ATTACHMENT C

BWROG HUMAN FACTORS ENGINEERING - CONTROL ROOM SURVEY SUPPLEMENT

ATTACHMENT C

BWR OWNERS GROUP

CONTROL ROOM DESIGN REVIEW COMMITTEE

HUMAN FACTORS ENGINEERING

CONTROL ROOM SURVEY

SUPPLEMENT

BWR OWNERS' GROUP

CONTROL ROOM DESIGN REVIEW COMMITTEE

HUMAN FACTORS ENGINEERING

CONTROL ROOM SURVEY

SUPPLEMENT

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CONTROL ROOM SURVEY SUPPLEMENT

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INTRODUCTION

This supplement is intended to augment Revision 1 of the BWR Owners Group Control Room Survey (CRS) Program dated 1/1/81. It is to be included as part of the Control Room Review Checklists (Section III of the CRS Program) to further document proposed control room enhancements. The additional items listed in the supplement have been drawn from human engineering guidelines recommended in NUREG-0700 and verified through considerable experience of Owners Group Survey teams.

Major sections of the supplement checklists are identified by letters corresponding to section designations used in the original checklists. In order to differentiate between the two numbering systems, an "S" prefix has been assigned to each supplement item.

The CRS Supplement is to be implemented in accordance with the methodology discussed on page 15 of the CRS package. As before, Sections SA, SB, and SC are to be completed for each panel containing controls and displays normally operated by control room operators. The remaining sections apply to the entire control room and therefore need to be completed only once. Sections A, B, and C should also be completed for the remote shutdown panel.

In addition to the attached checklist supplement, several other modifications have been adopted in the CRS Program. These are listed in Table I. All other aspects of the program remain unchanged.

TABLE I

CRS PROGRAM MODIFICATIONS

The following modifications have been implemented in the BWR Owners Group Control Room Survey Program:

- Sections A, B, and C of the Control Room Review Checklists are to be performed for the remote shutdown panel in addition to those panels previously recommended.

- A supplement (attached) has been added to the Control Room Review Checklists.

- Task analyses and walkthroughs are performed based upon symptom oriented emergency procedures developed from the BWR Owners Group Emergency Procedure Guidelines. If plant-specific procedures are not yet available, the guidelines themselves should be utilized in the analysis. In this case, existing procedures for a scram, relief valve failure, and loss of coolant accident should also be evaluated.

SA PANEL LAYOUT AND DESIGN

SA1 Anthropometrics

SA1.1 Is seating area adjacent to desks and sit-down consoles sufficient to allow the operator to get into and out of a chair easily and to turn in the chair to view the equipment behind (30" lateral space, 36" between desk and opposing panel or surface)?

4 3 2 1 0 x 1 = ___

SA1.2 Is sufficient space allowed between the panel and opposing surfaces such that the operator may perform required tasks without hindrance?

4 3 2 1 0 x 2 = ___

SA1.3 If the operator is required to see over a stand-up console, does the console height not exceed 58 inches?

4 3 2 1 0 x 2 = ___

SA2 Control Room Layout

SA2.1 Does the location of the shift supervisor's office permit prompt access to the control room under all conditions?

4 3 2 1 0 x 2 = ___

Panel______

SA2.2	Are operator's desks and chairs comfortable and in good repair?	4 3 2 1 0 x 1 = ___
SA2.3	For a multi-unit plant, are senior operators who supervise or assist in the operations of more than one unit stationed such that they may communicate effectively with all operators and view each control board?	4 3 2 1 0 x 2 = ___
SA2.4	Are operators provided with sufficient desk and working space for performance of required tasks?	4 3 2 1 0 x 1 = ___

SA3 Control/Display Grouping

	Is the association of feedback indication to related controls made readily apparent through labeling, mimics, demarcation lines or position?	4 3 2 1 0 x 3 = ___

Panel______

SA4 Labels

SA4.1 Where abstract symbols are used, are they of standard configuration, distinguishable from other symbols, and consistent in use within and across panels?

4 3 2 1 0 x 2 = ____

SA4.2 Are labels located such that they do not cover or detract from other necessary information?

4 3 2 1 0 x 3 = ____

SA4.3 Is extraneous information not included (e.g., manufacturer's trademark, patent notice, etc.)?

4 3 2 1 0 x 1 = ____

SA5 Unit Integration

SA5.1 For a multi-unit plant, are alarms for shared plant systems duplicated in all control rooms?

4 3 2 1 0 x 3 = ____

SA5.2 For multi-unit plants, if equipment is shared between control rooms, is there administrative control over use of the equipment?

4 3 2 1 0 x 2 = ____

Panel______

SA5.3 Is the status of shared equipment displayed in each control room?

4 3 2 1 0 x 3 = ____

Panel______

SB INSTRUMENTATION AND HARDWARE

SB1 Indicators

SB1.1	Are indicator scales easily read when stationed at the panel?	4 3 2 1 0	x 3 = ___
SB1.2	Is the use of multiscale and logarithmic scale indicators minimized?	4 3 2 1 0	x 2 = ___
SB1.3	Are displays which reflect only a demand signal labeled accordingly?	4 3 2 1 0	x 3 = ___
SB1.4	Are process units and multipliers specified?	4 3 2 1 0	x 3 = ___
SB1.5	Are drum-type counters readable from the normal viewing position?	4 3 2 1 0	x 3 = ___

Panel______

SB1.6 Are digital displays readable from the normal viewing position? 4 3 2 1 0 x 3 = ____

SB2 Recorders

SB2.1 Is all recorder information visible through recorder windows (i.e. open-door operation not required)? 4 3 2 1 0 x 2 = ____

SB2.2 Do multi-channel recorders clearly display the channel being plotted? 4 3 2 1 0 x 2 = ____

SB3 Indicating Lights

Have procedural or design provisions been implemented to prevent interchanging indicating light lenses? 4 3 2 1 0 x 2 = ____

Panel______

SB4 Switches

SB4.1 Where contiguous legend pushbuttons are used, are barriers provided to prevent inadvertent actuation of adjacent pushbuttons?

4 3 2 1 0 x 3 = ___

SB4.2 Are key-operated switches used only where appropriate (i.e., to prevent unauthorized control actuation)?

4 3 2 1 0 x 2 = ___

Panel______

SC ANNUNCIATORS

SC1 Window Design

Is the density of annunciator matrices such that the operator may quickly ascertain a window position?

4 3 2 1 0 x 3 = ____

SC2 Acknowledgement

Are annunciator response controls coded for ease of recognition (color, shape, demarcation, etc.)?

4 3 2 1 0 x 2 = ____

SD COMPUTERS

SD1 Console

SD1.1	Do typewriter keyboards conform to the standard "QWERTY" arrangement?	4 3 2 1 0 x 1 = ___
SD1.2	Do numeric keyboards conform to either the "telephone" style or the "calculator" style arrangement?	4 3 2 1 0 x 1 = ___
SD1.3	Do function keyboards contain only those keys which are used by the operators (i.e. no irrelevant keys such as used by programmers)?	4 3 2 1 0 x 1 = ___
SD1.4	Are function controls segregated from alpha-numeric keys?	4 3 2 1 0 x 1 = ___
SD1.5	Are function controls clearly labeled to indicate their function?	4 3 2 1 0 x 2 = ___

SD2 Capability

SD2.1	Is computer use and software access administratively controlled?	4 3 2 1 0	x	2	= ___
SD2.2	Is the system designed such that data is not lost during printer down periods?	4 3 2 1 0	x	2	= ___

SD3 CRTs

SD3.1	Are CRTs free from glare and easily readable from normal viewing positions?	4 3 2 1 0	x	2	= ___
SD3.2	Are messages which require immediate operator response highlighted to attract the operator's attention?	4 3 2 1 0	x	3	= ___
SD3.3	Are prompts and error messages used to guide the operator in proper system operation?	4 3 2 1 0	x	2	= ___
SD3.4	Are abbreviations, acronyms, and synonyms used consistent with those used elsewhere in the control room?	4 3 2 1 0	x	2	= ___

SD4 Printers

SD4.1	Are printers located in a readily accesible area in the control room?	4 3 2 1 0 x 1 = ___
SD4.2	Do printers have the capability to record alarm, trend, and plant status data?	4 3 2 1 0 x 1 = ___
SD4.3	Is the system capable of providing a hard copy of any page appearing on the CRT?	4 3 2 1 0 x 1 = ___

SE PROCEDURES

SE1	Are procedures, reference materials and other documents readable (i.e. not dirty, torn, dog-eared or otherwise difficult to read)?	4 3 2 1 0 x 3 = ___	
SE2	Is a set of computer operating procedures available in the control room describing the computer system, procedures necessary to accomplish operator-computer interface functions and contingency actions in the event of a computer failure?	4 3 2 1 0 x 2 = ___	

SF CONTROL ROOM ENVIRONMENT

SF1 Communications

SF1.1	Are periodic maintenance tests performed on all communications sytems?	4 3 2 1 0 x 2 = ___
SF1.2	Is sufficient communications equipment (cords, jacks, etc.) provided in well marked locations?	4 3 2 1 0 x 2 = ___
SF1.3	Is an intercom system provided connecting the control room with the shift supervisor's office?	4 3 2 1 0 x 2 = ___
SF1.4	Are instructions provided for the use of all communications systems?	4 3 2 1 0 x 2 = ___
SF1.5	Are operators trained in the use of all communications systems?	4 3 2 1 0 x 3 = ___

SF2 Lighting

SF2.1	Are illumination levels at operator desks adequate for the tasks being performed (50 footcandles minimum, 100 footcandles maximum, 75 foot-candles recommended)? CHANGE RECOMMENDED	4 3 2 1 0 x 3 = ___
SF2.2	Is illumination uniform over a given work station and from one station to another?	4 3 2 1 0 x 2 = ___
SF2.3	Is shadowing avoided on panels and other operator work areas?	4 3 2 1 0 x 2 = ___
SF2.4	Have direct sources of glare been avoided (e.g. light emitted from displays and indicators)?	4 3 2 1 0 x 2 = ___

SF3 Emergency Response Equipment

SF3.1	Is operator protective equipment periodically checked?	4 3 2 1 0	x	2	= ___
SF3.2	Is a sufficient quantity of protective equipment and expendables provided?	4 3 2 1 0	x	2	= ___
SF3.3	Are instructions provided for the use of protective equipment and expendables?	4 3 2 1 0	x	2	= ___
SF3.4	Are operators trained in the proper use of protective equipment and expendables?	4 3 2 1 0	x	3	= ___
SF3.5	Are fire and rescue equipment periodically checked?	4 3 2 1 0	x	2	= ___
SF3.6	Are instructions provided for the use of fire and rescue equipment?	4 3 2 1 0	x	2	= ___

SF3.7	Are operators trained in the proper use of fire and rescue equipment?	4 3 2 1 0 x 3 = ___
SF3.8	Is radiation monitoring equipment periodically checked?	4 3 2 1 0 x 2 = ___
SF3.9	Are instructions provided for the use of radiation monitoring equipment?	4 3 2 1 0 x 2 = ___
SF3.10	Are operators trained in the proper use of radiation monitoring equipment?	4 3 2 1 0 x 3 = ___

SG MAINTENANCE AND SURVEILLANCE

SG1 Tags

Are maintenance tags securely affixed to panel components?	4 3 2 1 0	x	2	= ___

SG2 Spare Parts

Are inventories kept for operational spare parts and expendables?	4 3 2 1 0	x	1	= ___

ATTACHMENT D

BWROG HUMAN FACTORS DESIGN REVIEW OF THE PERRY CONTROL ROOM

SUMMARY REPORT

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ATTACHMENT D

BWR OWNERS GROUP
CONTROL ROOM IMPROVEMENTS COMMITTEE

HUMAN FACTORS DESIGN REVIEW
OF THE
PERRY CONTROL ROOM

SUMMARY REPORT

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

This report contains information regarding the Control Room Survey performed under the direction of the BWR Owners' Group with the assistance of General Electric Company. The only undertakings of General Electric Company respecting information in this document are contained in the contract between Cleveland Electric Illuminating Company and General Electric Company (Supplemental Agreement Number 27, Work Authorization Number 26), and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than Cleveland Electric Illuminating Company or for any purpose other than that for which it is intended, is not authorized. With respect to any unauthorized use, neither General Electric Company nor the BWR Owners' Group make any representation or warranty, and assume no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

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1.0 EXECUTIVE SUMMARY

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

FAVORABLE ASPECTS OF CONTROL ROOM DESIGN

1. Panels operated from a standing position generally conform to anthropometric guidelines.

2. Panel inserts define system operating areas.

3. Panel elements are generally functionally grouped within inserts.

4. Extensive use has been made of color-coded mimic arrangements to organize system layouts.

5. High contrast, easily read labels are provided. Summary labels are used to identify major system operating areas.

6. Escutcheons are used to associate labels with related switches and indicating lights.

7. Color coding has been consistently applied to indicating lights on the primary consoles.

8. Visibility of control surfaces within the primary control area is fairly good.

9. Controllers and switches are generally within easy reach.

10. Switches are usually actuated in the direction expected by population sterotypes.

11. Guard rails are used to prevent accidental disturbance of control settings.

12. Controls are well spaced, minimizing opportunities for disturbing adjacent controls.

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

14. The computer keyboard and CRT displays are integrated into the center console.

15. The normal illumination system meets recommended light levels in both primary and backpanel areas.

16. The high ceiling illumination in the control room tends to minimize glare and reflections on display faces.

17. A highly professional appearance has been created in the design of consoles and room decor.

GENERAL RECOMMENDATIONS FOR ENHANCEMENT

Panel Layout and Design

1. Some backpanels have controls and displays mounted above or below optimum heights. These should be reviewed to determine which, by virtue of importance or frequency of use, might benefit from relocation.

2. The dimensions of panel 680 are not optimized for a seated operator. Careful attention should be given to this panel to ensure that displays, labels, and CRT's are readable from a normal operating position. Demarcation techniques may be useful to highlight important indications.

3. Operator inputs should be obtained in the mimic design process.

4. Functional groupings of controls and displays on vertical segments of the consoles could be made more explicit through use of demarcation lines and summary labels.

5. Some backpanels and the remote shutdown panel would benefit from use of mimics or functional demarcation techniques.

6. A consistent color code should be implemented for pushbutton switches.

7. Some labels could be worded more succinctly or accurately.

8. The seismic support column between panels 870 and 601 can present a visual obstruction from certain locations in the control room. This concern should be kept in mind when operating stations are selected. No other items should be attached to these columns, so that the visual obstruction is minimized.

