines rather than bridging them.

RHR service water crosstie mimic flow arrow is pointing to an end point labeled "from RHR switch system." (Photo #7)

Core spray B suppression pool return lines for test and minimum flow bypass are very close and congested with the main turbine stop valve and a demarcation line. Congestion is also evident in the mimic lines from the pumps to the bypass valve. (A2.7)

10. Flow paths for the RCIC and HPCI systems of panels 648 and 647 are somewhat confusing. The steam traps on the steam drain lines appear to be bypasses and the drain pot bypass valves appear to be the main flow path. Also, the steam trap symbol is missing after the turbine drain pot in the HPCI mimic. (A2.7) 6

11. In safeguard system B, panel 661, safeguard switchgear feeder breaker synchronizing switch 101-D12 appears to connect with the 201 safeguard bus. This mimic line should connect with the 101 bus (Photo #8). (A2.7) 6

12. The control rod display of panel 649 presents a large array of small lights. It is very difficult to locate a specified position in this array, even with the aid of position labels along the sides. The use of small lines from position numbers to the edge of the array may aleviate some of this difficulty (Photo #9). (A2.7) 6

	Evaluation Product
13. A line of demarcation between the reactor water sample line isolation valve switches and the recirculation flow loop A system would clearly show recirculation systems A and B to be identical in layout, panel 602. (A2.8)	6
14. Flow arrows used in mimics on panels 601, 647, and 648 are generally located at the end of a mimic bar between components. Some use of intermediate flow arrows may clarify flow paths, especially where the paths are complex (not straight lines). (A2.9)	4
15. The end point from the barometric vacuum pump in the HPCI mimic panel 647, is not identified. (A2.10)	4
16. The destinations for the 220 KV plant output lines are not identified. (A2.10)	4
17. The mimics of panels 647 and 648 do not integrate manual valves. (A2.11)	4
18. The use of mimics may be advantageous to integrate components on the post LOCA hydrogen recombiners, panel 696, and to integrate remote start switches for fire pumps on panel 00C-650. (A2.11)	8

Evaluation Product

3.3 **Control Display Grouping**

1. The following displays and controls are mirror-imaged and as such do not provide identical lay-outs for repetitive groups nor consistent component ordering: (A3.1, A3.2) — 9

   Controls on panel 00C-681 (Photo #1)

   Circular meter displays of panel 00C-660 (Photo #10)

   Displays and controls between panels 10C-654 and 20C-654 (Photo #10)

2. The turbine bearing lift pump inlet pressure test buttons, inlet pressure reset buttons, and pump control arrays are not laidout identically, panel 670. (A3.1) — 6

3. The feedwater drain to feedwater heater switches and the feedwater heater dump and drain indicating lights are not all grouped together, panel 668. The feedwater heater dump to condenser switches and the moisture separator dump and drain lights separate these groupings (Photo #11). (A3.1) — 6

4. The RFPT turning gear switches of panel 603 are ordered from top-to-bottom (Photo #12), but the associated RFPT controllers are ordered from left-to-right (Photo #13). (A3.2) — 6

	Evaluation Product
5. The following components are ordered in a manner other than the expected orientations of top-to-bottom and left-to-right: (A3.2)	6
Heat flux detector bypass lights are top-to-bottom as D-C-B-A, panel 603	
SJAE discharge recycle valve, supply valve, second stage driving steam valve, and first stage valve selector switches are top-to-bottom as 1B-1A, panel 652	
Drywell unit cooling fan switches are ordered A-E-B-F-C-G-D-H, panel 681; groups 1 and 2 are right-to-left (Photo #14)	
Indicators and controls of panel 00C-681 are mixed in ordering (Photos #1, 3)	
Generator load adjust switches are increase-decrease from left-to-right, panel 654 (Photo #15)	
6. Controls and displays are not arranged in functional or sequential relationships in the following cases: (A3.3)	9
Controls and displays do not follow any functional relation on panel 00C-681 (Photos #1,3)	

Mimic flow paths are not smooth nor easily followed on panels 601, 647, and 648

Some component relationships are difficult to readily comprehend, panel 654

7. Lines of demarcation, hierarchical labeling, color contrast, spacing, or other aid could be utilized in some cases where strings or matrices of components of similar function are installed. Examples of this include: (A3.4) 9

The array of switches on panel 00C-681 (Photo #1)

The matrices of switches on panel 652 (Photo #16)

The strings of labels under the indicator banks on panel 681 (Photo #17)

The array of switches for turbine auxiliaries and main steam valves, panel 653

The arrays of test lights above RHR and core spray indicators, panel 601

Circular meter arrays, panels 654 and 660

	Evaluation Product
Switch arrays of the ESW system, panel 00C-667	9
Large arrays of switches, panel 668 (Photo #5)	
String of switches for ADS division 1 and for MSIV-LCS inboard division 2, panel 626 (Photo #4)	
Rod status display, panel 649 (Photo #9)	
8. Coding methods such as the use of demarcation lines, spacing and switch shape which are used across panels 651 and 652 are not consistently applied. For example, the spacing among the feedwater control valves, panel 651, varies the vertical position of columns of switches (Photo #18); this is not seen elsewhere. (A3.5)	9
9. The majority of vertical panels contain controls and/or displays outside of the recommended ranges. Controls are located as low as 20" and as high as 80"; there are also some lamp test switches as high as 91". Indicators are located as low as 22" and as high as 92". (Recommended ranges are 42" to 60" for controls and 48" to 68" for displays.)	9

Panels which have both controls and displays located high and/or low are:

601 (Photo #19)	668
647	669
648	607
670	00C-667
654 (Photo #10)	00C-671
661	00C-650
626	00C-693
600	Remote Shutdown

In addition, displays are located high on panel 00C-660. Some controls, such as the RBM bypass, are located high on benchboard 603 for a seated operator. (A3.6)

10 The hydrogen indicator range selector switch on panel 601 is not located within an arms reach of the indicator. (A3.7) 6

3.4 Color Usage

1. Status indicating lights are generally white. The status light for power supply generator lock out bus, panel 602, is green. (A4.2) 6

2. Labels which identify panels are not consistent in color, some are white others are yellow. (A4.2) 6

Evaluation Product

3. Across the electrical system panels, yellow is used for the 4 KV bus mimic on panel 661 but is also used for the 220 KV bus mimic on panel 654. (A4.2) — 6

3.5 Labeling

1. The generator ammeter range switch on panel 654 has an indicating light located above it. The function of this light is unknown and unidentified by label. (A5.1) — 6

2 Labels have been switched for the trend recorder and the reactor pressure and main turbine steam flow recorder on panel 603 (Photo #20). (A5.1) — 6

3. The following devices on panel 601 are not identified: (A5.1) — 6

   Some H_2 and O_2 system devices

   Mimicked devices for containment isolation ocated at the top of the panel (Photo #21)

   RHR loop A Leeds & Northup Speedomax recorder

4. Labels are not used at all to identify system designation on the following panels: (A5.3) — 8

   00C-681 652

   00C-650

Some systems are not identified by label on the following panels:

651	668
653	670

5. The following inconsistencies in label nomenclature, abbreviations, etc., were noted: (A5.5) 4

"Reactor feed pump turbine" is sometimes shown as RFPT and sometimes as RPT, panel 651

The word "volumn" is mis-spelled on the river broadcast speaker volume monitor, panel 00C-650

Multiple abbreviations for "valve" and "pump" are used on panel 652

The nameplate next to PD106-120 is blank, panel 603

The recirculation pump motor air cooling switch labels use different nomenclature, panel 681

Recirculation system legends inconsistently use 1A or 1B or no system descriptor, panel 602

Level control selector switch label should read "1 or 2 Element", panel 603

Heat exchanger condensate discharge pressure to RCIC, panel 601, has RCIC spelled "RICI" on label 4

The device, such as "valve" is sometimes included, sometimes not, on device labels, panels 601, 647 and 648

Some inconsistency in abbreviations, panels 601, 647, and 648

Components of similar function are labeled differently on panel 668. Some switches are labeled feedwater heater drain to feedwater heater, others are feedwater drain to feedwater heater.

The process radiation recorder for the H_2-O_2 recombiner, panel 600, is labeled "Recommended"

6. A hierarchical system of size coded labels has not been used. (A5.7) 8

	Evaluation Product
7. Labels are not easily read in cases where components are located very low and where projecting device housings obstruct vision on the following panels: (A5.9) 647 — 00C-656 648 — 00C-671 661 (Photo #22) — 00C-660 668 669 670 (Photo #23)	9
8. The recirculation run-back reset pushbuttons on panel 602 are for different levels, but these levels are not specified. (A5.10)	6
9. Switches for the low pressure condensate off-gas to mechanical vacuum pump valves are only differentiated by device numbers HV 07-133 through 136, panel 652. (A5.10)	6
10 Labels are located between panel inserts on panel 607. This requires the operator to view the complete panel to determine whether the label applies to the insert above or the one below. Locating the labels on the inserts would eliminate this condition. (A5.11)	6

4.0 INSTRUMENTATION AND HARDWARE

Control room instrumentation and hardware were evaluated against checklist criteria addressing controllers, indicators, recorders, indicating lights and switches. Most hardware was found to be in general compliance with recommended standards, although several specific areas may merit further attention.

To date there has been little attempt at color coding indicator and recorder scales to indicate normal and abnormal ranges. Such coding techniques can be a valuable operator aid, permitting a rapid, qualitative reading of system parameters. Control room instrumentation should be reviewed to determine which would benefit from this technique.

Human factors standards based upon laboratory research specify that for optimum readability, the number of intermediate marks between numbered scale divisions should not exceed nine, and that scale numbers should progress in decimal multiples of one, two, or five. Many exceptions to these criteria were found, and have been identified below. In addition, many indicators were identified which use non-linear scales. Such scales should be avoided except where applicable (i.e., logarithmic radiation monitors).

Labels for some indicating devices do not specify the units of measurement. Others specify units which do not directly relate to system operation. Particular caution should be observed in using "percent" for the unit of measurement on indicator scales. In few cases, other than valve travel, is this appropriate.