9. Annunciator legends on panel 680 are very small and difficult to read from a normal operating position.

10. Hierarchical labeling should be instituted.

Instrumentation and Hardware

1. Control room quantitative displays should be reviewed to determine which would benefit from the additions of markings or color coding to indicate normal, abnormal, and marginal ranges.

2. Non-standard, difficult to interpret scales should be avoided where possible.

3. Use of larger indicators should be considered for some parameters on panel 680.

4. Units should be specified on all indicator and recorder scales.

5. Alarm points should be designated on recorder scales.

6. Increased utilization of point select capability should be considered for multi-point recorders.

7. Lamp test capability should be provided for indicating lights.

8. Shape coding of switch handles should be considered.

9. Emergency switches should be clearly differentiated from other switches.

10. Emergency switches should be protected against the possibility of inadvertent operation.

Annunciators

1. Related alarms should be consistently arranged within system groupings.

2. Larger lettering should be used on panel 680 annunciator windows.

3. The usability of the annunciator system could be improved by prioritizing alarms, segregating informational and advisory displays, abbreviating wordy legends and providing an alpha-numeric code for window identification.
4. A first-out feature should be provided.

5. Providing separate acknowledge and reset buttons should be considered. Silence buttons at all panels would be convenient.

Computer

1. Viewing angles to the CRTs are unfavorable when the operator is seated directly in front of the computer keyboard.

2. The computer is not capable of automatic or manual switchover for processor failure since there is only one processor.

3. Color use on CRT formats should be standardized.

Procedures

1. Procedure laydown space should be provided at the control panels.

2. A permanent guideline should be instituted which standardizes all aspects of procedure format and content.

3. SOP's should address manual override of ECCS systems in more detail.

4. Procedure nomenclature should correspond to that used on panel labels.

Control Room Environment

1. Emergency lighting levels are below recommended and should be augmented.

2. Sharp edges on the primary console guard rails and insert corners should be eliminated.

Procedure Walkthroughs and Task Analysis

- Enhancement of the annunciator system may increase the effectiveness of these displays as operator aids.

- Certain modifications of display methods and formats could enhance the operability of the control room during transient conditions.

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

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

2.0 INTRODUCTION

This report summarizes findings of a one week preliminary human factors review of the Perry control panels using methodology developed by the Control Room Improvements Committee of the BWR Owners' Group (BWROG). A review team comprised of operations and engineering personnel from three utilities performed the evaluation, with the assistance of two human factors specialists and a representative from General Electric Company (see Table I). The review was completed on September 25, 1981.

The scope of this preliminary review was defined so as to be commensurate with the current status of the control room. Because Perry 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 insert 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. In addition, task analyses of the BWROG Emergency Procedure Guidelines were developed and used to evaluate the adequacy of control room instrumentation.

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.

Results of the Control Room Survey have been presented in two levels of detail. General conclusions of the survey team are summarized in narrative form in Section 3.0. Section 4.0 provides a complete list, grouped by subject, of all checklists items for which control room modification should be considered. After each entry, the applicable checklist cross-reference has been placed in parentheses.

A preliminary 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 PARTICIPANTS

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Table II

The following panels were reviewed by the survey team:

1C61-P001
1H13-P600
1H13-P601
1H13-P604
1H13-P612
1H13-P614
1H13-P618
1H13-P619
1H13-P621
1H13-P622
1H13-P623
1H13-P625
1H13-P628
1H13-P629
1H13-P631
1H13-P632
1H13-P642
1H13-P654
1H13-P655
1H13-P669
1H13-P670
1H13-P671
1H13-P672
1H13-P680
1H13-P691
1H13-P692
1H13-P693
1H13-P694
1H13-P800
1H13-P803
1H13-P804
1H13-P807
1H13-P808
1H13-P809
1H13-P810
1H13-P811
1H13-P821
1H13-P823
1H13-P842
1H13-P845
1H13-P865
1H13-P868
1H13-P869
1H13-P870
1H13-P877
1H13-P881
1H13-P882
1H13-P883
0H13-P902
0H13-P904
0H13-P906
0H13-P907
0H13-P969
0H13-P970

3.0 GENERAL FINDINGS

3.1 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. Many favorable aspects of panel design were evident, suggesting that considerable attention has already been paid to human factors engineering in the design of the Perry control room. Panels generally conform to recommended dimensions, controls and displays are functionally grouped, labels are very explicit, and mimic layouts are used for many systems. However, control room design could be further enhanced in several areas, resulting in a still more effective man-machine interface.

3.1.1 Anthropometrics

Control panel dimensions were measured and compared to anthropometric guidelines based upon a theoretical operator population extending from a 5th percentile female to a 95th percentile male. In general, control benchboards were found to closely comply with these guidelines. However, the dimensions of panel 680 do not seem optimized for a seated operator (Photo # 1). The following concerns were noted:

- Projecting controls, in combination with the rather shallow slope of the "C" inserts, tend to obscure labels mounted above associated switches (Photos #2, #3).

- CRT's are mounted above the height considered optimum for a seated operator (Photo #4).

- When the operator is seated at the keyboard under the left-hand CRT, he experiences an unfavorable viewing angle in relation to the center and right-hand CRT's.

- The small, two inch high meters used on this panel are difficult to read from a seated position at the center of the console (Photos #5, #6).

- Annunciator legends are very small and therefore difficult to read from a seated operating position. This situation has been recognized and a program is underway to increase character size (Photos #5, #31).

In view of the potential difficulties associated with operating panel 680 from a fully seated position, an evaluation was made to determine whether this console could be operated from a stool or high chair. While this position did afford better visibility of panel labels and CRT's, a lack of knee space became a concern (Photo #7).

The main benchboards in the horseshoe, panels 601, 870, and 877, were apparently designed to be operated from a standing position. Several indicators and controls are slightly above recommended limits, but these did not seem to cause any inconvenience for the smallest team member (Photo #8).

Non-conformance with anthropometric standards was, in general, more prevalent on the vertical panels, where a number of controls and indicators were found mounted above and below recommended heights. Similarly, many elements on the emergency shutdown panel are placed outside of the optimum range.

The guardrail on panel 680 (Photo #9) and the edges of the "C" panel inserts (Photo #11) possess rather sharp edges which could potentially cause injury to operators, especially in view of the rather narrow walking space between panels. This threat has apparently been recognized, for one corner of the guardrail on panel 680 has been encased with protective padding (Photo #10). A less obvious hazard occurs when panel 601, 870, and 877 inserts are lifted for maintenance purposes. In this elevated position, the sharp corners of the insert offer a potential hazard to passersby and to maintenance personnel working below (Photo #12).

3.1.2 Control/Display Grouping

Controls and displays are generally divided into system grouping by the panel inserts themselves, each insert being devoted to one or more specific systems. When combined with system summary labels, as used on panels 601 and 870, this technique provides effective panel organizations. However, within inserts, some consideration should be given to use of demarcation lines to delineate narrowly separated system operating areas and to accentuate important system groupings.

Extensive use has been made of mimic arrangements to visually organize controls on the main benchboards and some vertical panels. These are usually well laid out, but operator interview comments indicate that some of the more complicated arrangements may be confusing, RHR being one example. For these cases particularly, care should be taken that main system flowpaths are as direct as possible and readily distinguishable from auxiliary and bypass flows. Direction of flow should be clearly indicated and starting and end points identified. It is also recommended that operators be given the opportunity to review preliminary mimic layouts prior to finalization and be involved in the design process.

Demarcation techniques have currently not been applied to quantitative displays on the "B" panel inserts, where large strings and matrices of indicators are sometimes present (Photo #13). It is recommended that demarcation lines and hierarchical labeling systems be employed to functionally organize these displays.

3.1.3 Color Coding

A color code is in effect at Perry, standardizing color usage for mimic lines, indicator lights, and control switches. However, some inconsistencies in application of this standard were noted, and not all systems have assigned colors. Modifications to the standard may be beneficial in some areas to provide greater contrast of mimic lines against panel backgrounds, and to more clearly differentiate adjacent system layouts.

3.1.4 Labels

Fully descriptive, very explicit labels are used throughout the control room. However, these function labels are on occasion almost too explicit and accurate component designations are sometimes obtained at the expense of succinctness (Photo #14). In fact, the SOPF, controlling procedure formats and content permits abbreviating of panel labels in procedure texts. Notwithstanding possible confusion due to this difference in nomenclature, it would seem that if these abbreviated designations are descriptive enough for use in procedures, they are also sufficiently descriptive for use on the panels themselves. Panel labels could thus be made more succinct with no loss of accuracy. As discussed in Section 3.3, an effort is underway to shorten annunciator legends on panel 680, thus permitting larger, more visible lettering. A similar review program might also be beneficial for the panel labels.

Many instances of repetitive labels were noted on the control panels. In a series of related components, the labels may be virtually identical, save for a different component designator (Photo #15). By instituting a hiearchical labeling system, this redundancy can be avoided, resulting in shorter, more concise labels. As a side benefit, this type of labeling system also accentuates functional groupings of panel elements.

Initial attempts at hierarchical labeling may be seen on several panels, but the results are not as effective as they might be (Photos #16, #28). Definite size gradations should be used with the larger labels applying to general component groups. These summary labels should be spatially separated from individual component designators so that it is readily apparent that they apply to the entire group.

System summary labels have been applied to panels 601, 870, and 877, but to date have not been used on panel 680. These labels help to define panel operating areas and delineate system control groups, thus helping to visually organize panel layouts. Where these system summary labels are used, it appears redundant to repeat the system designation upon each individual component label, as is currently done. System labels thus become a part of the hierarchical labeling system discussed above.

Labels on the main control benchboards are written directly on a black escutchion which surrounds the associated control or indicating light. This technique avoids any ambiguity in associating a given label with its corresponding panel elements. Labels on vertical panels are engraved upon plates mounted below the associated components. On lower panel surfaces, these are sometimes difficult to read, as they tend to be obscured by projecting panel elements (Photos #17 - #20). Similarly, labels on the "C" inserts of panel 680 are obscured by the projecting switch actuators and cannot be read from a seated operating position (Photos #2, #3).

3.1.5 Control Room Layout

Visibility of control surfaces of the main benchboards is fairly good, although views of panels 870 and 877 from some locations are partially blocked by a support column (Photos #21, #22).

Two functions of potential importance have been relegated to backpanels, namely, radiation monitoring systems and the off gas system. Alarm windows and indicating lights on these panels can be seen over the top of panel 680 if the operator is standing, but not while seated (Photo #23).

Traffic patterns within the control room are difficult to evaluate at this time, as the final location of the operator's desk and the shift supervisors office have not yet been determined. The design of panel 803 (NOTE: 805) has also not been finalized, but it is known that it will occupy an area in the center at the horseshoe opposite to panel 680 (Photo #24). Since this area is a crossover point between the three major consoles, there is a potential for congestion in this area. Depending on the final configuration of this panel and the relative position of the operator's desk, walking paths and visual access to the control panels may be restricted.

3.1.6 Remote Shutdown Panel

Because the Emergency Shutdown Panel is designed to be used under extremely degraded conditions but is relatively unfamiliar to the operators, it is important that its design closely conform to human factors standards. Adequate training is also important to ensure proficiency in its use during an emergency. The following deviations from optimum human factors design criteria were identified (Photo #25):

- Area illumination, provided by a bare flourescent fixture is substandard and uneven. Considerably more light falls across the right side of the panel than the left. Glare and Shadows were observed.

- Panel elements are not consistently grouped by system or function. RHR and RCIC controls are dispersed across the left, center, and right sections of the panel. Blowdown valves are not grouped together.

- Controls are not functionally demarcated or mimiced to delineate system and subsystem groupings. Panel layouts do not clearly relate to system operation.

- The association of transfer switches to related controls is not readily apparent.

- Controls and displays are mounted above and below recommended anthropometric limits. Parallax and glare were observed on panel indicators (Photo #26) mounted 80" above the floor (68" maximum recommended).

- Label nomenclature does not correspond to that used on the main control panels.

- A good communications system is essential for effective operation of this panel. The operator must rely on auxiliary operators to effect manual control operations, and may also have need to communicate with the technical support center. To date, no such communication system is installed.

3.2 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, but several specific areas may merit further attention.

3.2.1 Indicators

Meter scales, in some cases, have more than the recommended nine intermediate graduations between numbered subdivisions. In other cases, scale subdivisions are numbered in non-standard progressions which are relatively difficult to interpret (Photos #27, #28).

To date there has been no attempt at color coding indicators and recorder scales to identify normal and abnormal ranges. Such coding can be a valuable operator aid, permitting a rapid, qualitative reading of plant parameters. Control room instrumentation should be reviewed to determine which would benefit from this technique.

One type of indicator, in widespread use on panel 680, is very small (approximately 2" scales) and uses a fine red line as a pointer (Photos #5, #6, #29). Indicators of this type are relatively difficult to read accurately from normal viewing distances. Alternate styles of indicators may be desirable in some applications, particularly for the more important parameters, such as reactor water level and SRM period.

Glare and parallax were observed on some indicators, particularly those placed high on the control panels. These concerns are particularly applicable to the miniature meters on panel 680.

3.2.2 Recorders

Several deviations from optimum design were noted on control room recorders. Alarm points are generally not identified and scales are not color coded to indicate normal and abnormal ranges. Some recorders have frosted windows which detract from chart readability (Photo #30). Others use very small numerals which are relatively difficult to read. The proper style of chart paper is not marked on recorder cases.

3.2.3 Indicating Lights

The intensity of green indicating lights was thought to be too low by one team member. This should be reevaluated once final control room illumination conditions have been established to assure that illuminated and extinguished states are clearly distinguishable.

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 capability has been provided, the operator might be unable to ascertain if the bulbs were providing accurate information, or were indeed defective.

3.2.4 Switches

Shape coding of switch handles can be an effective technique for differentiating pumps, valves, breakers and other component types. This would enable the operator to rapidly locate a pump control switch in the midst of a complex mimic layout and provide a reference point for tracing the system flowpath. While several styles of switch handles are in use, no concerted attempt at consistent shape coding was obvious.

It is desirable that the operator be able to immediately locate certain potentially important switches such as turbine trips, system isolations, and manual initiations. If these switches are similar in appearance to those immediately adjacent, rapid identification may be difficult in a time critical situation. It is suggested that such switches be distinctively marked using colored pushbuttons or labels. In some cases this has been done, but the technique is inconsistently applied.

3.3 ANNUNCIATORS

With few exceptions, annunicators are generally grouped by system and placed above related controls and displays on the panels. However, some inconsistencies in window arrangements were noted within system groupings. For example, on panel 870-7, alarms for trips of steam packing exhausters A and B are arranged vertically (A3 and B3) but the alarms for trips of mechanical vacuum pumps A and B are placed in a horizontal relationship (H2 and H3). Low level alarms for the HPCS fuel storage tank are arranged vertically on panel 601-16 (A3 and B3) but low level alarms for the emergency diesel fuel storage tank are arranged horizontally on panel 877 (A3 and A4).

Many different types of alarms may be found within annunciator panels: pump trips and system insulators, warnings of abnormal conditions, informational displays describing switch positions and system status, and diagnostic displays actuated by various points in system logic trains. These alarms have currently not been divided by type, but are interspersed among each other. One alternative for enhancing the annunciator system might be to reposition alarm windows within panels into hierarchical arrangements, i.e. place the most significant trips and warnings together at the top of the panel. Informational and diagnostic displays would then be segregated in the lower rows of the annunciator panels.

This technique facilitates rapid evaluation of system and plant status, as the most important information is immediately provided to the operator.

An associated enhancement technique involves color coding annunciator windows by type. Red may be adopted to indicate a component trip or system isolation, amber to mean a pre-trip warning, blue for system status indications, etc. This method of coding annunciators provides a visual prioritization of alarms and further accentuates hierarchical groupings.

Most annunciator legends describe very explicity the function of the alarm. A design tradeoff is involved here, as exactness has sometimes been obtained at the expense of brevity. In some cases, the precision of the description may actually detract from annunicator readability, as the legends become very wordy. Window 601-20-A3 for example, "LOGIC FOR LPCS/LPCI FM RHR A DW PRESS HIGH" could alternatively be worded "HI DW PRESS (LPCS/LPCI)." This technique of shortening legends has been employed on panel 680 as part of a program to increase lettering size. The same strategy applied throughout the control room would produce more succinct readable annunciator legends.

A number of alarms were identified which are associated with parameters having multiple action levels. Reactor water level, for example has alarms for many different levels; an annunciator reading only "low water level" might signify a scram, an isolation, an emergency system initiation signal, or any of several other trips. Although there are a few exceptions, this ambiguity was generally not observed at Perry. Most such legends clarify the intent of the alarm with additional wording such as 601-20-B3, "LOGIC FOR LPCS/LRCI FM RHR A RPV LEVEL 1." However, as discussed above, the utility may wish to consider rewording some of these legends to achieve more concise descriptions. An alternative wording for the above example would simply be "RPV LEVEL 1." In any case, it is suggested that the most important part of the legend, "RPV LEVEL 1," should appear on the top line with clarifying statements below. In some cases, adding actual numerical setpoints may also be beneficial. This may be especially appropriate for parameters with technical specification limits and for those having action levels related to the emergency procedure guidelines.

Annunciator windows on panel 680 are very small, making the legends difficult to read from a normal viewing position (Photo #5). Perry apparently recognizes this concern, as they have already instituted a program to rectify this situation (Photo #31). Annunicator legends are abbreviated and shortened wherever possible, then the lettering size is increased. This technique has resulted in enhanced readability for these windows. However, care should be taken that the abbreviations adopted for these windows are standardized and do not conflict with those used in other areas of the control room.

No alpha-numeric location code has been provided for annunciator panels. In order to cross-reference the applicable alarm response procedure, the operator must identify a window by counting down and across the matrix. This could conceivably increase the chance for error, particularly during conditions of increased stress. Adding reference letters and numbers to the borders of the annunciator inserts would greatly facilitate this process.

The recommended design for the annunciator response system specifies four separate buttons at each panel - test, acknowledge, silence, and reset. This arrangement is considered optimum in terms of convenience and usability.

Alarm silence buttons have only been provided on the 680 panel at Perry. This design may affect operator response paths and increase walking distances during transients. In order to quiet the control room as new alarms are actuated while responding to the situation, the operator must either continually walk back to panel 680 to press the "silence" button, or walk directly to the panel having the alarm and press the "acknowledge" button. He is unable to silence an alarm from all panels.

"Acknowledge" and "reset" functions have been combined into one button at Perry. This may result in loss of information during transients, as any "cleared" annunciators will be reset when subsequent alarms are acknowledged. Alternatively, all information may be retained by using the silence button exclusively until such time when all activated alarms may be reviewed and analyzed. However, this method may require many trips to panel 680 during the transient.

3.4 PROCESS COMPUTER

The computer keyboard and three associated CRTs are integrated into the center console. As noted earlier, there is some question as to the position that the operator will assume in using the computer. If the operator is seated at the keyboard, he has straight, head-on visual access to the left-most of the three CRTs. The other two CRTs, however, offer unfavorable viewing angles. Also, the CRTs are placed rather high for seated operation. Since the operator may have difficulty seeing and reaching other controls and displays while seated at the computer keyboard, there are indications that the computer may be operated from a standing position.

The computer consists of only a single processor having auto-restart capability within thirty minutes. If heavy dependence is placed on the computer during plant operation, addition of a second processor should be considered.

About one dozen CRT display pages were reviewed briefly. While great care and innovation has obviously been applied in developing CRT formats, some potential concerns are foreseen. Perry personnel are currently developing their own color coding schemes. If Perry-developed displays and displays from other vendors are integrated into one system at a later time, it may be anticipated that inconsistencies in color usage will become apparent. Furthermore, the Perry displays reveal several internal inconsistencies in the use of specific colors. For example, on one graphic display, the color red is used merely to differentiate core system function from others. Elsewhere, red is reserved for conveying danger, malfunction, or out-of-tolerance limits.

While the CRT displays reviewed were not yet color adjusted, some of the colors used for mimics, especially green, appeared very intense. Mimic colors and associated symbols that are static should be less intense (e.g., dark blue), reserving more intense colors for dynamic information of greatest relevance to the operator.

During interviews, operators expressed a desire for more CRT displays using simplified P&ID formats. It is recommended that a systematic approach be adopted to incorporate operator inputs in the process of formulating CRT displays.

3.5 PROCEDURES

Since few procedures had been prepared at the time of the control room survey, a thorough evaluation of plant procedures could not be performed. However, a document titled System Operating Procedure Format (SOPF) is available, serving as a guide to procedure writers. Some preliminary comments can be provided, based upon reviews of this document and initial drafts of several system operating procedures (SOP's).

The SOPF is, for the most part, clear and complete. Numbering conventions, terminology, cautions, system lineups, and content are all fairly thoroughly covered. However, a few items may merit further attention.

The introduction to the SOPF states that the document is intended to serve as an "informal guide" for procedure writers and that it will have "little, if any, use" after all SOP's are written. If consistency in procedure structure is to be assured, the guidelines provided in the SOPF must be considered permanent, formal requirements, applicable to all procedures currently being prepared and all future revisions. Otherwise, the same conventions may not be followed by other writers later in the life of the plant.

It may be desirable to include some of the information presented in the SOPF in the front of each procedure or in a general, introductory SOP, particularly if the SOPF is only a temporary document. Definitions of terms such as "in service," "secured," "jog" and "throttle," value numbering conventions, and electrical designations must be clearly understood by the users of the procedures. This information should be readily available for easy reference.

Section 3.4 of the SOPF states, "when writing SOP's, approximate numbers should be specified, e.g., increase pressure to approximately 75 PSIG." This practice may not, in all cases, provide sufficient guidance to the operator. Permissible ranges, upper and lower bounds, and degree of acceptable deviation are not apparent from this terminology.

Section 3.1 of the SOPF allows paraphrasing of component labels in SOP's. While this practice may result in more readable procedures, it is more desirable to always use "as labeled" component designations. In addition, if a paraphrased label is descriptive enough for the SOP, the same simplified wording should suffice for the panel labels themselves, thus resulting in more succinct labels. As illustrated by an example provided in the SOPR, "RCIC PMP FM STRG TANK SUCTION VALVE" could be labeled as simply "CST SUCTION VALVE" (Photo Ø14).

According to the SOPF, panels are referred to by complete name and number the first time they appear in a procedure, subsequently by P-number only. If, as stated in the SOPF, P-numbers are not unique throughout a unit, the complete number should be used in all cases, as in some situations a procedure may not be entered at the beginning.

The SOPF specifies a convention for differentiating between units in writing SOP's. Depending upon the circumstances, one SOP may be written for both units with a number symbol (#) replacing the unit prefix in valve numbers, differing valve numbers may be put in brackets, clarifying sentences noting unit differences may be added in brackets, a separate section may be written in the SOP, or completely separate SOP's may be prepared. In the SOP's reviewed, these methods seemed effective and unambiguous. However, to prevent any possible confusion it is recommended that each procedure be carefully reviewed as it is written to assure that unit differences are clearly defined. Separate procedures are probably appropriate for the more complicated systems which have many unit-specific value numbers. On the other hand, emergency procedures are probably best written as applicable to both units whenever possible.

No laydown space has been provided at the panels themselves to allow use of procedures while actually operating panel controls. This often means that the operator must either set the procedure on the panel or hold it in one hand while operating with the other. This arrangement is particularly inconvenient at panel 680. Two handed operation is often required in a plant startup, during which time the operator must continually refer to his rod sequence list (Photo #32).

3.6 CONTROL ROOM ENVIRONMENT

An evaluation of control room environmental typically includes a review of normal and emergency illumination, noise levels, heating and air conditioning, the communication system, auditory alarms, protective equipment, personal storage facilities, habitability provisions and housekeeping. At Perry, however, many of the foregoing factors could not be evaluated since the plant is not yet operational. Such factors as noise levels and adequacy of auditory alarms cannot be assessed until a representative operational environment is experienced. Similarly, the design of the communication system and equipment storage space could not be evaluated since these design decisions had not been made at the time of the review.

Despite these limitations, the following general conclusions can be formulated:

3.6.1 Normal Lighting

Normal and backup emergency illumination were measured by means of a WESTON Light Meter, model 614-60. Typically the light falling on the apron sections of the primary consoles was greater than the light available on the vertical sections. However, the lighting on all panels either met or exceeded the recommended 30-50 foot candle range.

A conflict may exist between the ambient lighting environment optimal for viewing the CRT's imbedded in the center of panel 680 and that for viewing other displays. Use of hoods might be appropriate to provide greater contrast on the CRT's, but such hoods may further complicate viewing angle considerations discussed in Section 3.4.

3.6.2 Emergency Lighting

While normal illumination levels are satisfactory, emergency lighting levels categorically fell below the recommended minimum, ranging from 2 to 12 ft-c. It is recommended that this system be augmented to provide illumination of at least 20 ft-c at panel surfaces.

3.6.3 Noise, Alarms, Communications

As noted earlier, noise levels in the control room are not representative during the present construction period. Alarms tested during the review appeared overly intense but such judgements are subjective and not valid until a realistic signal-to-noise ratio may be evaluated.

The communications console will be located in a space-limited area in front of panel 680 and will be flanked by panels 870 and 601. The final design of this console has not yet been determined but it is evident that special care will be needed to insure that it does not impede the movements of operator personnel to and from the three main control panels.

3.6.4 Protective Equipment

Fire extinguishers have been placed in the immediate vicinity of the operator's normal location (attached to the seismic support columns). Provisions for storing protective garments, face masks, air bottles, etc., have not been established at the present time.

3.6.5 Storage Space

Provisions for storing operator personal effects and spares (lamps, chart paper, tapes, tools, etc.) had not been established and could not be reviewed. Similarly, no storage shelves or cabinets were available for procedures, schematics, manuals, etc. Care should be taken that sufficient storage space is provided for these items without obstructing walking paths.

3.6.6 Heating and Ventilation

These systems were not fully operational and could not be reviewed.

3.6.7 Sanitary Facilities

Kitchen facilities and restrooms are presently located outside of the control room, at distances of approximately 45 yards and 32 yards respectively. This configuration may prove somewhat inconvenient, and consideration should be given to providing these facilities immediately adjacent to the control room.

4.0 DETAILED FINDINGS

4.1 PANEL LAYOUT AND DESIGN

4.1.1 Anthropometrics and Control Room Arrangement

	Evaluation Product[1]
1. Panel 680 is four inches deeper than recommended. (A1.1)	4
2. The relative positions of Division I and Division II controls on panels 622 and 623 differs between units. (A1.2)	4
3. The corners of panel inserts and the edges of the guardrail on panel 680 are somewhat sharp (Photos #9 - #12). (A1.4)	2
4. Operator pathways between panel 680 and other benchboards may be obstructed by the centrally located panel 803 (Photo #24). (A7.1)	6
5. Views of panels 870 and 877 are partially blocked from some positions in the control room by a centrally located support column (Photos #21, #22). (A7.2)	6
6. The off gas and radiation monitoring panels cannot be seen from the normal operating area (Photo #23). (A7.2)	9

4.1.2 Demarcation Lines and Mimics

1. Mimic layouts have been utilized on most inserts of the main benchboards. However, a few opportunities still exist for which this technique may be appropriate. These include the recirculation system on panel 680 (Photo #33) and the air removal system on panel 870-7, which are currently not mimiced. (A2.2)	9

[1]See Section 2.0 for explanation of Evaluation Products.

Evaluation Product

2. Controls and displays on the main benchboards are generally divided into system groupings by the panel inserts themselves. However, there are occasions in which controls for two systems are present within one insert. In these cases, use of demarcation lines and system summary labels should be considered to delineate operating areas and accentuate system groupings. These techniques might be applied in the following instances: (A2.2). 9

   Divide main and auxiliary steam to reheater controls on panel 870-7 (Photo #34).

   Separate RCIC and LPCS controls on panel 601 (Photo #35).

   Distinguish relief valve controls from main steam line valves on panel 601-19 (Photo #36).

   Delineate standby liquid control system operating areas within panels 601-18 and 601-19.