Both pen and multipoint recorders have been used on the control panels. Multipoint recorders on other plants typically suffer from crowded, unreadable printouts. Where this format has been used, the incorporation of point select capability should be considered. Many instances are noted where chart paper scales do not correspond to the recorder scales.

Several instances were identified in which extinguished indicating lights are used to indicate "normal" system status. In these cases, if the bulb failed, an abnormal condition might not be detected. Because no lamp test feature has been provided, the operator might be unable to ascertain if these bulbs were indeed defective of if they were providing accurate information.

Human factors standards specify height and depth ranges for the placement of instrumentation and hardware (see Section 3). Due to the placement of many controls and displays outside of these ranges, potential problems were noted with glare, parallax, hand support, and general readability. Also, several instances were noted where switches are spaced extremely closely. Consideration should be given to providing more hand space in these cases.

Several emergency pushbuttons have been utilized which have armed and disarmed detent positions. Clear position markings should be added to these buttons to readily show their status.

Evaluation Product

4.1 **Controllers**

1. Controllers which require manual operation are all located such that they are easily reached. However, the following cases were noted in which more hand space could be provided for hand support: (B1.5) — 3

    RFP speed controllers 1A, 1B, and 1C, panel 603

    Main steam to 1A air ejector, panel 652

    Pump discharge flow, panels 647 and 648

Evaluation
Product

4.2 Indicating Devices

1. With the exceptions of turbine speed, oil tank level, and generator hydrogen purity indicators on panel 653, indicating devices have not been marked to show normal or abnormal, safe or unsafe, or expected or unexpected range of operation. (B2.1) 12

2. Most indicating recorders on the following panels have no process units specified: (B2.3) 9

601	00C-624
603	00C-667
600	

3. The following indicating devices are not scaled in process units which relate to system operation: (B2.3) 6

   Pump suction pressure indicators on panels 647 and 648 have a lower scale for vacuum, but the units of inches Hg have not been specified

   Main generator rotor temperature is in °C rather than the expected °F, panel 670

   Heat flux indicators have no specified units, panel 603

	Evaluation Product
Recirculation pump speed and demand speed are in %, panel 602	6
Recirculation flow recorder has no units specified, panel 602	
Turbine oil reservoir has no units specified, panel 653 (Photo #24)	
Low pressure turbine A,B,C stage 11 exit pressure indicators do not specify the units of inches Hg for vacuum, panel 653 (Photo #25)	
Turbine speed is in %, panel 653	
Reactor chamber temperature control indicator is in %, panel 696	
4. Graduation marks are obscured by pointers on most Bailey recorders (Photo #20). (B2.5)	6
5. Pointers were found to obscure graduation marks, numerals or process units in the following cases: (B2.5)	4
Generator watts recorder (red pointer) on panel 670	
Turbine vibration recorder, panel 647	
SJAE discharge recorder (lower scale), panel 600	

Turbine speed/control valve and bypass valve position recorder, panel 653

Cleanup filter demineralizer inlet pH recorder (lower scale), panel 602

IRM/APRM recorders (lower scale), panel 603

6. Pointers partially obscure numerals on the circular meters of panels 654, 661, and 00C-660. (B2.5) 4

7. The generator load adjust pushbuttons on panel 654 are not positioned in the expected manner; increase is on the left and decrease is on the right (Photo #15). This is the opposite of control movement as well as the opposite of like pushbuttons located on panel 653. (B2.7) 4

8. The SJAE discharge recorders on panel 600 are not provided with identical scales, nor scales of the same class (one is linear, the other is logarithmic). As such, comparative reading is difficult. (B2.8, B2.10) 4

9. The heating and ventilating indicators of panel 00C-681 are not visually aligned to aid in comparative reading (Photo #3). (B2.10) 6

	Evaluation Product
10. The following indicating devices are not visually aligned or are not provided with identical scales to facilitate comparative reading: (B2.10)	4

Generator cooling system temperature, metal temperature, and thrust bearing temperature recorders are not aligned, panel 670

Drain cooler drain flow and third stage heaters drain flow indicators have different scales, panel 668

GE/MAC's are not in alignment, panel 669
V/102-2 has a different scale than V/101-2 and V/107, panel 654

11 and 12 unit auxiliary bus circular meters are not aligned, panel 654 (separated by one row)

RWCU 1A and 1B filter flow scales are not aligned, panel 602

RWCU dump flow and inlet flow have different scales, panel 602 (Photo #26)

Cooling tower makeup and blowdown flow recorder has one differing scale, panel 655

In addition, the 1A condensate pump ammeter on panel 652 has units of AC kiloamperes whereas the 1B and 1C ammeters have units of AC amperes.

11. The cleanup filter demineralizer inlet pH recorder on panel 602 has two scales (one variable) and no apparent scale selector switch. It is not clear which scale is to be used by the operator. (B2.11) 4

12. The following indicating devices have greater than nine intermediate graduations between numbered markings: (B2.12) 6

Panel 670:

Millivolt meter

Main steam temperature

Generator cooling system temperature

Metal temperature

Thrust bearing temperature

Panel 668:

RFP turbine lube oil temperature

Thrust bearing temperature

	Evaluation Product
Panel 669:	6

Condenser shells and hotwells conductivity

Panel 601:

RHR loop flows

Panel 600:

Area radiation monitor (Westronics)

Panel 607:

Flux probing monitor % power scale

Panel 614:

All temperature recorders

Panels 647 and 648:

Pump discharge pressure

Turbine supply pressure

Suppression pool level

Panel 00C-624:

Area radiation monitor recorder

Evaluation Product

Panel 602: 6

RWCU heater inlet pressure

RWCU 1A and 1B filter flow

Panel 655:

Instrument air pressure

Service air pressure

Turbine building cooling water pressure and temperature

Reactor building cooling water temperature

Panel 652:

SJAE indicators

Panel 653:

A,B,C low pressure turbine stage 8 exit pressure

A,B EHC fluid pump amperes (Photo #27)

Panel 00C-660:

Safeguard transformer megavars

	Evaluation Product
Station auxiliary switchgear megawatts	6
Startup bus megawatts	
Panel 654:	
All transformer ammeters within mimic	
W/G101, A/X102, V/102-2	
Emergency Shutdown Panel:	
Suppression pool level, both units	
ESW discharge pressure, unit 1	
13. The following indicating devices are scaled with subdivisions in decimal multiples other than 1, 2, or 5: (B2.13)	3
Panel 670:	
Generator cooling system temperature	
Metal temperature	
Thrust bearing temperature	
Thrust bearing wear	

Evaluation Product

Panel 600: 3

SJAE discharge recorder RR26-1R602

Panels 647 and 648:

Pump discharge pressure

Pump suction pressure

Turbine supply pressure

Suppression pool level

Panel 603:

IRM/APRM recorders

IRM-APRM/RBM recorders

Heat flux indicators

Standby liquid control discharge pressure

Panel 00C-681·

SGTS heater and filter temperatures

A,B control room temperature

SGTS carbon filter air temperature

Outside air temperature

Evaluation Product

Panel 681: 3

Nearly all indicators

Panel 653:

A, B, C, D main steam line flow (Photo #28)

Steam chest pressure

Pressure setpoints A, B

A, B, C low pressure turbine stage 8 exit pressure

A, B EHC fluid pump amperes (Photo #27)

Panel 00C-667:

A, B, C, D RHRSW pump ammeters

Panel 654:

V/101-2, V/102-2, V/107

Panel 00C-693:

DC voltmeters

In addition, the indicating devices noted for item B2.12 for panels 602, 607, 655, 00C-660, and the Remote Shutdown Panel (both units) are all scaled in decimal multiples other than 1, 2, or 5.

	Evaluation Product
14. The following indicating devices contain non-linear scales (other than logarithmic) over their entire range or part of that range: (B2.11. B2.13)	6

Panel 670:

Vibration phase angle

Panel 601:

All ammeters

Panel 614:

Recirculation drive and generator bearing temperatures

Recirculation pump temperature

RHR water temperature

HPCI turbine and pump temperatures

ADS safety/relief valve temperatures

Panel 603:

CRD water pump motor ammeters 1A and 1B

CRD system, cooling water, and drive flows

RFPT turning gear ammeters 1A, 1B, 1C

Evaluation Product

Panel 00C-681: 6

A, B control room temperature

Outside air temperature

Ammeters

Panel 681:

A through H drywell cooling inlet and discharge air temperatures (Photo #29)

Recirculation pump cooling inlet and outlet flow

Recirculation filter temperatures

Drywell chiller ammeters

Panel 653:

Generator hydrogen purity

Ammeters

Panel 00C-667:

A, B, C, D RHRSW pump ammeters

RHR heat exchanger cooling water flows

	Evaluation Product
Panel 654:	6
Ammeters and kilovolt meters	
Emergency Shutdown Panel:	
RCIC pump discharge flow, both units	
15. Numerals are not oriented in an upright position on the percent power and volts scales of the flux probing monitor, panel 607. (B2.15)	4
16. The 2A condensate pump ammeter on panel 20C-652, has units and numerals oriented sideways (Photo #30). (B2.15)	4
17. There is no clear differentiation between the psi and vacuum scales on the pump suction pressure indicators of panels 647 and 648. (B2.18)	4

4.3 Recorders

1. Multipoint recorders on the following panels do not have point select capability: (B3.6)	8

614	669
670	00C-624
668	

2. Incorrectly scaled chart paper was noticed in the following recorders: (B3.7)	4

Evaluation Product

Panel 600: 4

Service water

Radwaste cryogenic

Reactor building closed cooling water

H_2-O_2 recombiner ventilation

Panel 00C-624:

Bailey recorders are scaled 10 to 10^6 but the chart paper is scaled 100 to 600

Panel 603:

RFP turbine control valve position

Steam and feedwater flow

Panel 00C-667:

All recorders

3. All four recorders on panel 00C-667 are labeled "RHR HTX RADIATION" and apply to RHR loops A and B. The pen colors for the loops are reversed on the top two recorders and black is used for both A and B loops on the bottom recorders. (B3.10) 4