   Similarly, use of demarcation lines may be beneficial on some backpanels to divide system groupings and demarcate undifferentiated matrices of controls. The following examples were identified: (A2.2)

   Remote shutdown panel (Photo #25)

Panel 970 (Photo #37)	Panel 655
Panel 904 (Photo #38)	Panel 865 (Photo #40)
Panel 845 (Photo #41)	Panel 881 (Photo #39)
Panel 632	Panel 882
Panel 654	

	Evaluation Product
3. Within system groupings, additional use of demarcation lines may be made to divide subgroups of related components. The following examples are provided: (A2.3)	9

Divide A and B recirculation loops on panel 680-4 (Photo #33)

Demarcate inserts on the right wing of panel 680

Subdivide the remote shutdown panel (Photo #25) and and panel 845 (Photo #41)

Functionally demarcate components on panels 881, 882, 883 and 865 (Photos #39, #40)

Subdivide quantitative displays on "B" panel inserts

4. While quantitative displays on the "B" inserts of the main benchboards are generally grouped by system above related controls, these arrangements could be accentuated through use of demarcation lines to define system operating areas (Photo #13). (A2.2)	12
5. Graphic techniques used in mimic arrangements generally provide visual distinction between main and auxiliary flowpaths. Two exceptions were noted on panel 970, where the fuel pool cooling filter demineralizer and heat exchanger bypasses appear to be main flowpaths. (A2.4)	4
6. The blue mimic lines as used on panels 680 and 601 provide poor contrast with the dark brown panel background (Photo #42). Similarly, the grey lines on panels 800 and 904 are difficult to see against the beige background of these panels. (A2.5)	4

	Evaluation Product
7. Dotted white lines are used to represent both the containment and feedwater injection lines on panels 601-17 and 601-20 (Photo #42). (A2.5)	4
8. Mimic flowpaths generally appear orderly and easily recognizable. However, the RHR system layout on panel 601 (Photo #42), the ventilation mimics on panel 904, and the containment mimic on panel 800 appear somewhat convoluted. (A2.7)	6
9. The mimic on panel 601-19 incorrectly indicates the safety-relief valves in series (Photo #36.) (A2.7)	6
10. Additional use of flow direction arrows may be beneficial in the mimic on panel 904 (Photo #43). (A2.9)	2
11. Starting and ending points are difficult to identify in the containment and drywell purge mimics on panel 800 and the nuclear component cooling mimic on panel 970. (A2.10)	4
12. A symbol should be devised which more clearly represents the suppression pool than that currently used on panel 601. The present open "U" shape is rather non-descript and is unlabeled (Photo #42). (A2.12)	4

4.1.3 Control/Display Groupings

1. Controls and displays are generally grouped by system with identical layouts for repetitive groups. Examples of exceptions include: (A3.1)	6
a. The arrangements of relief valve indicating lights differs on panels 601-19, 628, and 631.	

Evaluation
Product

b. Equipment drain system components are interspersed with floor drain system components on panel 881/882.

c. Standby liquid control system components are divided between panels 601-18 and 601-19.

d. Drywell pressure and temperature indications are not placed adjacent to each other on panel 601, but are interspersed with containment pressure and temperature.

e. The RHR controls on panel 601 are separated into left-center-right panel segments. The RCIC controls are distributed across center and right panel segments. Relief valves controls are not aligned.

2. The ordering of control-display elements was not always in the recommended left-to-right or top-to-bottom arrangement. Examples are: (A3.2) 6

a. Steam lines on panel 601 (18 and 19) are arranged B D A C.

b. CCW Chillers on panel 904 are arranged A C B from top-to-bottom.

c. Control-display sequences on panel 628 show no correlation to those of related elements on panel 601-19. No obvious numerical sequence was observed on panel 628.

d. On panel 870-4, condensate inlet valves are arranged in a 2A - 2B - 2C - 1A - 1B - 1C top-to-bottom sequence.

3. The association between transfer switches and related controls is not evident on panel 001. (A3.3) 6

4. The association of selector switches to recorders on panel 883 is not obvious. (A3.3)

	Evaluation Product
5. Some panels contain undivided strings or matrices of related components. These groupings should be differentiated from adjacent controls with demarcation lines, hierarchical labeling, spacing or color coding. The following examples were noted: (A3.4) VALVE STM LEAK-OFF switches on panel 865 (Photo #40) Matrix of ARMs on panel 902/906 Meters on panel 970 (Photo #37) Control-display elements on panel 628/631 Control-display elements on panel 881/882 (Photo #39)	6
6. Many backpanels have controls and indicators mounted both above and below recommended heights. (A3.6)	9
7. The top rows of indicators on panels 601, 870, and 877 are above recommended heights. (A3.6)	6
8. Out-of-service switches on panels 601, 870, and 877 are higher than recommended. (A3.6)	6
9. The uppermost indicators on panel 680 are higher than recommended. (A3.6)	9
10. The emergency shutdown panel contains controls and displays placed above and below recommended limits. (A3.6)	9

4.1.4 Color Usage

1. A color code is in effect at Perry, specifying color applications for mimic lines and indicating lights. However, not all systems have assigned colors. (A4.1)	6
2. Blue mimics are used for both the nuclear component cooling and the fuel pool cooling system on panel 970. (A4.2)	6

	Evaluation Product
3. Unlabeled white indicating lights are used on panels 669 and 672 for both LPRM downscale and LPRM bypassed indications. Similarly, red hydrogen purge lights and amber high/low vacuum lights on panel 845 are not individually labeled (Photos #44, #45). (A4.3)	6

4.1.5 Labels

1. The following components are missing function labels: (A5.1)	6

Four indicators on panel 680-3 (Photo #6)
Indicating lights on panels 622 and 623 (Photo #46)
Two meters on panel 870-1
Ten switches on panels 881 and 882
Four indicating lights on panel 632
One pushbutton on panel 654
Numerous components on panel 845 (Photo #47)
One switch on panel 870-5 (Photo #48)
Indicators on the right wing of panel 680 (Photos #49, #50)

2. System labels, seen on panels 601 and 870, are not used on most other panels. (A5.3)	6
3. Panels are generally not identified by both number and function. (A5.4)	6
4. The following inconsistent abbreviations were noted: (A5.5)	4

SUPPR/SUPR
V/VLV
SUP/SUPP
CST/STRG TANK
MOTOR FDW PUMP/MFP
SUPR POOL/SUPPR POOL/SP

Evaluation
Product

SVCE AIR/SA
INST AIR/IA
CIRC WATER/CIRW
CNTM/CNTMT
DG/DIESEL GEN
MANUAL BLOW/SRV
PP/PMP
VV/VLV
LKD/LD
COND/CNDS
OT BD/OTB
DR (Door)/DR (Drain)

5. Label syntax is not always consistent. For example, most valve labels include a "VLV" designation, but this designation is missing on a panel 970 label reading "NCC TO/FROM FPCC HEAT EXCHANGERS." (A5.5) 4

6. The terminology used on panel 001 relief valve control switch labels does not correspond to that used on panel 601. (A5.5) 6

7. Many instances of repetitive labeling were found (Photo #15). Institution of a hierarchical system should be considered to shorten device descriptions and accentuate functional groupings of panel components. (A5.7) 6

8. Labels above controls on the "C" inserts of panel 680 are obscured by the projecting switches and cannot be read from a seated operating position (Photos #2, #3). Labels below components on the lower surfaces of some vertical panels are difficult to see from a normal operating position. These include panels 600, 632, 655, 800, 823, 842, 845, 883, 902, 906, 904, 907, and 970 (Photos #17 - #20). (A5.9) 9

Evaluation
Product

9. The following labels do not clearly describe the function 6
of the associated components: (A5.10)

a. Valve controls on panel 865 are identified only by number

b. "RCIC" on panel 632 should read RCIRC

c. "1P" is incorrectly used twice on panel 870-4, instead note: instead of "IP."

d. The center position marking of switch E31A-513A on panel 632 appears to be part of the function label (Photo #51)

e. Valve controls on panel 865 are identified by number only.

f. Containment isolation valve indicating lights on panel 601 are labeled by number only.

g. Two physically similar, adjacent switches on panels 691 and 694 also have very similar designations - STEAM LINE DRN VLS ISOL LOGIC TEST and MAIN STEAM DRAIN LOGIC TEST (Photo #52). The possibility of confusion could be reduced by more distinctive labels.

h. The meaning of "PERS AL EL603 OTBD DR LRT SA ISOL VLV" on panel 881/882 is unclear. A more concise label would be more readable.

i. On panel 601-19, the label for switch B21-F015 currently reads "MAIN STEAM LINE B SAFETY/RELIEF VALVE." The correct legend is "MST LOW POINTS DRN SHUTOFF VALVE".

j. Reactor water cleanup dump flow indicator G33-R602 on panel 680-1 is incorrectly labeled "PUMP FLOW."

k. The condenser vacuum trip reset button on panel 680-7 is labeled only "COND VACUUM TRIP."

l. "UPSTREAM" and "DNSTREAM" designations are reversed on drain valve indications 2N22-F190A, F230A, F180B, and F210B on panel 870-5.

m. Labels for valves N25-120A (B) and 125A (B) on panel 870-5 incorrectly imply that scavenging steam is sent to the condensor.

n. On panel 870-6 identification numbers are reversed on labels for main steam pressure indication upstream of reheater 1B and 2A control valves (N11-R146A and R141B)

o. On panel 870-8, RFPT vacuum trip override switches are labeled as resets.

p. RFPT high pressure stop valve before and after seat drain valve control switches have incorrect numerical designations on panel 870-8

q. Labels for RFPT lube oil test switches and associated indicating lights on panel 870-8 should specify that a pressure test is involved.

r. "ST SEAL EVAP DRN" on the label for indicator 1N22-F270 on panel 870-7 should read OFF GAS PREHTRS.

s. The word "fan" should be included on the label for exhaust fan A control switch on panel 870-7 (1N33-C001A).

t. The label for the low pressure condensor vent valves control switch on panel 870-7 (1N62-FC10) should specify that all three valves (A, B, and C) are actuated.

Evaluation
Product

u. "RFPT A (B) ST SEAL LEAK OFF DRIV VLV" on panel 870-8 (1N22-F260A, B) should read RFPT A (B) FIRST STAGE DRN VLV.

v. The stator water cooling pump reserve cutoff switch on panel 870-9 is labeled only "CUTOUT." Its numerical designation incorrectly implies that it operates stator water cooling pump A.

w. Escutcheons are provided for "MST TO 2ND STAGE RHTR B DRAIN VLV" control switch on panel 870-5 and for "S/V V POSIT" indication on panel 680-3, but no associated components are installed (Photos #6, #53). NOTE S/U

10. Labels are mounted below most indicators, but have been placed above controllers. (A5.11) 12

11. Identifying labels on the SRM/IRM drawers on panels 669 and 672 are not distinctive against the panel background. (A5.13) 6

4.2 INSTRUMENTATION AND HARDWARE

4.2.1 Controllers

1. The following controllers were not easily reached from a normal operating position: (B1.1) 6

   a. RCIC controllers on panel 001 are mounted high.

   b. Four controllers on panel 800 are mounted low.

2. Based on experience at the simulator, an operator reported that the RCIC PUMP FLOW controller on panel 601 is too sensitive in the manual mode. (B1.2) 2

	Evaluation Product
3. Controllers are clearly marked to show manual and automatic control options. However, on panel 001 the MANUAL/AUTO designations are obscured by the controller lever due to the high placement of the controller. (B1.3)	4

4.2.2 Indicators

1. Indicator scales are generally not marked or color coded to indicate normal, marginal, and abnormal ranges. (B2.1)	12
2. Glare or parallax were observed on the following panels, usually on the uppermost displays: (B2.2)	9

001	623	803
601	632	804
604	642	870
619	680	904
622	800	970

3. Process units are not specified on labels for the following indicators and recorders: (B2.3)	4

IRM/APRM recorders, panel 680
LOOP A/B Flow, panel 680
TOTAL RECIRC FLOW, panel 680
PRESSURE, panel 680
REACTOR LEVEL, panel 680
Bailey recorders on panel 001
Indicators on panel 619
Hydrogen analyzer and glycol pump temperature displays, panel 845
Indicators on panel 811

	Evaluation Product
The label for the drywell pressure recorder on the emergency shutdown panel does not specify whether the pressure is displayed in psig or psia.	
4. Some indicators and recorders were found for which alternate process units may provide more useful information to the operator: (B2.3)	6
a. HEATER 1 LEVEL (N26-R042A) on panel 870-4 is incorrectly scaled in lbm/hr.	
b. HEATER 1 PRESSURE and MAIN CONDENSER SHELL PRESSURES on panel 870 are scaled in psi vac, whereas in Hg-vac would be more common.	
c. The feedwater check valve indicator on panel 612 is inappropriately scaled in amps.	
d. The hotwell level controller on panel 870-2 is scaled as 0-100, corresponding to dump/makeup (Photo #54).	
e. The condensate storage tank level indicator on panel 870-2 is scaled 0-100%, but procedure references specify level in gallons (Photo #55).	
5. Small indicators such as those used on panel 680 are not easily read. The control band on the SRM period meters subtends a very small visual arc when viewed from a normal operating position (Photos #5, #6, #29). (B2.4)	6
6. Scales on panel 823/842 are not identified clearly. Units are small and often obscured from view. Sometimes the scales are not marked at all. (B2.4)	6

	Evaluation Product
7. Pointers partially obscure scale markings or numerals on round indicators located on panel 680 and four indicators on panel 632. (B2.5)	4
8. The direction of thumbwheel motion in automatic controllers is opposite to the resulting motion of the moving scale. (B2.7)	4
9. On panel 601, RX LEVEL recorders cannot easily be correlated with the REACTOR FUEL ZONE LEVEL indicator since the latter is not labeled or provided units. (B2.8)	4
10. On panel 001, references used for water level indications are at variance from those used in the control room. Also, the SUPPRESSION POOL LEVEL display is not clear since the zero point is not specified. (B2.8)	4
11. On panel 845, the RECOMBINER A and B DIFF PRESS scales are different thereby rendering comparative reading more difficult. (B2.10)	4
12. Some indicating devices are not scaled in subdivisions consistent with the accuracy required by the operator. Suppression pool level instruments provide indication to only ± 2 ft; a wider range may be required. On the remote shutdown panel, wider ranges may also be desirable for reactor level and drywell pressure indications. (B2.11)	6
13. A reactor pressure indicator on panel 680 has no scale (Photo #6). (B2.11)	6

Evaluation Product

14. The following indicators possess greater than nine intermediate graduations between numbered scale divisions (Photos #27, #28). (B2.12) — 6

Panel-601:	C11R100 B/A CRD PUMPS A/B
	E51-R601 RCIC PUMP DISCH PRESS
	E51-R602 MST TO RCIC TURBINE PRESS
	E22-R601 HPCS PUMP DISCHARGE PRESS
Panel 001:	SUPPR POOL LEVEL
Panel 622/623:	All meters
Panel 632:	EQUIPMENT AREA AMBIENT TEMP
Panel 642:	SUMP LEVEL
Panel 669-672:	APRM Indicators
Panel 823/842:	Bailey meters
Panel 845:	Several discrepant indicators
Panel 970:	FPCC SURGE TANK LEVEL A NCC PUMP A and B
Panel 811:	Several discrepant indicators
Panel 821:	Several discrepant indicators

15. Numbered scale divisions that were not in decimal multiples of 1, 2 or 5 were observed on the following panels (Photos #27, #28). (B2.13) — 4

001	680	870
601	800	904
622	821	970
669/672	823/842	

Evaluation Product

4.2.3 Recorders

1. Printed values on recorder charts may be difficult to read on the following panels: (B3.1) 6

   a. Panel 601 has mini trend recorders with very small numerals.

   b. On panel 865, a "frosted" cover causes "haziness" in reading the numbers (Photo #30).

   c. The lower recorder scales on panel 883 are not visible from a normal operating position.

2. Alarm points are generally not identified on recorder scales. (B3.3) 9

3. The multi-pen recorder on panel 845 does not provide adequate distinction between markings. (B3.4) 6

4. Some chart recorders are provided with dual speed capability while others are not. The operator is given no indication from the front of the panel to distinguish between single and dual speed capabilities. More widespread application of dual speed capability may be desirable, particularly for those parameters closely monitored during transient conditions and the instruments on the emergency shutdown panel. (B3.5) 6

5. Point select capability is not provided for most multipoint recorders. (B3.6) 8

6. Recorders are not generally marked to indicate proper size and type of chart paper. (B3.7)

	Evaluation Product
7. Nuclear instrumentation bypass switches could be disturbed when paper is replaced in IRM/APRM recorders (Photo #56). (B3.8)	4
8. The association of pen color to input parameter is generally not specified on recorder labels, except for those on panel 680. (B3.10)	4
9. Glare or parallax were observed on recorder faces located on panels: (B3.14) 600 680 907 642 800	6
10. Recorder scales are generally not marked to indicate normal and abnormal ranges. (B3.15)	9

4.2.4 Indicating Lights

1. Green lights on panels 680, 800, and 881/882 were relatively dim. However, normal operational room illumination conditions have not been established. (B4.1)	6
2. There currently exists no positive means for testing or detecting failed indicating lights. (B4.4)	8
3. Relief valve position indications on panels 001 and 601 display only the condition of the actuating solenoid, rather than the actual valve position. (B4.7)	6

Evaluation Product

4.2.5 Switches

1. The direction of switch motions on the following panel 601 controls is not in accordance with accepted conventions: (B5.1) 9 6.4

   MAIN STEAM LINE INBD and OUTBD MSIVs close to the right and open to the left.

2. Several switches on panel 001 have escutchons incorrectly listing position options as "OFF-1-2" (Photo #57). (B5.1) 6

3. Switch positions were not always clearly marked: (B5.2) 6

   Panel 669 has controls with missing nameplates
   Panel 800 lacks markings for:
   AEGT A/B CHAN FLTR DELUGE
   DW Keylock Switch
   OG BLDG EXIT A/B CHAR FLTR DELUGE
   CNTMT AND DW EXH A/B FLTR DELUGE
   AB EXH CHAN FLTR DELUGE

4. Pushbutton switch N22-F300B on panel 870-8 is incorrectly provided with a rotary switch escutchion (Photo #58). (B5.2) 6

5. Center positions for the following switches are labeled "AUTO", but should be labeled "NORMAL": 6

   1N27-F140, panel 680-3
   1N11-F115B, panel 870-6
   1N33-F110, panel 870-7

   The center position of switch 1N27-C005A on panel 870-8 is labeled "NORMAL," but should be "AUTO."

Evaluation Product

6. Switches on the following panels have been placed above or below recommended heights and are not easily reachable from a normal operating position: (B5.3) 9

001	632	865
601	669-672	970
604/803/804	800	

7. Operators report that the annunciator pushbutton controls sometimes trap fingernails when depressed. (B5.5) 6.4 6

8. Switch handles have not been shape coded to distinguish switch functions (B5.10) 6.4 8

9. While red pushbuttons are usually provided for manual trip functions, similar distinctive marking is not used to highlight manual initiation pushbuttons for automatic systems. (B6.1) 6.4 9

4.3 ANNUNCIATORS

1. While most annunciators are grouped together by system within panel inserts, a few alarms were identified which could be better arranged: (C1.1) 6

   601-17-E4 and D5 are separated
   601-20-P3 and E4 are separated
   All scram signals are not grouped together on panel 680
   RHR pump room cooling for alarms are not grouped together on panel 800-R400
   Containment vacuum relief alarms for A and B trains are separated on panel 800-R405
   Combined gas mix system compressor alarms are separated on panel 800-R405

	Evaluation Product
Windows 904-R655-A3 and B3 are inverted relative to the surrounding windows 904-R655-B3 and E3 are separated Other alarms are interspersed with low flow alarms on the left side of panel 904-R655 Arrangements for RHR A and B alarms are not identical on panels 601-17 and 601-20	
2. Within system groupings, some inconsistency in arrangements of annunciator windows was apparent. Some related windows, such as 601-16-A3 and B3 are arranged vertically. Others, such as 877-A3 and A4 are arranged horizontally. Other examples of this variation in placement may be found on panels 845, 870, 904, and 680. (C1.1)	4
3. The following annunciators are not located above related controls and displays: (C1.2) 870-1-H1 870-5-D1 680-7-C9, C10, C11, C12, D9, D11, D12, E11, E12 680-15-B1	6
4. Annunciator windows have not been grouped by type; i.e., informational and diagnostic alarms are not segregated from trips and warnings. (C1.3)	8
5. The following inconsistent abbreviations were found on annunciator windows: (C2.1) ST LN (680-1-C3) versus MSL (680-3-A8) CNDR (680-1-A6) versus COND (680-3-A6, A7) ATWB (680-4-E12) D/W (680-4-D6, D15) versus DW on other panels RX versus RPV (680-5-C5)	4

CIRW PUMP (870-3-E1)
TB (870-3-H2) versus TURBINE BLDG (870-3-H1)
Periods are used in abbreviations on windows 870-4-A1, A2
CND STRG TK (870-7-A2) versus CST (601-16-F5)

6. Annunciator legends on panel 680 are not easily readable from a normal operating distance due to the small lettering size. (Photos #5, #31) (C2.3) 12

7. More succinct wording would enhance the readability of the following annunciator legends: (C2.5) 6

601-21-H1
601-20-A3, B3, C3, D5, E5
601-17-A3, B3, C3, D3
601-17-B1 (delete "B")
601-20-B2 (delete "A")
601-19-A2, B2
680-1-C3, D3, B4
680-4-C1, D1, E1, D1, D2, A6, C10, D10, E10
800-R405-E5, F5
870-7-D2

8. Wording for the following legends could more clearly define the purpose of the alarm. (C2.5) 6

601-17-H6 (indicates a particular valve lineup)
601-29-H2 (indicates a particular valve lineup)
601-18-A1, A2, B2, B2 ("identified" means equipment drain, "unidentified" means floor drain)
601-21-C6 (unclear whether this is associated with RCIC or LPCS)

	Evaluation Product
680-4-A5, A14 ("needs maintenance" is unclear) Electrical designations on annunciators on panel 870 are somewhat abstruse.	
9. The following alarms annunciate abnormal conditions for parameters which may have more than one trip, alarm, or action level. For example, "DRYWELL PRESS A HIGH" could be an alarm, a scram, an isolation, or a safety system initiation signal. In such cases the annunciator legend should clearly specify the intent of the alarm. (C2.6)	4
680-5-B5 870-3-H1 601-20-G2, H2, E6 601-17-G1, H1, E2, E5	
10. The following annunciators may be actuated from multiple inputs (high/low, etc): (C2.7)	9
601-16-A2, E5 601-19-G4, H4 601-17-G3, G4 601-20-D5, G4 601-21-66 680-1-A1, A2, A3, A6 680-2-B1, B2, B3 680-3-A9 680-4-A1, D8, E8, A10 680-5-B5 845-A4, B2, B4, B7, B8, C1, C2, C7, D1, E5, E8 870-3-E3 870-7-F2, G2 870-9-C2, C3, F1, F2 877-A2	

	Evaluation Product
11. While some attempt has been made at prioritizing annunciators with color coded windows, application of this technique does not appear to be well defined or consistent on all control panels. (C2.8)	9
12. Annunciator panels are not marked with an alpha-numeric location code. (C2.9)	8
13. Annunciator audible alarms are not directionalized or prioritized. (C4)	12
14. Silence buttons are only available on panel 680. (C5.1)	9
15. Separate acknowledge and reset buttons have not been provided. (C5.2, C5.3)	9
16. One set of annunciator response buttons on panel 680 is of a different style and configuration from all others (Photos #59, #60). (C5.5)	4
17. A first-out feature has not been provided. (C5.6)	8
18. The "cause" section of annunciator response procedures is somewhat long, including sensor identity, setpoint, reset point, and possible contributing factors. This section should be much more concise. Toward this end, listing sensor identity and setpoint separately may help, and also make this information easier to locate. (C7.1, C7.2)	6
19. There is currently no procedure or window markings to assure that annunciator legend plates are replaced in their corret locations when removed for maintenance. (C8.1)	12

	Evaluation Product
20. No administrative procedure is in effect specifying a method of identifying out-of-service annunciators. (C8.2)	12

4.4 PROCESS COMPUTERS

1. While the computer keyboard is appropriately located for a seated operator at panel 680, the CRT above the keyboard is placed too high and the other two CRTs offer unfavorable viewing angles. The operators indicate that the computer will probably be operated from a standing position. (D1.2)	8
2. The computer is capable of displaying selected input information, however, the C91 has a limited number of inputs (about 800). (D2.1)	4
3. The computer is not capable of automatic or manual switchover for processor failure since there is only one processor. (D2.7)	4
4. CRT displays are accessible and easily visible from a standing operator position but are too high and at unfavorable viewing angles from a fixed seated position in front of the keyboard. (D3.1 and D1.2)	4
5. Color standards for CRT displays are not fully developed but it appears that locally developed standards will be in conflict with vendor supplied display formats. (D3.4)	8
6. The computer printout is not prioritized. (D4.1)	8
7. The computer output is very difficult to modify and it is not anticipated that output will be periodically reviewed and updated. (D4.2)	8

	Evaluation Product
8. Ribbon replacement on the computer printer is difficult. (D4.7)	2

4.5 PROCEDURES

4.5.1 Procedure Availability and Accessibility

1. Storage space has not yet been alotted for procedures and reference materials. When space is designated, care should be taken that bookshelves do not obstruct walking paths in the control room. (E1.5)	12
2. Laydown space for use of procedures at the panels has not been provided (see Figure 6-1). This is especially important for panel 680 (see Figure 6-2). During startup, the operator must refer to the startup procedure and the rod sequence list. Operators reported that while practicing startups at the simulator they found it necessary to hold the rod sequence list on their knees. (E1.7)	8

4.5.2 Format and Content

1. SOPF guidelines do not specify standardized type size and style for procedures. (E3.1)	6
2. The SOPF does not require the use of as-labeled component designations in procedures. SOP-E51, Reactor Core Isolation Cooling System, requires the operator to verify condensate storage tank level greater than 150,000 gal. However, the level recorder on panel 870 is scaled in 0-100%. (E3.3)	8
3. SOP-C41, Standby Liquid Control System, states that the system is to be used only if there has been a loss of reactivity control. However, the methods by which "loss of reactivity control" may be diagnosed are not discussed. (E4.8)	6

	Evaluation Product
4. Valve locations are provided only on the valve lineup sheets, not in the body of the SOP. SOP-C11 for example, Control Rod Drive System, states, "All controls for this system are located on the ECCS Benchboard, # H13-P601." However the procedure calls for operation of pump discharge valves, which are not in the control room. Care should be taken that the above statement, typical of all SOP's reviewed, is in fact accurate. The procedure should provide locations for valves not in the control room. (E4.12)	9
5. The Precautions and Limitations sections provide technical specification limits only by referring to applicable sections of the technical specifications. Actual numerical limits should be stated. (E4.15)	6
6. SOP's do not discuss manual override of ECCS systems during transients, or specify when the systems may be reset after automatic initiation. (E4.20)	12

4.6 CONTROL ROOM ENVIRONMENT

1. Glare was observed on the remote shutdown panel, particularly on the uppermost indicator faces (Photos #25, #26). (F3.2)	4
2. The kitchen and toilets are outside the control room and relatively inaccessible. (F6.6)	4
3. Emergency lighting levels are below the recommended 20 footcandles minimum at panel surfaces. (F6.8)	12

5.0 EMERGENCY PROCEDURE TASK ANALYSIS

The Emergency Procedure Guidelines developed by the BWR Owners Group will form the foundation upon which Perry'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 existence 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 the annunciator panels disclosed that annunciators have been provided for all parameters associated with entry conditions to the guidelines. However, as discussed in Section 3.3, certain modifications of the annunciator system could enhance the effectiveness of these displays.

In several cases, redundant annunciators have been provided at multiple locations for the same action level, particularly for low reactor water level and high drywell pressure conditions. These annunciators are used to signify actuation of various points within logic trains and initiation signals for various systems. For instance, six different alarms are provided for high drywell pressure trips, three for level 8 RPV water level, three for level 3 and four for level 2. While repetition of key annunciators at 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. In any case, the design is not always consistently implemented. High reactor water level is annunciated for the HPCS system but not for RCIC. Channels A and B are annunciated for RPV level 2, but only one annunciator is provided for a low level scram. Similarly, A and B channels are annunciated for suppression pool level and temperature, but not for a high reactor pressure scram.

Alarms have generally been placed above the related system operating areas. For instance, the annunciator for a low water level scram is on panel 680, the alarm for HPCS initiation (level 2) is on panel 601-16 and the alarm for RPV level 2 containment isolation is on panel 601-19. This practice provides indication necessary for each system, but increases the difficulty of mentally integrating all indications to evaluate the condition of the plant. Thus, to determine the status of reactor water level, the operator must look in several different locations.

Most annunciators are very explicit in describing the nature of their inputs, but often this has resulted in very lengthy, even redundant legends. For instance, window 680-5-C5, "RPS LOGIC RX LEVEL HIGH RPV LEVEL 8" could be shortened to RPV LEVEL 8 (SCRAM) without sacrificing accuracy. Window 601-20-B3, "LOGIC FOR LPCS/CPC1 FM RHR A RPV LEVEL 1" could be abbreviated to RPV LEVEL 1 (LPCS/LPCI) and still supply the same information.

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 parameter, 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 the following concerns:

1. • If reactor water level has dropped below the top of the fuel, the operator is left with only one water level indicator on scale, which may not be calibrated for the existing conditions.

2. • Drywell and containment pressure instruments are calibrated in psia, whereas trips and alarm points are specified in psig.

3. • No direct indication of safety-relief valve position is provided.

4. • Suppression pool water level is referenced to normal, but technical specification limits are referenced to the bottom of the suppression pool.

5. • No discharge pressure indication is available for LPCS or RHR pumps.

6. • A given parameter covered by the Guidelines may possess several action levels. Suppression pool water level, for example, has at least eight limits of concern to the operator. 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.