	Evaluation Product
5. Leeds and Northrup recorders on panel 603 have green-blue-red pointers from top to bottom, but the labels identify red-black-green. (B3.10)	4
6. Recorders have not been marked to show normal or abnormal, safe or unsafe, or expected or unexpected range of operation. (B3.15)	12

4.4 **Indicating Lights**

1. For the following indicating lights, a failed bulb cannot be distinguished from a normal condition: (B4.2) 6

    RFPT zero speed lights, panel 603

    RFPT emergency governor trip lights and RFPT main bearing oil pump test lights, panel 668

    ADS solenoid pilot valve B lights, panel 626

    Generator ammeter range select switch indicating light, panel 654

    Startup and trickle heat power on light, panel 696

    Yellow alarm lights, panel 00C-693

	Evaluation Product
2. On the Remote Shutdown Panel (both units), a failed bulb cannot be distinguished from a normal condition for the following lights: (B4.2) RCIC turbine trip RCIC turbine bearing oil pressure low RCIC high and low pressure bearing oil temperature high RHR heat exchanger outlet radiation high RHR service water loop return radiation high	6
3. No lamp test feature is available to diagnose failed indicating lights. (B4.4)	8
4. Indicating light bulb repacement is not easily performed on the Response Spectrum Analyzer of panel 00C-693. The panel instrument insert must be pulled out and the bulb replaced from behind. (B4.5)	4
5. Sets of lights are not in alignment on panel 00C-681 so as to facilitate comparison between related system elements. Components are mixed and the panel is partially mirror-imaged (Photos #1,3). (B4.6)	6
6. Indicating lights are reversed for switch HV02-113C on panel 668.	4

	Evaluation Product
7. Sets of lights are not in alignment between related system elements in the following cases: (B4.6)	4

1A and 1B level out of service lights are not located over their respective selector switches, panel 603

RHR loop shutdown cooling suction valves 2A and 2B lights are not aligned, Remote Shutdown Panel (both units)

4.5 Switches

1. The following switches do not move in the expected direction (i.e., right for start or open, left for stop or close, etc.): (B5.1)	6

Reactor feed pump recirculation valve switches have auto to the left, panel 651

Main steam line safety/relief valve switches are open-close from left to right, Emergency Shutdown Panel (both units)

Manual valve control switch has closed to the right, panel 607

Exciter voltage regulator transfer switch is manual-auto from left to right, panel 654

Condensate filter demineralizer switches have standby and service positions right to left, panel 651

Also, position labels are generally placed consistently relative to each other, but not always consistently relative to the switch (e.g. "open" may be above the switch or to the right).

2. Switch positions are not clearly marked in the following cases: (B5.2) 6

Pushbuttons for inboard and outboard valve control logic and testable check valve have two position rotary escutcheons, panel 601 (Photo #31)

Generator ammeter range switch has a position unlabeled, panel 654

220 KV breaker synchroscope check relay selector switch has an unmarked position, panel 654

Normal position is not marked on the steam seal evaporator extract steam test switch, panel 653

Condensate filter demineralizer control switches appear to be three position switches but have only two labeled positions, panel 651

The siren tone generator tone selector switch is not synchronized with the position indications, panel 00C-650 (Photo #32)

Evaluation
Product

3. Several emergency switches are present which are pushbuttons with disarmed/armed positions. A small red line is painted on the side of the pushbutton collars to indicate the position. This marking is not apparent. (B5.2) — 9

4. Switches were noted to be below a normal reaching/operating distance on the following panels: (B5.3) — 6

600	647
670	668
648	601 (Photo #33)
607	00C-693
661	00C-667

Also, the transfer switches are low on the Emergency Shutdown Panel (both units) and the RHR head spray inboard isolation valve switch is high.

5. The 1A auxiliary lube oil pump control of panel 602 and the 1C RFPT turning gear motor switch of panel 603 are located near the edges of these panels, but are not protected from inadvertent operation. (B5.4) — 12

6. The Westinghouse switches on panel 652 are extremely difficult to "pull to stop". (B5.5) — 9

7. Some small rotary switches such as those used on panel 00C-681, do not effectively detent in each position. (B5.7) — 6

Evaluation Product

8. Switches are spaced very tightly in the following cases: (B5.9) — 6

   Loop A and B service water and fuel pool pump switches, panel 655

   Reactor and turbine building cooling water switches, panel 655

   Arrays of switches, panel 668 (Photo #5)

   Adjacent J-handle keylock switches, panel OOC-667 (Photo #34)

9. No physical distinction is provided between switches for pump, valves, etc., on panels 601 and 655. (B5.10) — 8

10. Inconsistencies were noted in switch shape in the following: (B5.10) — 4

    Pump switches are usually J-handles, but not on panel 653

    No. 3 and 4 control valve below seat drain switches types are different, panel 653

    Pump switches and open-close valve switches are of the same type, panel 651

	Evaluation Product
1A and 1B SJAE first stage valve selector switches are different, panel 652 (Photo #35)	
11. Switch knobs may obstruct position labels on the following switches: (B5.11)	4
RFPT control signal failure reset, panel 603 (Photo #36)	
A, B reactor building recirculation fan and filter, panel 681 (Photo #37)	
12. Rotary switches for 1A and 1B scoop tube brake are raised such that position indications are obscured. (B5.11)	4

Evaluation Product

5.0 ANNUNCIATORS

1. Annunciators are generally grouped within alarm panels by specific system. Not all annunciators, however, are above related controls and displays. The following are examples of this: (C1.2) 4

   Relating to panel 661, the D11 alarms are above the D13 controls, the D13 alarms are above the D12 controls, and the D12 and D14 alarms are above panel 00C-656

   The location of ADS and MSIV leakage control alarms in alarm panel 10C826 is the reverse of the location of related controls on panel 626

   The reactor isolation system alarms of alarm panel 1AC802 are above the ADS panel

   Excess flow check valve and fuel pool alarms of alarm panel 1BC802 are located with the recirculation and RWCU alarms related to panel 602

   Radiation monitoring alarms in alarm panel 00C824 are above panel 668

   Feedwater alarm panel 1BC868 is located above panel 669

From: Ron Bunker 5793 GE
To: Garrett Edwards PECO

Fire protection alarm panel OBC850 is located above the control room entrance, to the left of fire protection panel OCC-650.

2. Warning and diagnostic alarms are generally segregated from informational and advisory displays. A few instances were noted in which this is not entirely the case. These are: (C1.3) — 4

   Trip alarms are usually located in the top row of annunciator windows within an alarm panel, but this is not the case for the condensate pump trips and the circulation water pump trips

   Scram input alarms are not all grouped together

   The RHR auto start alarm window is not directly above the permissive to start alarm window.

3. The following inconsistent abbreviations were noted: (C2.1) — 4

   HTX/HX
   REACTOR LO LEVEL/REACTOR LEVEL 3
   D/G versus D-G

	Evaluation Product
4. The abbreviation CONT is used for two different applications. On alarm panel 00C881, CONT refers to "containment," but on alarm panel 1AC854 this refers to "control". (C2.1)	4
5. The following inconsistencies in type size and style were noted: (C2.2) In the common alarm panel over panel 00C-624, window 1 has a smaller, darker type Window 19 of alarm panel 0BC850 has a smaller than standard type size Window 17 of alarm panel 1AC870 has smaller, darker type	4
6. Annunciator alarm panels are located at such an angle and height that is difficult to view windows when standing between the vertical panels and the benchboards. (C2.3)	9
7. Many annunciator legends were found to be insuccinctly worded. The following are some examples of this: (C2.5) GENERATOR HYDROGEN COOLERS H_2 OUTLET HI/LO TEMP, panel 1BC870, window 34	6

	Evaluation Product
EHC EMERGENCY TRIP PRESS LO PRESS TRIP, panel 1AC870, window 46	6
CONT ENCL ST FLDNG DMPR PNL 00C729 TROUBLE, panel 00C881, window 20	
A REFUELING FLOOR ISOLATION SIGNAL INITIATED, panel 10C881, window 23	
1A CRD WATER PUMP TRIP, panel 1BC803, window 31	
UNIT 1 REAC BLDG EL 352 NORTHWEST AIRLOCK SEAL BROKEN, panel 10C889, window 1	
CIRC WATER PUMP COOLING WATER BASKET STRAINER FAILURE, panel 10C855, window 43	
1 GEN BKRS 452-535/635 POSITION MONITOR CKT CONTROL PWR FAILURE, panel 1BC854, window 5	

	Evaluation Product
D11 D-G DIESEL OIL STORAGE TANK HI/LO LEVEL, panel 1AC861, window 19 DIV 1 ADS MANUAL INITIATION SW ARMED/RELAYS SEALED IN, panel 10C826, window 2 DIV 2 LO REACTOR PRESSURE RHR PERMISSIVE TO START, panel 1CC801, window 25 CONTROL RM EMER FRESH AIR SUPPLY CHARCOAL FILTER A FIRE, panel 0BC850, window 26 EMER COOLING SUPPLY FROM CONDENSATE STORAGE TANK MOV OVLD LOSS OF PWR, panel 10C847, window 21	6
8. A few windows were noted in which the system referred to is not fully identified. These include: (C2.5) SUPPRESSION ATMOSPHERIC ANALYZER TROUBLE, panel 10C800, window 28 TRAIN "A" PIPING FILL PMP AP256 LO PMP DISCH, panel 1BC801, window 14	6

	Evaluation Product
9. No process variable is specified in the following window legends: (C2.5) EHC HYD FLUID FILTER HI DIFF, panel 1AC370, window 43 EHC HYD FLUID COOLER STRAINER HI DIFF, panel 1AC870, window 50	6
10. The annunciator legend, DIV 1 SHUTDOWN COOLING & MIN FLOW VALVES OPEN, on alarm panel 1AC801 would more accuractely be worded RHR A rather than DIV 1. (C2.5)	6
11. The annunciator legend, CORE SPRAY LINE INTERNAL BREAK, on alarm panel 1AC801 is not literally correct. (C2.5)	6
12. Several alarm windows use terminology which refers to varying setpoints for parameters with multiple trip levels. These levels could be made more clear. Examples of this are: (C2 6) REACTOR LO LEVEL TRIP versus REACTOR HI/LO LEVEL and REACTOR HI LEVEL TURBINE/RFPT TRIP RECIRC PUMP HI PRESS/LO LEVEL TRIP (ATWS)	4