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 change of error. Several positive aspects of panel layouts were noted by the survey team in these areas:

7. • System operating areas are generally separated by panel inserts

8. • Controls are generally functionally grouped within panel inserts

9. • Extensive use has been made of color coded mimics to organize system arrangements

Several other areas were identified in which modifications may be beneficial:

- No reactor pressure indication is available immediately adjacent to safety relief valve controls.

650?

- No wide range reactor pressure recorder is available on panel 650.

- No indication of reactor temperature is available in the main control area.

10. • The suppression pool level recorder has not been mounted in the main control area.

11. • CST level is not available in the HPCS or RCIC operating areas.

12. • No level indication is available in the HPCS operating area

13. • Emergency diesel controls and indications are located on panel 877, but controls and indications for the remainder of the electrical systems are located at the opposite end of the control room on panels 680 and 870.

Key controls and indicators indentified in the task analyses were compared against pertinent checklist criteria, item by item. This review disclosed the following points:

14. • Wording of component labels is generally very wordy and repetitious.

15. • Status lights for containment isolation values are labeled by number only.

16. • The full core display contains a large matrix of multi-colored lights. When under stress, it is conceivable that the operator might miss one or two non-illuminated red bottom lights.

17. • Verifying correct operation of emergency system status could be facilitated if major flowpaths were made more distinctive.

18. • Locating important indications could be facilitated by providing visual identification cues, particularly in areas of high instrument density (See Photo #5).

19. • Different zero references are used for reactor water level instruments. This may complicate comparing readings from multiple indications.

20. • Water level indication on panel 680 is available only on recorders and very small indicators in an area of high instrument density. This impedes visual location and accurate reading of this parameter.

21. • The wide range/narrow range level recorder on panel 680 is missing its label. Another level instrument on 680 is unlabeled; its purpose is unclear.

22. • The wide range level recorder on panel 680 has been supplied with an incorrect scale.

23. • The left hand wing of panel 680 has a very high density of instrumentation (Photos #5, #6). In the midst of these inserts are some of the operator's most important indications - water level and reactor pressure. These use either very small indicators which are difficult to read from normal operating distances, or are on recorders, which are more appropriately used for trend indication. Larger, more clearly labeled indications would be much easier to locate and use when evaluating plant conditions during major transients.

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

24. • 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 probable that expanded ranges for suppression pool level will be necessary.

25. • No indication of containment water level is available.

26. • No indication of suppression chamber pressure has been provided.

27. • 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.

28. • The operator must be able to determine drywell temperature adjacent to reference leg vertical runs.

29. • 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 system addressed by NUREG-0696.

30. • A given parameter covered by the Guidelines may possess several action levels. Suppression pool water level, for example, has at least eight limits of concern to the operator. Limits or action levels of immediate concern to the operator should be marked in fashion on the indicator or recorder. They 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.

31. • 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.

6.0 OPERATOR INTERVIEW SUMMARY

Ten operators were interviewed by the survey team, including five supervising operators, two operations engineers, two associate operations engineers and one reactor engineer. A complete list of all interview comments is attached as Appendix B to this report. In this section, those topics must frequently mentioned during the interviews are listed. Because Perry has no operating history, these comments primarily reflect experience obtained at the simulator.

- Six operators thought panel 870 to be rather confusing. Specifically, they found layouts for reheat steam and feedwater vents and drains to be hard to follow.

- Four operators found the high density of instrumentation on panel 680 to detract from the usability of that panel.

- Six operators complained of trouble reading the small indicators on panel 680.

- The stanchion in the center of the control room was considered a potential obstruction by five operators.

- Five operators desired more space in the control room for procedures, chairs, print laydown areas, etc.

- Condenser vacuum indicators were thought to be difficult to use by four operators, due to differences in scaling units.

- Five operators had experienced difficulty in operating the feedwater controller at low flow rates.

- Shape coding of switch handles was considered desirable by four operators.

- Five of those interviewed requested that an annunciator silence button be installed at each panel.

- Increased use of graphic CRT displays was desired by four operators.

- Five operators expressed displeasure with the depth and content of the present training program.

APPENDIX A

CHECKLIST ITEMS FOR LATER REVIEW

Because Perry 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.

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

A2.6 Are lives of demarcation, mimics or other graphic displays permanent and maintained?

A6.1 Are temporary changes minimized?

A6.2 Are temporary changes controlled in application?

A6.3 Are temporary modifications consistent and controlled in nomenclature, font and color?

A6.4 Are temporary changes accurate with respect to use or design intent?

A6.5 Are temporary changes incorporated into procedures?

A6.6 Are temporary changes applied to not obscure adjacent or background information or colors?

A6.7 Are temporary modifications reviewed periodically and made permanent or removed?

Instrumentation and Hardware

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

B3.12 Are chart recorders marked periodically (at least once per shift) and when chart speed is changed with date, time and initials to aid in data recovery?

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

B7.4 Are keys for key-lock switches administratively controlled?

B7.5 Where key-lock switches are used do procedures provide specific instructions for use?

B7.6 Where key-lock switches are used is switch action smooth and positive without use of excessive force?

Computers

D1.3 Are the computer console and output devices arranged for visual distinction and use of dials, buttons, and switches?

D2.4 Is the computer capable of receiving all inputs and performing programmed functions without becoming overloaded?

D3.2 Are CRT displays comprehensible with a minimum of visual search?

D3.3 Are CRT displays of adequate brightness for lighting conditions or equipped with conveniently located focus, brightness, and/or contrast controls?

D3.5 Are CRT displays color coded so that loss of a primary color gun does not result in loss of a numerical value or scale.

D3.6 Are CRT displays consistent with checklist standards for procedural format (See E3)?

D3.7 Are CRT displays identified by system or program?

D3.8 Are CRT displays provided with an access mode for display selection (either display menu or sectoring mode)?

D4.3 Is the capacity of the typer/printer sufficient?

D4.8 For the computer typer/printer are printouts easily readable (spacing, headings, formats, prints, etc.)?

Control Room Environment

Most aspects of the control room environment could not be reviewed at the time of the survey. This section should be re-evaluated when a representative environment exists.

APPENDIX B

OPERATOR INTERVIEW COMMENTS

OPERATOR INTERVIEW COMMENTS

The following is a complete list of all operator comments (see Section 6.0 for a summary of these concerns). 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. Refer 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 necessarily be interpreted as recommendations of the survey team.

Control Room Layout

The stanchion in the center of the control room obstructs visual paths and hinders movement.

The printer table blocks walking paths.

The center of the horseshoe is crowded.

There is no room for chairs, bookshelves, etc.

Chairs will have to have coasters.

Laydown space is needed at the panels for logs and procedures.

Personnel walking through the control room on routine business will be distracting to the operator; it may be desirable to locate the shift supervisor's office outside the control room.

Convenient restroom and kitchen facilities should be provided.

The off gas panel cannot be seen form the main control area.

Control rod drive system parameters cannot be monitored while pulling rods.

Panel Design

Panel 870 is confusing (specifically, reheat steam, heater vent and drain layouts)

The left side of panel 680 is very crowded with instrumentation; labels are small and it is difficult to locate desired indications.

The RHR system layout is involved and somewhat confusing; it is difficult to distinguish the three loops.

Mimics should be laid out better.

Mimics should show connections to other systems.

The association of control valve to related controller is not always apparent.

All feedwater pump controls should be in the same place.

IRM recorder labels are reversed.

Nuclear instrumentation bypass joysticks could be better arranged.

The control rod drive system mimic is not accurate.

HPCS diesel controls are too close to controls for other systems.

The TBCC system controls are not effectively grouped.

Recirculation system controllers should be mimiced.

Feedwater controllers should be mimiced. The main steam system layout is confusing; it is difficult to distinguish isolation valves from drain valves.

A consistent color code is needed.

Control Room Instrumentation and Hardware

~~Condenser vacuum indications have been scaled in many different units.~~

Many recorder labels do not provide the units of measurement.

The small indicators on panel 680 are difficult to read.

Reactor level and pressure indications are available on panel 680 only on recorders.

Level instrumentation is scattered throughout the control room.

The RHR recorder should be provided with point select capability.

Bailey recorders are difficult to read.

Bailey recorders often jam.

It is difficult to change the paper in Bailey recorders.

Suppression pool level should be referenced to the bottom of the suppression pool rather than normal level.

Reactor water cleanup drain flow should be scaled in gallons per minute rather than percent.

All steam and condensate flows should be scaled in lbm/hr.

Bypass jack demand and actual position indicators should have identical scales.

Panel switches should be shape coded.

The hotwell level controller should be labeled "dump-makeup" rather than "0-100."

Throttle valve switches should be distinctively labeled.

Pushbuttons should be distinguished from simple indicating lights.

~~Light bulbs in recorders, controllers and indicators are difficult to replace.~~

Some switches require too much force to operate.

The recirculation system controller is difficult to fine tune.

The feedwater system controller is difficult to adjust at low flows.

The recirculation system controller sometimes gets stuck in the full open position.

Controls and Instrumentation Needed in the Control Room

A concise display of isolation demand signals is needed.

The relief valve mimic should show the geometric arrangement of the valves in the suppression pool.

There is no indication of reactor temperature in the main control area.

NCC pump control should be at panel 680.

Off gas indication should be available in the main control area.

Turbine lube oil sump level should be available in the control room.

Several additional instruments may be necessary to operate in accordance with the Emergency Procedure Guidelines. These include:

Containment water level

ADS bypass capability

Low reactor water level main steam isolation bypass capability

Containment average temperature

~~Containment temperature adjacent to level instrument vertical piping runs~~

An alarm is needed indicating that the auto transfer switch for house loads is not in auto.

Unnecessary Controls and Instruments

Feedwater heater temperature and pressure indicators, panel 870.

Suppression pool cleanup controls.

EHC transfer pump controls.

Fuel pool cooling to upper containment pool valves.

The meters for feed pump RPM and control valve position are too large.

Redundant generator power indications, panel 680.

Controls Prone to Inadvertent Operation

The turbine load limit switch frequently gets bumped.

Two valves on panel 870, MST to ST SEAL EVAP SUPPLY VLV and EXST to 1st STAGE RHTR B DRAIN VLV have similar MPL numbers, (N33-F010 and N22-F010) which sometimes causes confusion.

The generator breaker (S-610-PY-TIE) and the sync select switch on panel 680 are similar in appearance and adjacent to one another.

Manual scram and manual isolation buttons on panel 680 are similar in appearance and close together.

Annunciators

~~Annunicators are useful during normal operating conditions, but less~~ so during major transients.

Annunciator windows should be more logically grouped.

More color coding should be instituted.

Color coding is not useful.

A first out feature would be useful.

Too many alarms actuated during transients simply indicate normal system operation.

Silence buttons should be installed at every panel.

A different tone should be used for local panel trouble alarms.

Panel 877 alarms should be part of the panel 601 annunciator system.

Annunciator windows on panel 680 are too small.

The RHR high conductivity alarm is usually actuated due to stagnant water.

The condenser high level alarm is on until approximately 90% power is reached.

Breaker trip alarms are confusing.

The logic defeating "low flow" alarms does not distinguish between pump trip and pump off conditions. Thus, if a pump trips, the low flow alarm is defeated.

Computers

More use should be made of graphic displays.

High speed line printers should be used.

More auto log capability should be provided.

Computer capability should be expanded.

Interactive displays should be used, particularly in the access mod

A CRT should be installed at panel 601.

More data points should be available for window display.

More windows should be provided.

The operator should be able to obtain a hard copy of CRT displa

Procedures

Procedures should use "as-labeled" component designations.

Drawings are in need of updating.

Control Room Environment and Communications Systems

A better point-to-point communication system is needed for should not be placed on radios.

Circuit cut-out switches are needed for handsets.

A better HVAC system is needed.

Lighting is too dim.

There is too much light.

The reactor operator should be able to dim the lights

Shift Manning and Turnover

Shift turnover procedures should require a plant tour.

Shift should be nine hours to allow for adequate turnover time.

Two reactor operators should be assigned to each unit.

A total of three supervisors should be on each shift (for two unit operation).

Training

A comprehensive training schedule should be set up.

The training program should concentrate more heavily on integrated plant response to transients.

The training program is not oriented to operator needs. Too much emphasis is placed on NRC requirements.

More simulator time should be allotted.

The quality and depth of the training program should be improved.

Miscellaneous

Some valves fully open once started and cannot be reversed in mid-stroke.

The diesels start on a loss of power to Division 3 bus, but then trip on high temperature because the ESW valves shut.

A reactor water cleanup system isolation must be reset locally.

RCIC and HPCS start at level 2, but ESW and ECC do not start until level 1. This causes high temperatures in RCIC and HPCS.

APPENDIX C

PHOTOGRAPHS

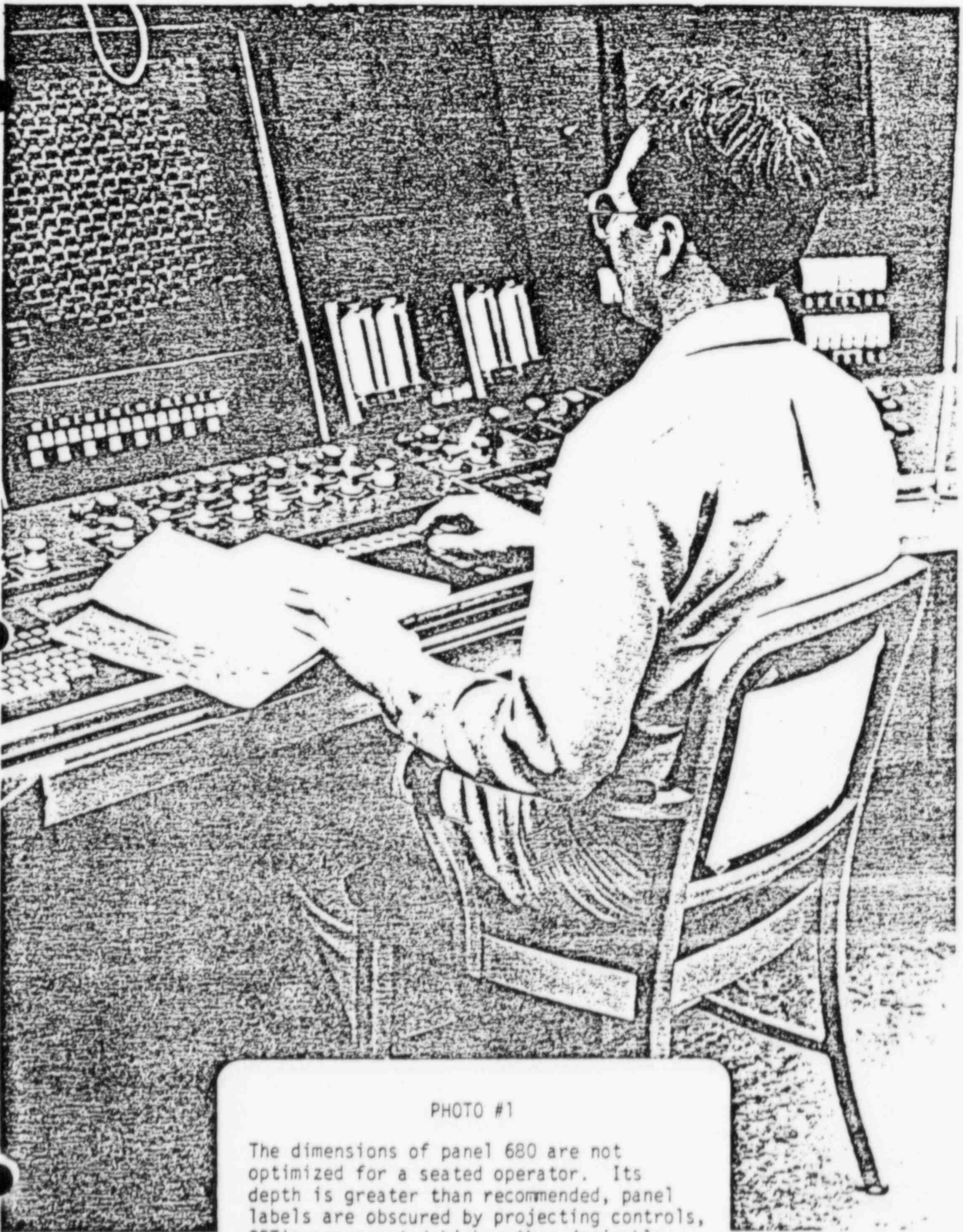


PHOTO #1

The dimensions of panel 680 are not optimized for a seated operator. Its depth is greater than recommended, panel labels are obscured by projecting controls, CRT's are mounted higher than desirable, and no procedure laydown space is provided.

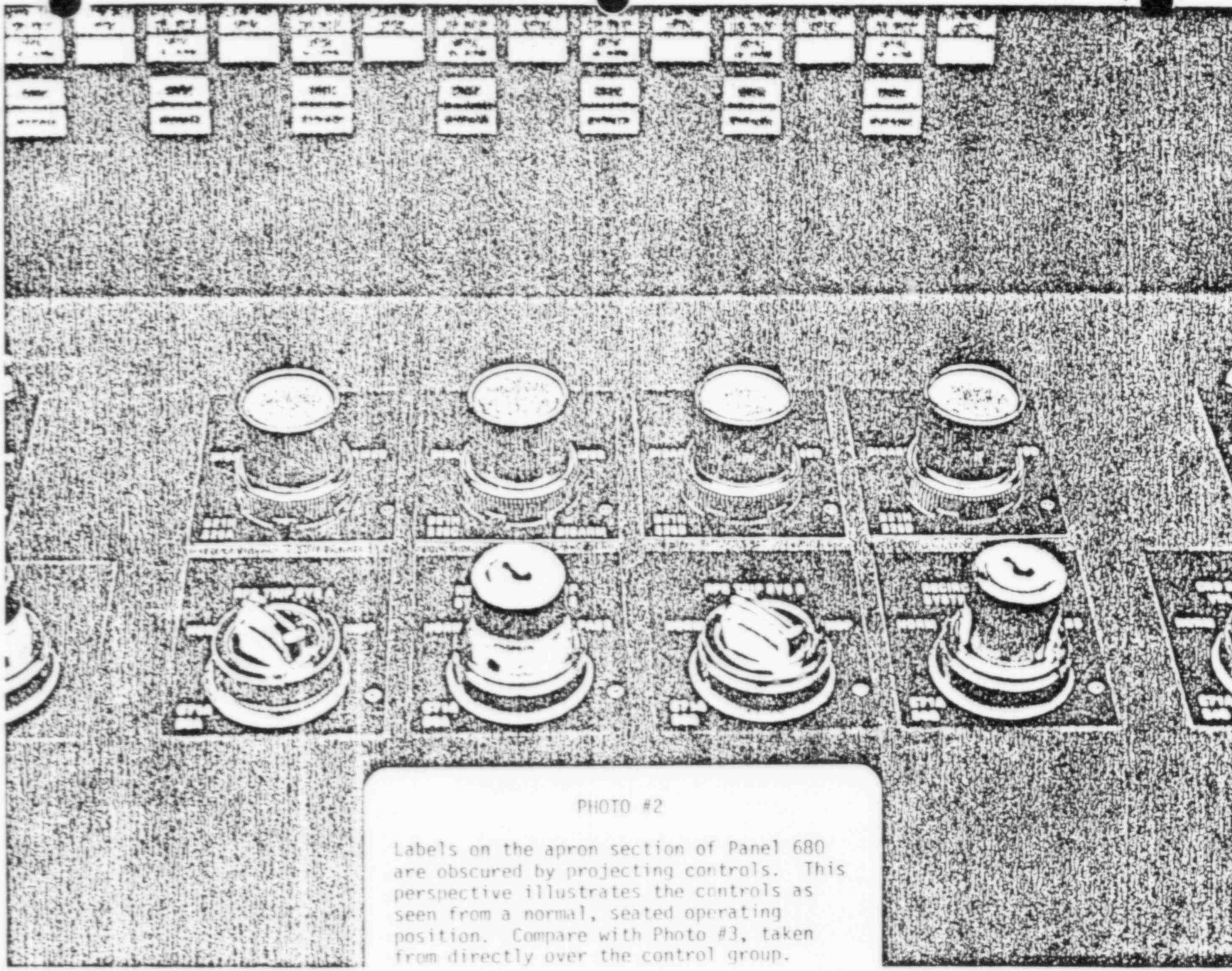


PHOTO #2

Labels on the apron section of Panel 680 are obscured by projecting controls. This perspective illustrates the controls as seen from a normal, seated operating position. Compare with Photo #3, taken from directly over the control group.

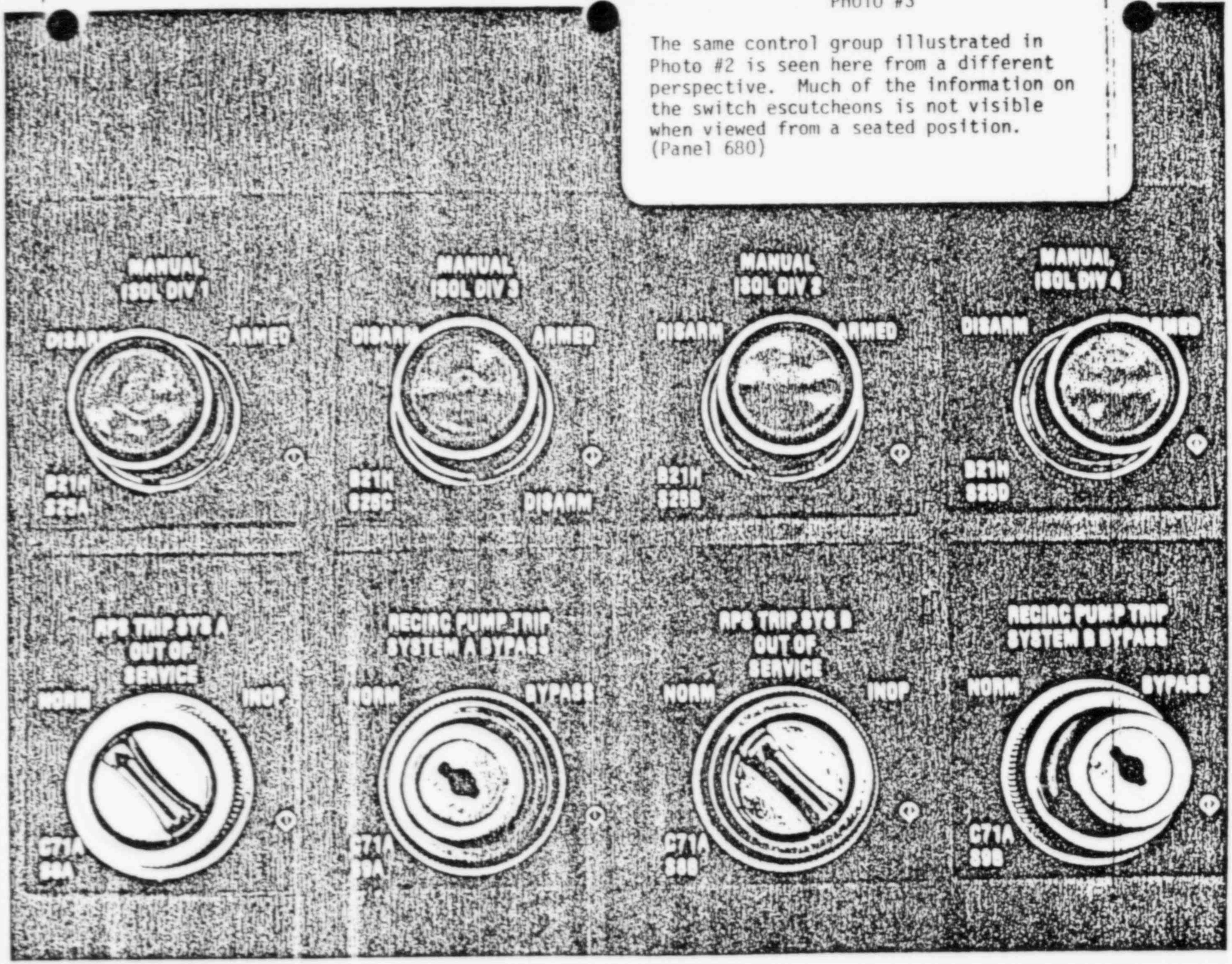


PHOTO #3

The same control group illustrated in Photo #2 is seen here from a different perspective. Much of the information on the switch escutcheons is not visible when viewed from a seated position. (Panel 680)

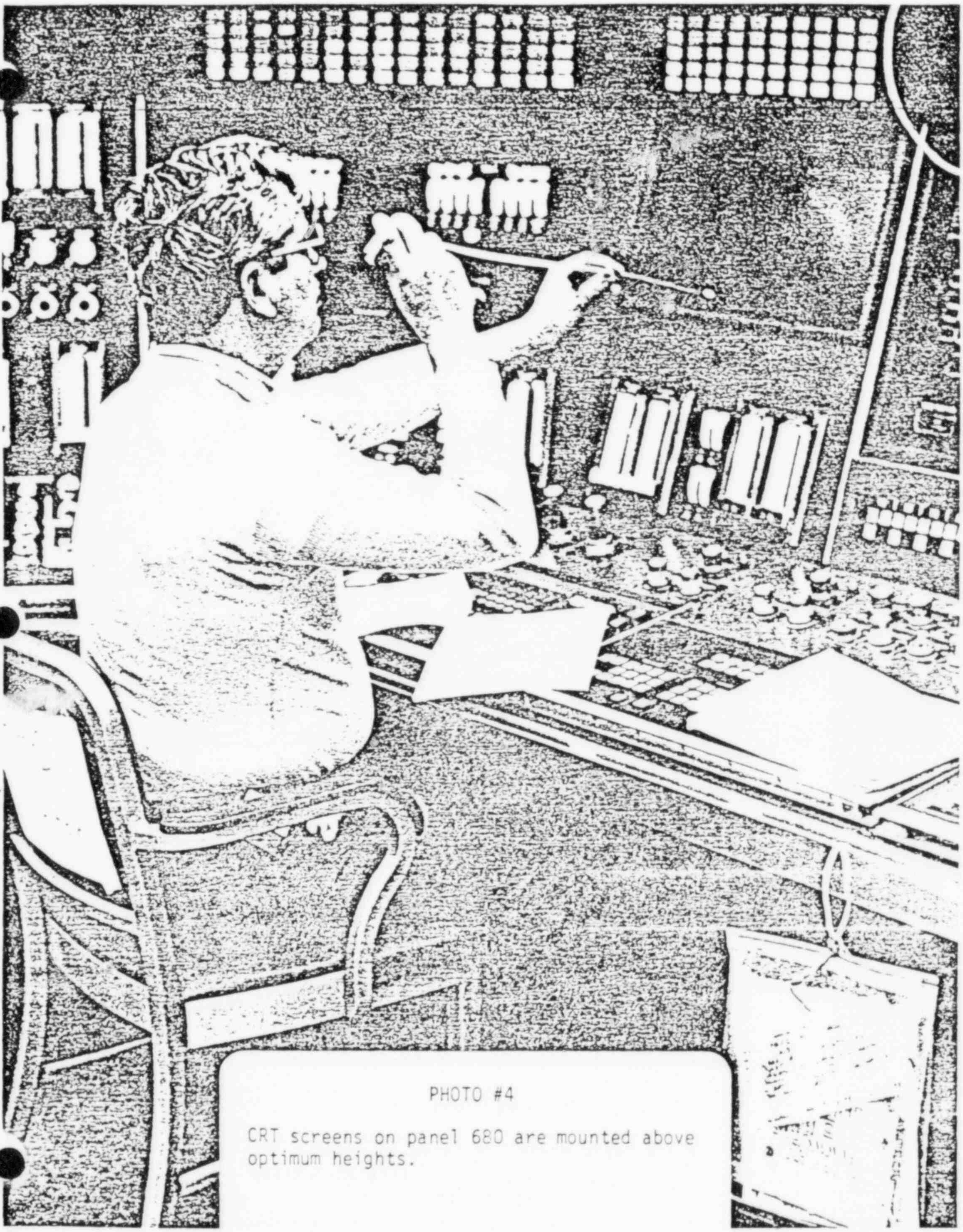
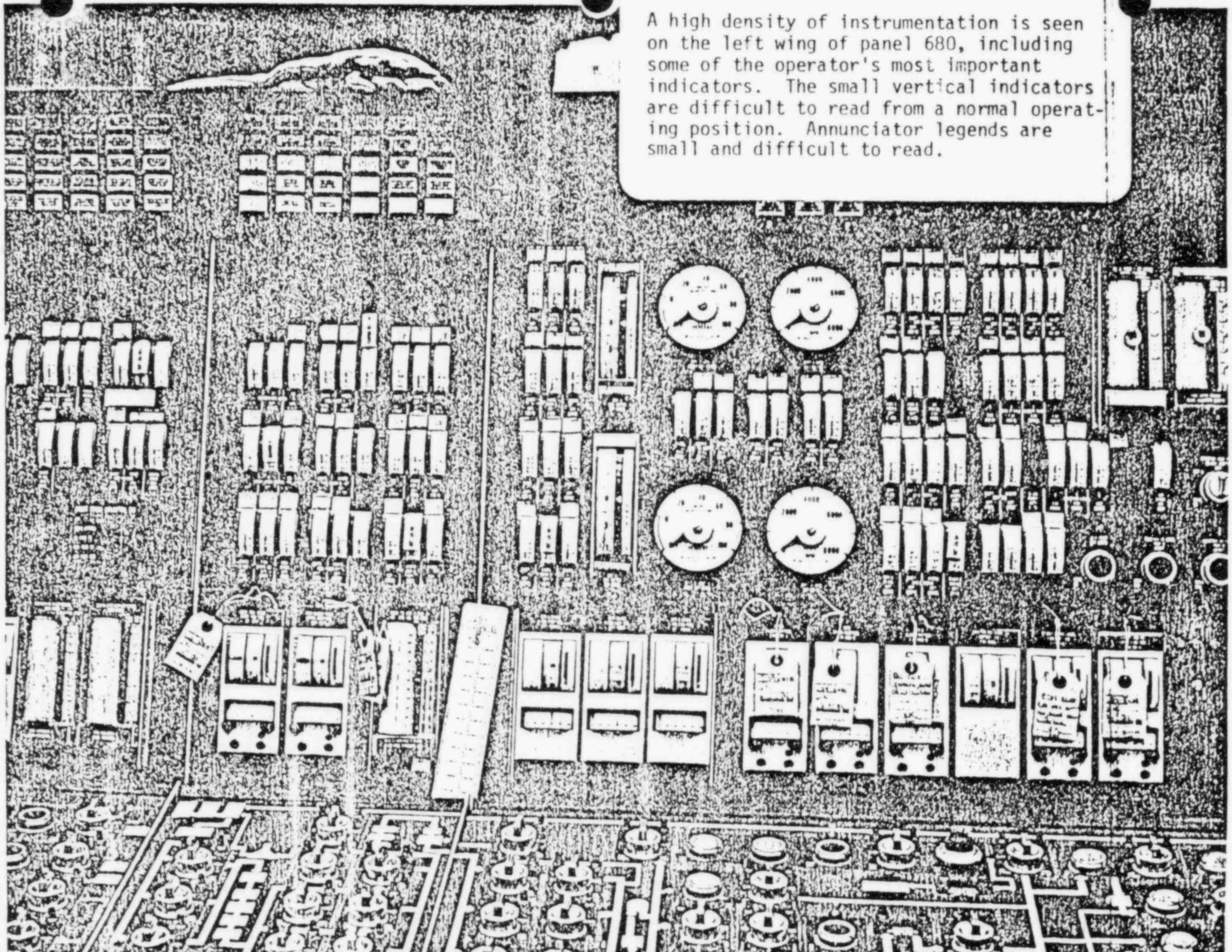