CONDENSER LO VACUUM versus
CONDENSER LO VACUUM TRIP

MAIN CONDENSER LO VACUUM
versus STEAM BYPASS LO VAC

DRYWELL HI PRESS versus
DRYWELL HI PRESS TRIP

13. Many annunciator legends were noted to have multiple choice indications. Some examples include: (C2.7) 6

TRIP RELAY LOW VOLTAGE OR
386 PROT RELAY TRIP, panel
1BC870, window 6

HPCI VAC PUMP/COND PUMP/MOTOR
OVLD/LOSS OF PWR, panel 10C847,
window 16

COMMON AREA RAD MONITORS DOWNSCALE,
panel 00C824, window 35

CONDENSATE STORAGE TANK HI/LO
LEVEL, panel 1BC869, window 1

SGTS VENT HI-LO/INOP
RADIATION, panel 00C881, window 26

	Evaluation Product
1A RFPT MAIN BRG OIL PUMP 1 OR 2 OVLD TRIP/INOP, panel 1AC868, window 1	6
MSIV LC VALVE/HEATER/BLOWER OVLD/POWER FAILURE, panel 10C826, window 25	
1A/1B/1C RFPT BRG METAL HI TEMP, panel 1AC868, window 26	
NORTH STACK/SOUTH STACK ISO KINETIC SAMPLE HI/LO FLOW, panel 00C824, window 30	
14. Various alarms have been prioritized by the use of amber or red bulbs. However, based upon observations made at the simulator, the color contrast between amber and white annunciator lights is low. (C2.8, C3)	3
15. A numeric code has been provided for each alarm panel. The numerals printed on the windows though are very small and difficult to read from the benchboards. No means has been provided to identify each alarm panel. (C2.9)	8
16. No silence button has been provided for alarm response. (C5.1)	12

	Evaluation Product
17. Alarm windows do not all automatically blink at a slower rate when the alarm input clears. This is dependent on the internal alarm switch setup. (C6.4) The same is true for clearing of alarms only by operator action. (C6.5)	4

6.0 OPERATOR INTERVIEW SUMMARY

Eight operators were interviewed by the survey team, representing a wide range of experience levels. A complete list of all comments from these interviews is included as Appendix B to this report.

In this section, an attempt has been made to identify common areas of operator concerns. Based on this review, the following items were found to be mentioned most frequently (one-half or more of operators interviewed), and as such should be given particular attention:

- Seven operators commented on the need for more simulator training. Specifically mentioned was time for normal operations training, systems and theory training, and team building.

- The ESW panel was noted by seven operators as being difficult and confusing to operate. Color coding, switch spacing, and system layout improvements were all discussed.

- Multi-point recorders were felt to be difficult and confusing to read by seven operators.

- Five operators expressed the need for color coding of switches. This was felt to be especially useful in locating group isolation controls and synchroscope switches.

- Half of the operators interviewed felt that the location of the ECCS panel is non-optimal. Much of this panel is not within the operators view from the normal operating position.

- Four operators expressed concern over the annunciator system. Specifically, all alarm panels must be scanned before acknowledging an alarm, since all alarms are acknowledged at once. This may cause the loss of an incoming alarm if all alarms are not scanned prior to acknowledgement.

7.0 EMERGENCY PROCEDURE TASK ANALYSIS

The Emergency Procedure Guidelines developed by the BWR Owners Group will form the foundation upon which Limerick's emergency procedures will be developed. Using these Guidelines, a task analysis was prepared which identified instrumentation required to evaluate plant conditions within the framework of the procedural steps. This instrument list was then compared to the actual control room inventory to verify that the specified parameters are in fact available to the operator.

As the first step in analyzing control room design with respect to the Guidelines, all parameter limits defined as entry conditions were identified. Since exceeding any one of these limits transfers the operator from normal to emergency procedures, he must be immediately aware of the existance of such a condition. This line of reasoning leads to the conclusion that the presence of any condition requiring entry into the guidelines should be indicated by actuation of an annunciator, or otherwise called to the operator's attention. A review of Limerick's annunciator panels revealed that no alarms are currently provided for drywell temperature, suppression pool temperature, suppression chamber pressure, suppression pool level, or an open relief valve. In addition, as discussed in Section 5.0, certain modifications to the annunciator system could enhance its effectiveness as an operator aid.

In several cases, redundant annunciators have been provided in multiple locations for the same action level. These annunciators are used to signify actuation of various points within logic trains, and initiation signals for various systems. For instance, two alarms are provided for a 54" reactor water level, three for 12-1/2", and four for -149". Eight alarms are provided for 2 psig drywell pressure. Two alarms are provided for 23 in-Hg condenser vacuum.

While repetition of key annunciators in individual system operating areas may be desirable in some instances, it also increases the total number of windows and compounds the amount of information the operator must assimilate during transients.

The terminology used in annunciator legends does not always clearly define the corresponding action level. For instance, annunciator 1AC801-24, "DIV 1 DRYWELL HI PRESS" and 1AC803-26, "DRYWELL HI PRESS TRIP," both signify 2 psig drywell pressure. Annunciator 1BC869-25, "1A CONDENSER LO VACUUM" alarms at 25 in-Hg vac while 1BC870-17, "CONDENSER LO VACUUM" alarms at 24.5 in-Hg vac and 1BC801-7, "MAIN CONDENSER LO VACUUM" alarms at 23 in-Hg vac. In all cases, the purpose of an alarm should be made clear through explicit nomenclature or inclusion of setpoints.

The Emergency Procedure Guidelines written by the BWR Owners' Group may be considered in one respect as a series of action levels associated with various plant parameters, guiding the operator through increasingly degraded conditions. Displays of these critical parameters must be immediately available in the control room and easily readable, with corresponding limits readily discernible. Task analyses and walkthroughs of the Guidelines disclosed that no indications are currently provided for RHR pump amps, RHR pump discharge pressure, or primary containment water level. ?

The control room arrangement and the method of organizing controls and displays within panels can directly impact operator efficiency during transient response. Frequently required trips to backpanels detract from the operability of the control room and may affect shift manning levels, whereas conveniently located instruments promote rapid evaluation of plant status. Logically arranged, well thought-out panel layouts enable the operator to locate correct controls and indicators and minimize the chance of error. Several areas were noted in which modifications may prove beneficial:

- The division of the control room into wall-mounted vertical panels and free-standing consoles sometimes obstructs visual and walking paths. The location of the ECCS panel, particularly, seems inconvenient. Many indications of importance to the operator are obscured by panels 602, 655, and 681. For example, in order to verify MSIV isolations and ECCS operation, the operator must walk around panel 602 to view the necessary indicating lights, many of which are mounted low on panel 601, close to the floor.

  The present floor plan suggests that it may be necessary to assign one operator to panel 601 exclusively during major plant transients. Even those indicators which are visible from in front of panel 602 cannot be read accurately from this position; the operator must walk around panel 602 and read the indicators from directly in front of panel 601. Fuel zone reactor water level, drywell pressure, suppression pool temperature, suppression chamber pressure, and suppression pool level are all available only on panel 601 and 648. These parameters become particularly important within the context at the Emergency Procedure Guidelines.

- No indication of reactor pressure is available in the relief valve operating area.

- No indication of reactor water level is available in HPCI and RCIC operating areas.

- Controls and indications associated with the turbine control system are divided between panels 670 and 653.

- ESW system controls and indications are located on panel 667, some distance from RHR controls on panel 601.

Certain modifications or enhancements to existing design should be considered to more effectively support the operator in important decision, evaluation, or action steps identified in the Guidelines:

- The full core display consists of a large matrix of many-colored lights. Among other functions, this display is used by operators to verify insertion of all control rods into the core following a scram. Since all rod bottom lights are not aligned, but are interspersed between many other multi-colored lights according to the physical core layout, it is conceivable that one or more rods not fully inserted might not be noticed in a time-critical, stressful situation. This suggests that reliance will be placed upon CRT displays to obtain rod position information.

- There currently exists no concise display of group isolation valve position. Consequently, when verifying group isolations, the operator must monitor valve status in individual system operating areas.

- No direct indication of safety-relief valve position is provided. Available indicating lights sense only the condition of the actuating solenoids.

- Drywell and suppression chamber pressure indications on panel 601 are scaled in 0-100 psig. This range of indication does not allow the operator to accurately monitor these parameters under normal conditions, when pressures will be maintained at $<$ 2 psig.

- Suppression pool level indication on panel 648 is scaled 0-75 inches. The reference level for this instrument should be clearly stated and easily correlated with operating limits.

- As presently designed, HPCI and RCIC manual isolation buttons do not work once an initiation signal has been sealed in.

- Main condenser vacuum may be monitored on indicators on panel 653 and recorders on panel 652. However, both indications span a range of only 25-30 in-Hg vac. This does not allow for monitoring this parameter during plant startup.

- Two different zero references have been used for water level indications. This may complicate direct comparison of multiple channels of instrumentation. Another source of confusion may arise from the choice of scale ranges; both upset and fuel zone indications are scaled +60, -150", even though different zero references are used.

- No capability presently exists for manually overriding an ADS initiation signal. If the operator must prevent depressurization, he must press a reset button every two minutes.

Because the Emergency Procedure Guidelines represent a new concept in methods of transient response, some aspects of plant design will require careful consideration when the plant specific procedures are written. The following concerns related to the Guidelines were noted:

- Certain steps within the Guidelines address limits which may require instrument ranges in excess of those currently used. Because the actual limits are based on calculations yet to be performed, this consideration could not be actually evaluated at the time of the survey. However, it is possible that an extended range for suppression pool level will be necessary.

- The guidelines require the use of bulk suppression pool water temperature and average drywell atmosphere temperature. No provision has yet been made to obtain these "average" temperatures.

- To evaluate the validity of level indications, the operator must have available drywell temperature adjacent to reference leg vertical runs. While drywell temperature indication is presently available from two locations, it is not known if either of these correspond to the locations of the reference legs.

- Some limits discussed in the guidelines are "two dimensional" i.e., the operator must correlate two different parameters and plot the resulting operating point on a graph defining the permissible operating regions. In one case he must relate three different parameters, utilizing two separate graphs. In a time critical situation this severely compounds the operator's workload and requires careful design of both control room layout and procedures. The parameters involved should at least be situated in close proximity to each other with the associated graph provided nearby. However, a more innovative approach may prove more satisfactory, perhaps involving two dimensional CRT plots or X-Y recorders. This area of the guidelines must be given extremely close attention as actual plant specific procedures are prepared. Limits involving correlation of multiple parameters include suppression pool heat capacity, RPV saturation, suppression pool spray, pressure suppression, suppression pool load, and heat capacity level limits. Potentially of most concern in this respect are limits involving suppression pool temperature and level, as these parameters are located on a backpanel. Specific recommendations for display formatting are contingent upon the final form of the plant specific procedures and the philosophy utilized in development of emergency response systems addressed by NUREG-0696.

- A given parameter covered by the Guidelines may possess several action levels. Limits or action levels of immediate concern to the operator should be marked in some fashion on the indicator or recorder. This may include such points as the top of active fuel for reactor water level, normal operating limits and vacuum breaker elevation for suppression pool level, and low pressure injection system shutoff head for reactor pressure.

- Entry conditions into the Guidelines may involve action levels not currently addressed by procedures or alarmed in the annunciator system. As plant-specific limits are defined, the available annunciators should be evaluated to determine if entry conditions are adequately alarmed.

Resolutions of the above concerns will be largely dependent upon the form and content of the final written procedures. In addition, many of these aspects of control room design are intimately related to development of emergency response facilities, as discussed in NUREG-0696. It is suggested that work in these areas must be a closely coordinated, integrated process if optimum results are to be obtained.

APPENDIX A

CHECKLIST ITEMS FOR LATER REVIEW

Because Limerick was still under construction at the time of the review, a complete evaluation of the control room could not be performed. Some items cannot be evaluated until a realistic control room environment is observable. Others must await development of plant administrative procedures and definition of operating practices. A complete list of all of these items has been provided below.

All panels were not installed at the time of the review and some of those which were installed were missing some components. Panels 10C-673, 00C-674, and 00C-675, should be evaluated when fully installed.

While task analyses of the Emergency Procedure Guidelines were developed and compared to control room design, additional work should be performed at a later state in plant construction, concurrent with development of plant specific procedures. A complete analysis requires knowledge of all panels and should involve operating personnel.

The following items (listed by checklist number) could not be evaluated at the time of the survey:

Panel Layout and Design

A1.3 When panel components are permanently removed, are spaces covered to prevent debris or dust from entering panel internals and repainted to avoid visual distinctiveness?

A5.2 Are labels, legend plates and escutcheons used to identify operational limits or warnings?

A6 Use and application of temporary panel changes could not be evaluated.

Instrumentation and Hardware

B1.2 Are controllers that require manual operation designed to facilitate precise control where fine adjustments are required?

B2.2 Are indicating devices free from glare and parallax?

B2.16 Are indicating devices maintained, calibrated and surveillance tested on a regular basis?

B3.1 Are printed values easily read and distinguishable on recorder charts?

B3.2 Are recorder printing devices properly aligned such that printed values correspond to scale values?

B3.3 Are alarm points identified on recorders?

B3.4 Is there adequate distinction for markings on multi-pen recorders?

B3.5 Where fast tracking rates or trends are periodically required, do recorders have high speed capability?

B3.11 Do recorder chart papers not bind?

B3.12 Are recorder charts periodically marked with date, time, and initials?

B3.13 Has an administrative procedure been established for recorder chart marking and retention?

B3.14 Are recorders free from glare and parallax?

B4.1 Is there adequate distinction between lit and extinguished indicating lights?

B4.3 Is the size and intensity of alarm lights adequate to command attention?

B6.4 Are switches for emergency use controlled by specific procedural instructions?

B7 Use of key-lock switches could not be evaluated.

Annunciators

C2.4 Are alarm windows in accordance with checklist criteria for changes or modifications?

C4 Does the audible alarm meet checklist criteria for audible displays?

C7 Annunciator procedures were not available.

C8 Annunciator maintenance could not be evaluated.

C9 Alarms actuated during normal operating conditions were not known.

In addition, no evaluation could be performed of computers, procedures, control room environment, maintenance and surveillance procedures, training, or manning. LER analysis is not applicable at this time.

APPENDIX B

OPERATOR INTERVIEW COMMENTS

The following is a complete list of all operator comments (see Section 6.0 for discussion of common operator concerns). Where duplicate responses were received, the frequency has been indicated in parentheses. While responses have been abbreviated where possible and as such are not verbatim, the intent of the reply has been adhered to as closely as possible. Refere to actual comment sheets for detailed responses.

No attempt has been made in this section to judge the validity of the operators' criticisms or to make any suggestions for improvement. All comments are repeated here as a means of transmitting operator concerns to plant management for further review and should not be interpreted as survey team recommendations. In addition, operator concerns generally apply only to the Simulator and as such may not be entirely applicable to the Limerick control room.

Panel Layout and Design

The condensate and feedwater controls need rearrangement. The addition of large system labels may improve recognition.

The feedwater pump valve controls are too far from the RFPT controls.

The MSIV panel is difficult to see from the reactor control console.

Color coding is needed on group isolations to help locate some of the infrequently used devices. (4)

Color coding needed for normal valves on ESW board (service water outlet valves and backup valves).

Synchroscope switch should be color coded. (2)

Much of the ECCS system (panel 601) cannot be seen from the central operating location. (2)

Benchboard recorders on panel 603 are too high for shorter persons to read properly.

RFP controls are scattered across panels. (2)

Power range monitoring equipment status lights are out of view.

Labels on group isolation status indicators are too small to be read well. This display should be identified as well.

Mimics on panels such as the RWCU would be helpful.

No APRM instrument drawer's are provided in the control room.

Panels having more than one system should be divided by grouping related equipment with lines of demarcation. (2)

Schematic flow paths would be helpful.

Controls and Instrumentation Needed in the CR

A drywell pressure recorder is needed on panel 603.

Suppression pool water temperature. (2)

SRV leak detection for each SRV.

Turbine vibration trip bypass control.

Drywell chiller isolation bypass control.

APRM gain adjust controls.

HPCI/RCIC/MSL temperature monitors (trip units and individual indicators).

Recirculation pump vibration.

Narrow range suppression pool water level.

SRV open indications.

Controls Difficult to Operate

The reactor mode switch is hard to move from one mode to another. There is a fear of overshooting.

ESW keylock switches do not have enough hand space between them.

Hard to get the feel of fast/slow speed on controller pushbuttons.

Control rod buttons are tiresome on the fingers.

Some pistol grips switches are flimsy.

Control switches of the oblong clover leaf design have a non-positive feel.

Controls Prone to Inadvertent Operation

The relative positioning of the A and B SJAE controls on panel 652 is inconsistent.

The recirculation pump start switch is too close to the edge of the console.

The turbine load set buttons are opposite positions on the vertical board and the turbine console.

A number of nameplates are confusing or misnamed.

Controls Which Could Be Improved

There is difficulty in associating RFPT speed controls with the appropriate RFPT. Some system devices are ordered from top to bottom while others are left to right.

Recirculation pump discharge valve switch shape could be changed to indicate that the function differs from the normal pull to stop.

RPS static inverter alarms could be located next to the associated RPS channel trips to help recognize a half scram.

Panels Confusing or Difficult to Operate

ESW panel is very confusing. (7)

Computer console lacks operator instructional aids.

Heating and ventilating panel is confusing.

Location of switches and meters on the Main Turbine and EHC console.

Indicating Devices Difficult or Confusing to Read

Multi-point temperature recorders. (6)

Drywell atmosphere hydrogen and oxygen.

ECCS panel "Christmas tree". (2)

Drywell pressure, panel 601.

ESW to RHR service water return header flow, panel 667.

Turbine expansion recorder is too high.

Temperature meters on HVAC bench board have odd increments.

Drywell temperature indicators are not graduated evenly.

Eccentricity, bypass valve position, and control valve position recorder (labeling problem).

Important Indicators Difficult to See During Normal or Emergency Operation

Drywell pressure and suppression pool temperature on CRT.

Suppression pool temperature on multi-point recorder. (3)

Drywell pressure and temperature, suppression pool pressure and level.

MSIV position.

ECCS systems.

Full core display.

Annunciators

Windows should be color coded rather than using colored bulbs.

Yellow annunciator lights should be more pronounced. These are hard to distinguish from the white lights. (2)

Cannot acknowledge annunciators until all the alarm panels have been scanned so that incoming alarms are not lost.

A different tone alarm for each panel would be useful.

All scram input alarms should be located on one panel (e.g., move neutron monitoring system trip from panel 600 to 607).

Annunciator bells are too loud, causes difficulty in operator verbal communications.

Annunciator windows should continue to blink until locally acknowledged.

Operator Responsibilities

The RO-SRO interface was not clearly understood during cold license certification on the simulator.

Was not clear at the simulator what the RO could do after a scram (i.e., could he leave the reactor console).

Training

More time on the simulator should be given towards the RO and SRO becoming a team.

Simulator training should be extended by four weeks. One week more on systems, one week on reactor theory and fluid flow/thermodynamics, and two weeks on the machine. (2)

More simulator time should go towards normal operating conditions such as heat-ups, start-ups, and shutdowns. (4)

Information Flow

Would like to see more load dispatcher knowledge as to nuclear terms and problems.

Miscellaneous

Operations people should be involved early in the design phase and throughout modifications of panels to review equipment changes.

Operators need extensive instrumentation inputs from offgas and recombiner systems, not enough information was available on the simulator.

APPENDIX C

PHOTOGRAPHS

APPENDIX C

CRDR TEAM RESUMES

Resume

THOMAS J. CABREY

Mr. Cabrey received his B.S. in Electrical Engineering from the Pennsylvania State University in the Spring of 1979.

His Experience Includes:

One year (1983-Present): Limerick Controls Group, Electrical Engineering Division, responsible for reviewing, approving, and commenting on Electrical Schematics, P &ID's, QAD's, Functional Descriptions, Assigned Equipment Specifications, and various documents received from other Divisions of PECo, Bechtel Corp., and the NRC for the Systems for which he is responsible. Another project for which he has responsibility is the Limerick Control Room Design Review.

Three years (1980-1983): Shift Technical Advisor, at the Peach Bottom Atomic Power Station, responsible for monitoring plant operations and tranisents to insure safe operation of the plant. As part of this assignment he participated in a intensive six month training program conducted by the General Physics Corp., of Columbia, Maryland and approved by the Nuclear Regulatory Commission. This training program dealt with the Theory of Nuclear Reactions, Nuclear Power Plant Operations, Transient Analysis, Mitigating Core Damage and a three week session on the Limerick Plant Simulator.

One Year (1979-1980): Conventional Plant Controls Group, Electrical Engineering Division, responsibile for investigating and engineering various modification to the different Generating Stations throughout the Philadelphia Electric Company System.

RESUME

Michael J. Leahy
Philadelphia Electric Co.

Education

Drexel University, BSEE, 1974
Registered Professional Engineer - Penna, 1978

Continuing Education Courses:

- Instrument and Control Systems Application Engineering, Moore Products, 1976
- Automatic Process Control Loops, Instrument Society of America, 1977
- Control Systems Engineering, Foxboro, 1978
- Fundamentals of BWR Operations, General Electric, 1978
- Design and Control of Turbine - Generator Systems, George Washington University, 1980
- Applied Human Factors in Power Plant Design and Operation, General Physics, 1983

Professional Activities

Panel Member at IEEE/ASME Joint Power Symposium, 1981; Human Factors Experience in Non-Nuclear Facilities.
Author/speaker at ISA Power Instrumentation Symposium, 1982

Employment

Philadelphia Electric Company

1974 to 1982 — Engineer - Electrical Engineering Division - Computer and Controls Section - Conventional Plant Control Group

Responsible for various instrumentation and control systems (e.g feedwater, combustion control) at fossil fueled power plants and non-safety related I & C systems (e.g. feedwater, reactor recirculation, turbine control) at nuclear power plants. Responsibilities included design, design review, specification writing, and bid evaluation.

1982 to present	Engineer - Electrical Engineering Division - Computer and Controls Section - Peach Bottom Control Group. Same responsibility as above for various I & C systems at PBAPS, Units #2 and 3, including nuclear safety-related systems. Currently assigned to NUREG-0737 supplement 1, Control Room Design Review initiative.

MJL:sjb
SB82983M1020
8/83

Professional Qualification
Garrett D. Edwards
Engineer
Philadelphia Electric Company

My name is Garrett D. Edwards. I am an Engineer in the Electric Production Department of the Philadelphia Electric Company presently serving as the Power Generation Engineer at the Limerick Generating Station. In that capacity I have overall responsibility for the operation of the major electrical equipment throughout the power plant including both the 500 KV and 220 KV substations and associated equipment. I have a Bachelor of Electrical Engineering degree from Villanova University. I have been employed by Philadelphia Electric Company since 1970 and have been involved in power plant design or operations since that time as detailed below:

1. June 1970 - July 1973 - Electric Production Department, Test Engineer Barbadoes Generating Station - Responsible for (1) running and evaluating plant performance tests, (2) maintenance, calibration and troubleshooting plant control systems.

2. July 1973 to February 1976 - Engineering and Research Department Electrical Engineering Division Station Engineering Section - Responsible for design and review of modifications to Generating Station Power Systems.

3. February 1976 - December 1983 - Engineering and Research Department Electrical Engineering Division Computer and Controls Section - Responsible for the design of the Safety Related Control Systems at Peach Bottom and Limerick.

4. December 1983 - Present - Electric Production Department - Power Generation Engineer, Limerick Generating Station

I was the Co-Chairman of the BWR Owners Group Control Room Improvements Subcommittee from January 1980 to January 1983. This committee was responsible for formulating the BWR position on control room design related TMI items.

I was the PECo responsible engineer for implementation of the following TMI related items at Limerick:

1. Regulatory Guide 1.97
2. Control Room Design Review
3. Safety Parameter Display System
4. Emergency Response Facility Data System

I was the PECo technical representative with the NRC - Instrumentation and Control System Branch during the Final Safety Analysis Report review process.

Garrett D Edwards

SHIFT SUPERINTENDENT

DATE APPOINTED: December 31, 1979

NAME: William N. Barnshaw, Jr.

EDUCATION AND TRAINING

1956	Graduated from Mastbaum Vocational Technical High School in Philadelphia, Pa. - majored in machine
1957-1959	United States Army Completed Combat Engineer Training and Airborne Heavy Weapons Infantry Training. Discharged with the rank of corporal
1960	Mechanical Training Course - Philadelphia Electric
1962-1963	Nuclear Theory and Plant Systems Course Phase "A" - Philadelphia Electric Company
1964	Peach Bottom Atomic Power Station Unit 1 (HTGR) "On Site Training Program" - Philadelphia Electric Company
1966	Health Physics Training - Philadelphia Electric Company
1967-1968	Peach Bottom Atomic Power Station Unit 1 (HTGR) formal preparation for A.E.C. Licensing by completing on site pre-licensing training, pre-licensing self study program and pre-licensing simulator training
April 1970	Completed the General Electric Six Week BWR Simulator Operator Experience Program and BWR Technology Tape Program at the General Electric BWR simulator-Morris, Illinois
Nov 1971	Basic algebra course - Harford Junior College, Harford County, Maryland
1971-1972	In preparation for taking the AEC Senior Operator License (BWR) examinations. The following training Programs were completed: 1) NUS Corporation Nuclear Power Preparatory Training Course 2) On site review classes 3) Off site observation training at Oyster Creek Nuclear Station 4) BWR Simulator Refresher Program at the General Electric Simulator - Morris, Illinois 5) General Physics Corporation written audit examination 6) General Electric Company written audit and oral examinations
Dec 1973 through Dec 1979	Participated in the Operator Requalification Program that was initiated on site in Dec 1973 as follows: 1) Monthly reading assignments 2) Monthly lecture sessions 3) Minimum of ten reactivity changes logged each year

4) Annual written examination
5) Annual oral examination

Dec 1975	Fire fighting - two day training course at West Conshocken-Philadelphia Electric Company Fire School
Oct 1976	Management Training three day course presented for Philadelphia Electric Company by American Management Association
Nov. 1976	Red Cross multimedia first aid course and annual refresher qualification training - Philadelphia Electric Company
Feb 1978	Basic Nuclear Concepts, two week course presented for Philadelphia Electric Company by NUS Corporation
Feb 1979	Management Training - two day refresher course presented for Philadelphia Electric Company by Management Development Programs
Nov. 1979	Solid radwaste burial training - Department of Transportation (DOT) and NRC requirements - presented for Philadelphia Electric Company by General Physics Corporation
Annually	Cardiopulmonary resuscitation (CPR) training and fire fighting hands on training - presented by Philadelphia Electric Company

WORK EXPERIENCE

8/75 to 12/79 Shift Supervisor - Peach Bottom Atomic Power Station (BWR) Units 2 & 3

Duties: Second senior licensed operator on shift. Responsible for supervising operating personnel in all aspects of plant operation and administration. Actively participated in and supervised all phases of BWR operations including reactor start-ups, shutdowns, planned tests, plant transients, refueling operations, liquid radioactive waste releases, issuance of radiation work permits and safety blocking permits. Occasionally worked as radwaste supervisor, supervising off site shipping of solid radwaste.

2/71 to 8/75	Control Operator - Peach Bottom Atomic Power Station (BWR) Units 2 & 3	
	Duties:	Participated in writing operating procedures and working as the control room operator when equipment and systems were placed into service during initial start-up activities and pre-operational testing. Directed plant operations, operated major equipment, performed electrical switching, wrote blocking permits and directed their application and, on a regularly scheduled basis, worked as an assistant control operator at the reactor console manipulating the controls during plant startups, shutdowns or steady state operations.
9/70 to 2/71	Plant Mechanic - Peach Bottom Atomic Power Station (HTGR) Unit 1	
	Duties:	Performed or directed shift operations outside the control room. These included equipment blocking, system surveillance and operations.
11/68 to 9/70	Mechanical Operator (Reactor Operator) Peach Bottom Atomic Power Station Unit 1 (HTGR)	
	Duties:	Manipulated the reactor controls during reactor start ups, shutdowns and plant transients. Operated major plant equipment including reactor fuel handling equipment.
7/68 to 11/68	Health Physics Technician - Peach Bottom Atomic Power Station Unit 1 (HTGR)	
	Duties:	Qualified for this position in August 1966 and relieved the regular Health Physics Technicians during heavy work loads. Performed routine radiation surveys, prepared and issued radiation work permits, monitored personnel working on contaminated equipment in radiation

areas, calibrated radiation survey instrumentation and analyzed radioactive liquid waste samples in connection with processing of liquid waste for discharge.

10/63 to 7/68 — Auxiliary Operator - Peach Bottom Atomic Power Station Unit 1 (HTGR)

Duties: Participated in the initial plant startup activities and assisted in the work of preparing operating procedures and cnecking construction progress; operated equipment outside the control room such as chlorine handling systems, demineralizers and water treatment systems; performed normal equipment sureveillance duties; and applied safety blocking.

12/59 to 10/63 — Various Positions - Southwark Generating Station

Duties: As auxiliary operator, operated chlorine handlinc systems, demineralizers, and water treatmert systems. As mill operator, operated mills and subsystems and ash and slag removal equipment. As boiler house helper, performed general boiler room duties.

LICENSES AND CERTIFICATES

Sept 1968 — Received AEC Operators License for Peach Bottom, Unit 1 (HTGR).

May 1973 — Received AEC Senior Operators License for Peach Bottom Unit 2 (BWR).

June 1974 — Peach Bottom Unit 2 Senior Operators License was amended to include Peach Bottom Unit 3.

APPENDIX D

SUPPLEMENTARY OPERATOR EXPERIENCE QUESTIONNAIRE

APPENDIX D

Supplementary Operator Experience Questionnaire

QUESTIONNAIRE INSTRUCTIONS

A design review of the Limerick 1 control room is being performed, as required by the NRC. Its purpose is to identify and correct design deficiencies in operator-control room interface. The best sources of information for this review are the operators who will be working in the unit. A preliminary review of operator experience has already taken place. Since then, however, we realize that design changes have been implemented and that operators have gained more experience in the control room since the original survey was completed. The attached questionnaire is being administered in order to incorporate these changes into the review.

Please respond to the questions as they apply to your job or position, and in relation to your experience. Where you feel unqualified to answer, please indicate so, and explain. Full explanatory sentences are much more informative and useful than yes-no answers, so please use them whenever possible.

Feel free to ask The Interlock Group and/or the PE project team any questions that you may have concerning the questionnaire. Thank you for your cooperation.

PERSONAL INFORMATION:

Education (Include schooling currently in progress):

Associate degree:

Under Graduate degree:

Major area of study: (Engineering, Physics, etc.)

Position Title:

Years experience in industry:

Years with Philadelphia Electric (include any Peach Bottom experience):

Years at Limerick:

Training in Current Position:

School/Facility (name):

Course Title(s):

Length of Training (weeks/months)

Job Related Experience:

Military

Other

1. Could controls and indicators be better arranged to support operation in (a) normal conditions and (b) casualties/ emergencies? Please comment on your responses.

2. What would a general suggestion be for improvements in panel arrangement and location relationships of controls and indicators?

3. Where would it be easy to become confused regarding the association between indicators and controls? (Please give at least four specific situations.)

(1)

(2)

(3)

(4)

4. Significant numbers of controls and indicators are located on the vertical boards. As specifically as possible, indicate how you feel this would impact both normal and casualty/emergency operations.

5. In the symptom oriented context, do procedures guide you in coordinating operations when information from several indicators must be integrated into actions on several different panels (e.g. expected information and possible operator actions)?

6. Are controls and indications clearly labeled in conjunction with procedures and their functional name, easy to locate and read? Indicate the type, or where the deficiences may exist.

7. Comment on panel mimicing - are they clear and not confusing?, do they aid in operation?, are more or less needed? (Please explain.)

8. Comment on the location of annunciator panels and how they are arranged to respond effectively to alarms.

9. Have you found that audible alarms aid or distract you in plant operations? Explain the situation or experience. Include simulator sessions.

10. Do you feel the CRT displays you have seen have actually helped you in operating a nuclear power plant or have they provided extraneous data that do not aid your interpretation? Please provide an explanation.

11. Have you found the panel arrangement aid mimics consistent with system diagram's (P&IDs) and training diagrams of the same system?

12. What proportion of normal operations require coordination between individuals at different panels? How is it different for casualty situations?

APPENDIX E

OPERATOR EXPERIENCE REVIEW, LICENSEE EVENT REPORT SUMMARY

APPENDIX E

Licensee Event Report Summary

PECO-LIMERICK LER REVIEW

METHOD

Plant specific LER data generated since the BWROG review of the Peach Bottom plant were reviewed for their applicability to the Limerick CRDR. Emphasis was placed on LERs resulting from the following: plant procedural/operational deficiencies such as changes or updates of plant technical specifications; inadequacies in operator training; and inadequate or improper instrumentation, such as a missing display or alarm. Of some 195 LERs reviewed, only 32 fell into one or more of the above categories.

PROCEDURAL/OPERATIONAL LERs

LERs resulting from procedural inadequate made up only 16% of the LERs reviewed (5 LERs). The majority of these involved instrument malfunction that occurred due to missed surveillance or monitoring procedures (3 occurrances). The remainder involved failure of personnel to update plant technical specifications as called for by procedures (2 occurrances).

TRAINING-RELATED LERs

Training-related LERs made up 28% of the LERs applicable to the Limerick CRDR (9 LERs). The most common cause of these events was failure on the part of the operator to perform tasks in accordance with procedures (6 occurrances). Operators were either unaware of specific procedures (4 occurrances) or performed tasks without following the procedures (2 occurrances). Other LERs occurred because the operator was not familiar enough with procedures to complete tasks within the required time (1 occurrance), or because the operator inadvertently manipulated the incorrect control (2 occurrances).

INSTRUMENTATION-RELATED LERs

The most common causes of LERs were instrumentation inadequacies and failures (56%, 18 occurances). Of these, eight resulted from faulty electronics such as incorrect grounding of components. An additional eight were due to instrument drift, primarily of flow indicators. Two LERs resulted from instrument failure that was un-noticed by the operator. In both cases, the instruments had no failure or off-scale indication.

RESULTS

Several LERs were resolved through panel enhancements and class improvements. Copies of the remaining LERs were presented to the appropriate departments for further consideration.

APPENDIX F

SCALE GRADUATIONS SPECIFICATION

APPENDIX F

Scale Graduation Specification

Clear, accurate scale markings and graduations aid the control room operator immensely in task performance. To evaluate the Limerick control room display scales, accepted human performance criteria were consulted (MIL-STD 1472C, NUREG 0700) and scale graduation specifications developed.

In general, the scale on a display should be selected so that it is consistent with the degree of precision required for the operator to properly perform the task. The scale should not require operator conversion or calculation to determine the information required, and should span the expected range of operation.

Scale Markings

No more than nine graduations should exist between numerals on a scale. Major and minor graduations should be used if four or fewer graduations are used between numerals. Major, minor, and intermediate graduations should be used if five or more graduations are used between numerals. Graduation height is considered a function of viewing distance (see Table 1.) An example of major, minor and intermediate graduations can be found in Figure 1.

Graduation height is determined as a function of viewing distance. Figure 1 demonstrates graduation height at a viewing distance of three feet. Figure 2 depicts graduations at a viewing distance of nine feet.

Characters on scales should conform to the same recommendations made for label and annunciator characters, and should sublend a minimum visual angle of 15 minutes of arc (or .ØØ4 x viewing distance) with a visual angle of 2Ø minutes (.ØØ6 x viewing distance) preferred.

VIEWING DISTANCE (feet)	INDEX HEIGHT (inches)		
	MAJOR	INTERMEDIATE	MINOR
1½ or less	0.22	0.16	0.09
3 or less	0.40	0.28	0.17
6 or less	0.78	0.56	0.34
12 or less	1.57	1.12	0.65
20 or less	2.63	1.87	1.13

TABLE 1: Scale Graduation Heights in inches for various viewing distances (NUREG 0700).

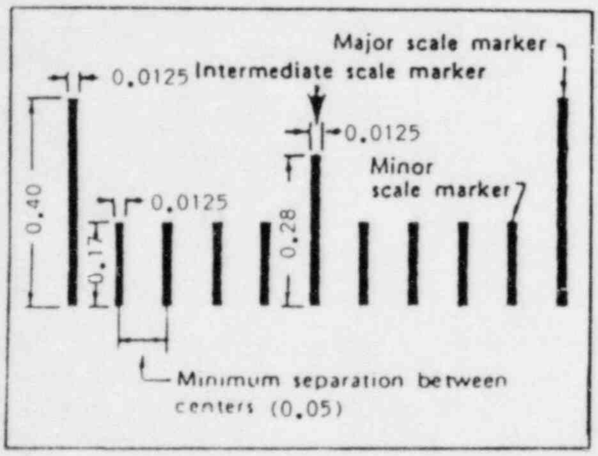


FIGURE 1: Graduation dimensions in inches for 3' viewing distance (adapted from McCormick, 1976).

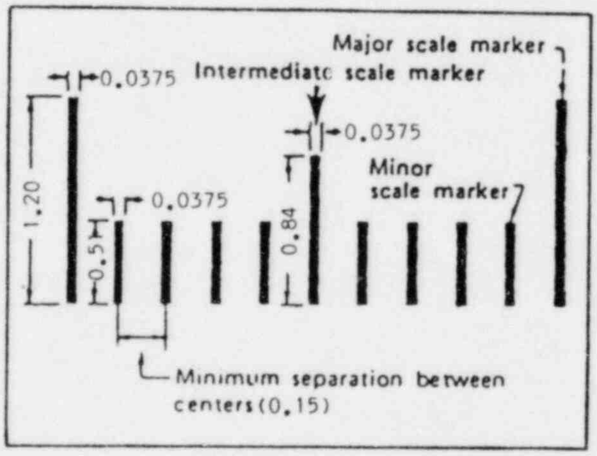


FIGURE 2: Graduation dimensions in inches for 9' viewing distance (adapted from McCormick, 1976).

APPENDIX G

LABELING FONT SPECIFICATION FOR THE PHILADELPHIA ELECTRIC COMPANY'S LIMERICK PLANT

APPENDIX G

LABELING FONT SPECIFICATION
FOR THE PHILADELPHIA ELECTRIC COMPANY'S
LIMERICK PLANT

The following are the labeling font styles and size hierarchy for the Philadelphia Electric Company's Limerick plant. The selection of font style and size was based on specific human engineering criteria. The criteria established was based on letter height vs. viewing distance relationships, (H = Ø.ØØ2D + K + K), width-height ratios (1:1 to 3:5 W-H ratio), and operational requirements.

H = height of letter in inches

D = viewing distance

K = correction factor for illumination and viewing condition

K = correction for importance (for emergency labels K = .Ø75 all other conditions K = .Ø)

Reference documents such as NUREG Ø7ØØ, EPRI Report NP-2411 (Human Engineering guide for Enhancing Control Rooms), and McCormack's Human Factors in Engineering and Design were consulted when establishing the criteria and making the font style and size selection.

The font proposed is Helvetica Medium for all functional groupings and components. The individual component identifier numbers are Helvetica Regular. The rationale for the difference is based on operational considerations. The functional groupings and components are of paramount operational concern, therefore the bolder Helvetica Medium font was selected. The component identifier numbers are primarily used for non-operational maintenance and calibration, they are the smallest size and the lighter Helvetica Regular font.

Six font sizes are used throughout all control panel labels. Each font is discussed below:

- Three quarter (3/4) inch Helvetica Medium (H.M.) - Panel Identifiers

  Each individual control panel should be identified by a functional name. Three quarter inch letters are recommended for this. As an example, panel 10C603 functional name is the REACTOR panel. These labels are centered on each individual panel, and below the angle annunciator break on vertical boards.

- 36 point H.M. - Channel/Train identification

  When channel and/or train distinctions are required, they are identified using this font.

- 30 point H.M. - Major groupings

  The concept of color shaping for enhancements, groups functionally related controls and indicators within a particular color shape. To identify these major groupings, this font is used. The convention requires that subgroupings must exist within the color shaping for the 30 point font to be used.

- o 24 point H.M. - Major Subgroupings

  In consonance with the above, the Subgroupings within each major grouping are identified using this font. The convention requires that if a color shape has no major subgroupings (only related individual components) this font is used to identify that shape alone.

- o 14 point H.M. - Component labels

  Two basic uses of this font are specified. The enhancement design requires bracketing with or without the use of color fields. This font is used with these brackets. The second use is for individual components. Each component (switch, indicator, etc.) has been assigned a functional name or designation. These component labels are designed to facilitate operator identification, location and operation without having to refer to a numbering scheme. This font has been used to label all panel components.

- o 8 point Helvetica Regular - Component and Power Supply Identifiers

  Recognizing that extensive documentation such as the FSAR, P&IDs and Technical Specifications refer to and require specific numerical designations, each component has been labeled with the appropriate numerical identifier. These correspond directly with all technical documentation. As indicated previously, since these numbers are not routinely used in the operational context, they will be less prominent so as not to interfere with efficient functional operation.

Examples of this labeling scheme are illustrated in Figures 1, 2, 3.

FONT SPECIFICATIONS

(ACTUAL SIZE)

HELVETICA MEDIUM 36 PT

HELVETICA MEDIUM 30 PT

HELVETICA MEDIUM 24 PT

HELVETICA MEDIUM 14 PT

HELVETICA REGULAR 8 PT

Figure 1

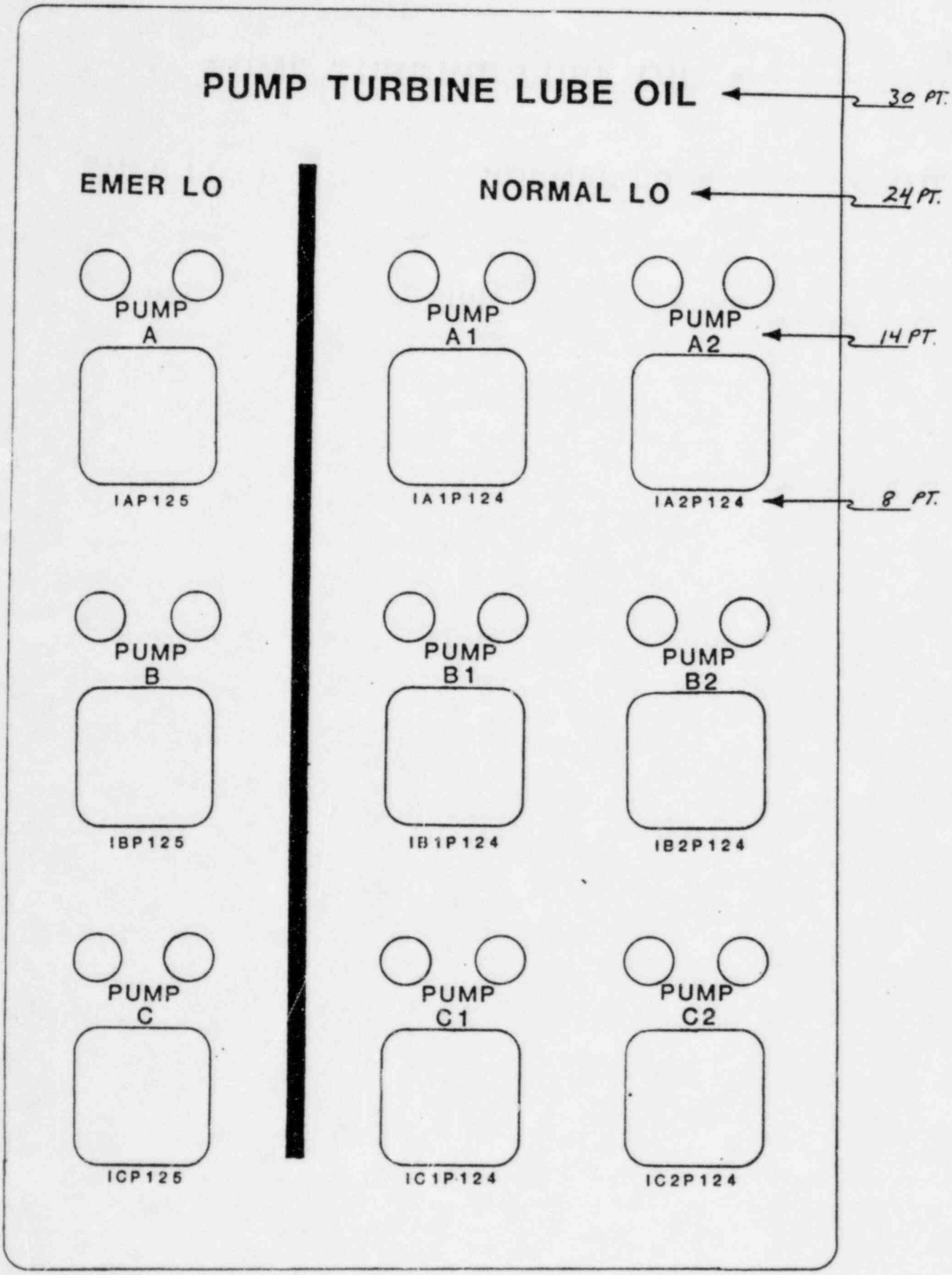
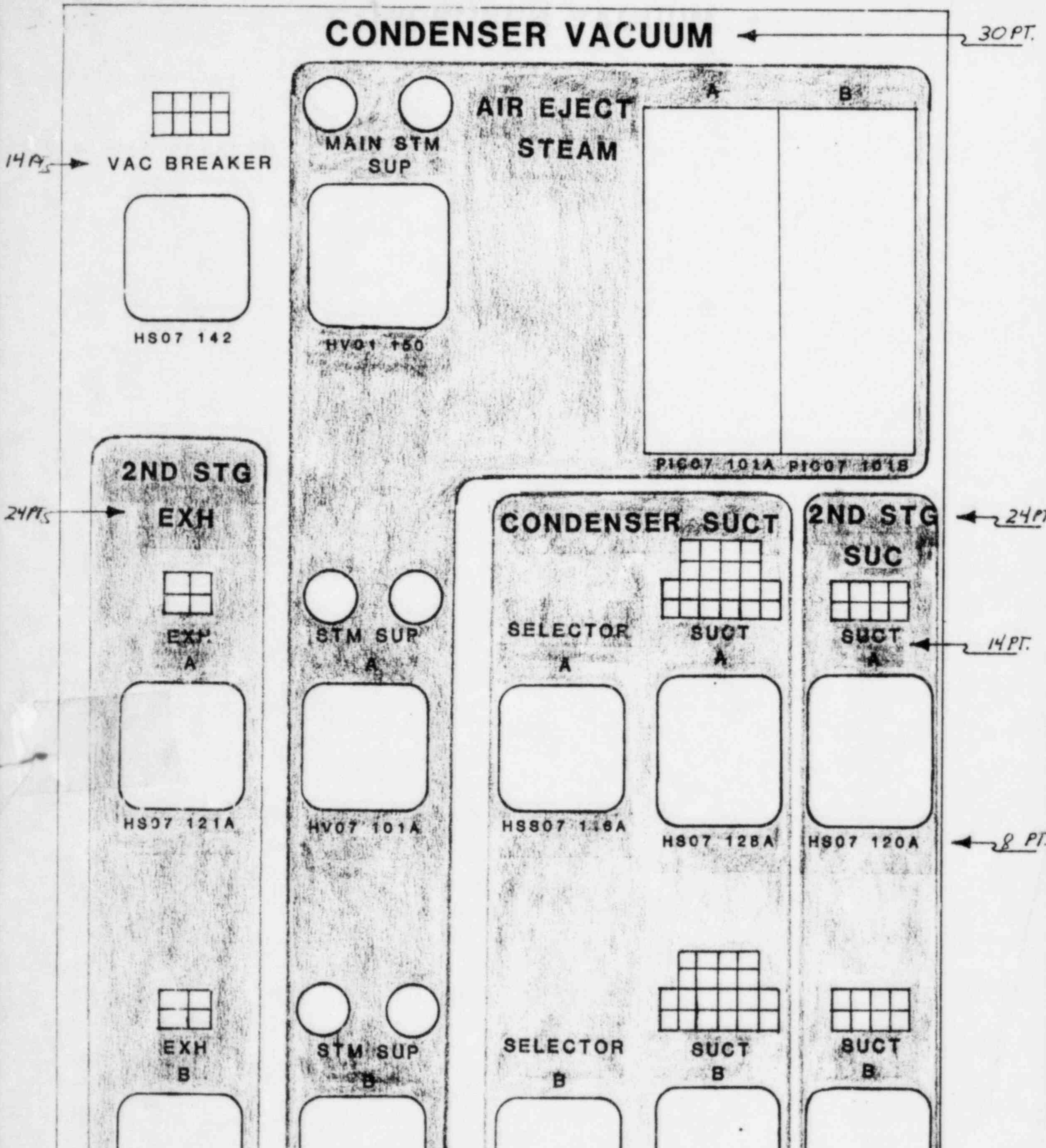

PUMP TURBINE LUBE OIL
30 PT.
EMER LO
NORMAL LO
24 PT.
PUMP
A
PUMP
A1
PUMP
A2
14 PT.
IAP125
IA1P124
IA2P124
8 PT.
PUMP
B
PUMP
B1
PUMP
B2
IBP125
IB1P124
IB2P124
PUMP
C
PUMP
C1
PUMP
C2
ICP125
IC1P124
IC2P124

Figure 2



NOTE: The letters in this example are used to demonstrate a hierarchal scheme, and do not represent actual size. See Font Specification sheet (Figure 1) for actual font sizes.

Figure 3