PHOTO #4

CRT screens on panel 680 are mounted above optimum heights.

PHOTO #5



A high density of instrumentation is seen on the left wing of panel 680, including some of the operator's most important indicators. The small vertical indicators are difficult to read from a normal operating position. Annunciator legends are small and difficult to read.

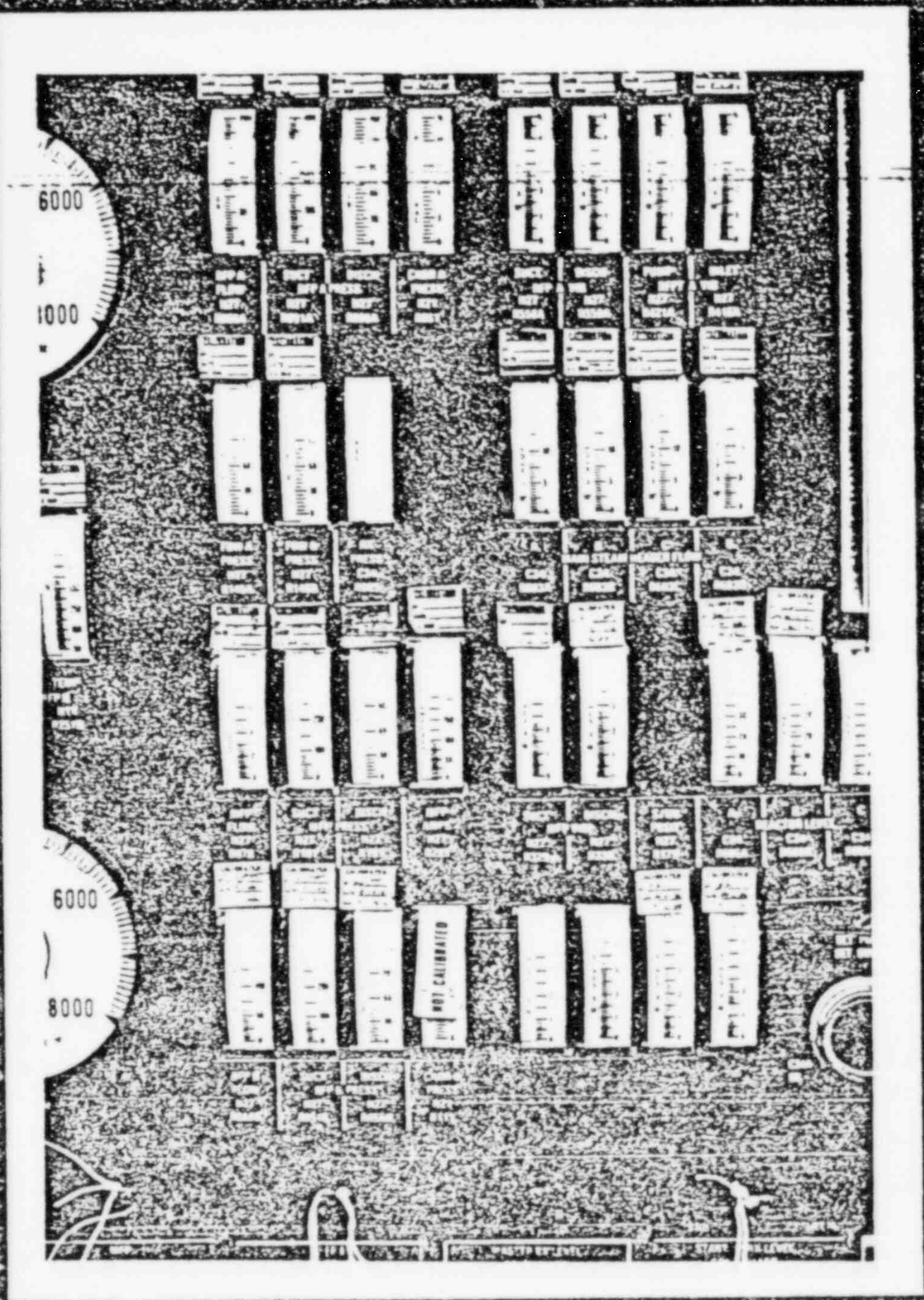


PHOTO #6

A closeup of instrumentation on panel 680. Note the four indicators at lower right without labels. One label has no associated indicator (N27-R179). Reactor pressure indicator C34-R605 has no scale.

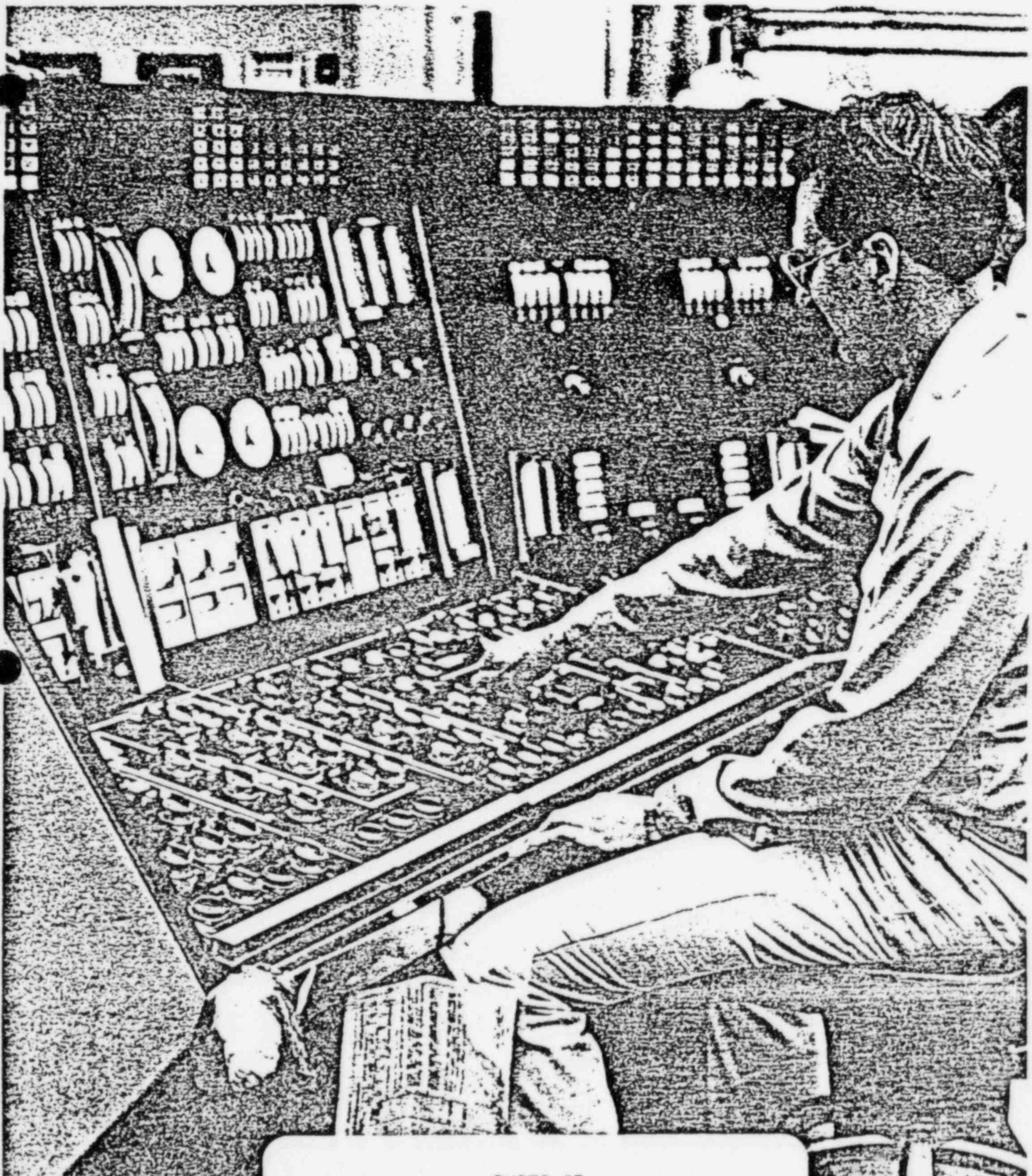


PHOTO #7

When Panel 680 is operated from a higher seating position, control surface visibility and access are improved, but knee space becomes a concern.

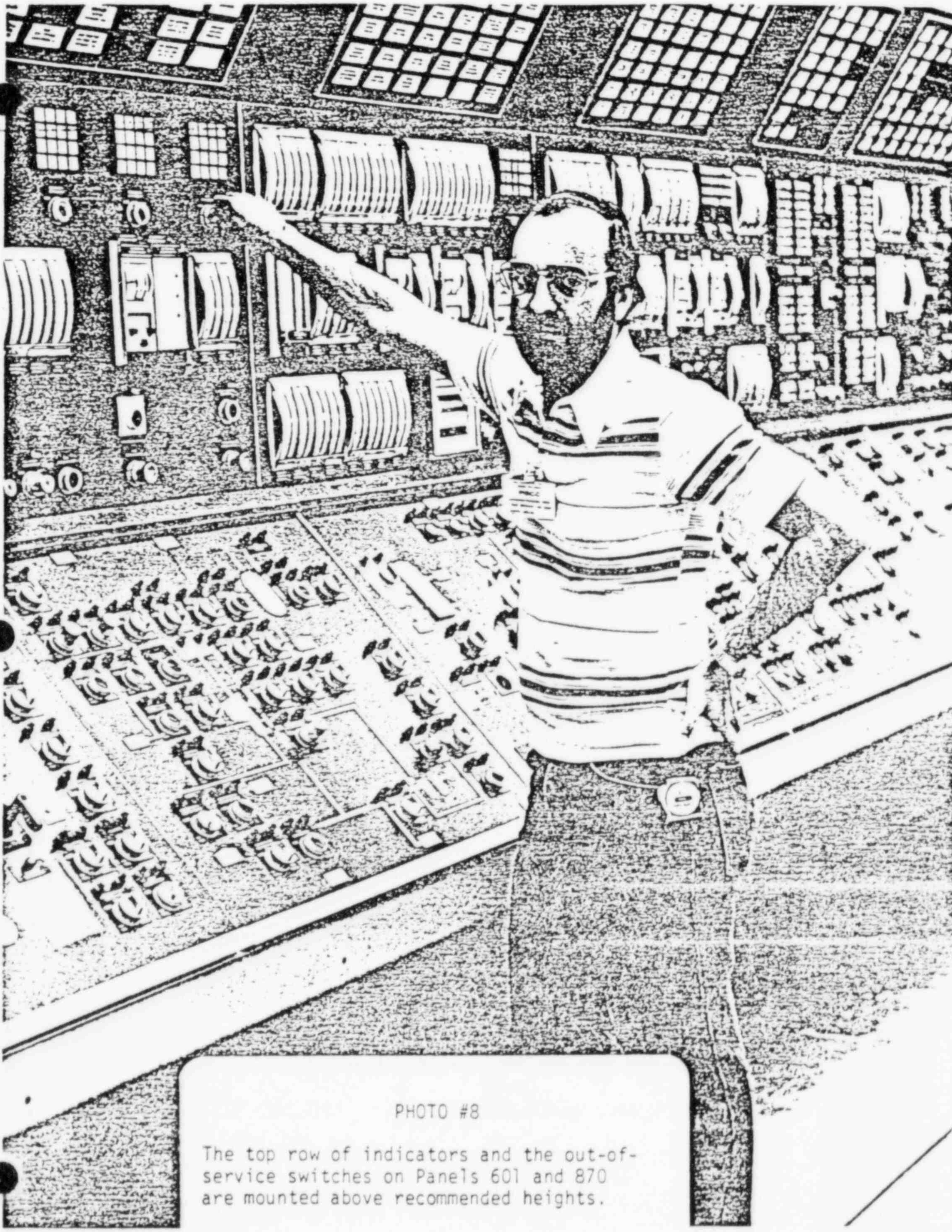


PHOTO #8

The top row of indicators and the out-of-service switches on Panels 601 and 870 are mounted above recommended heights.

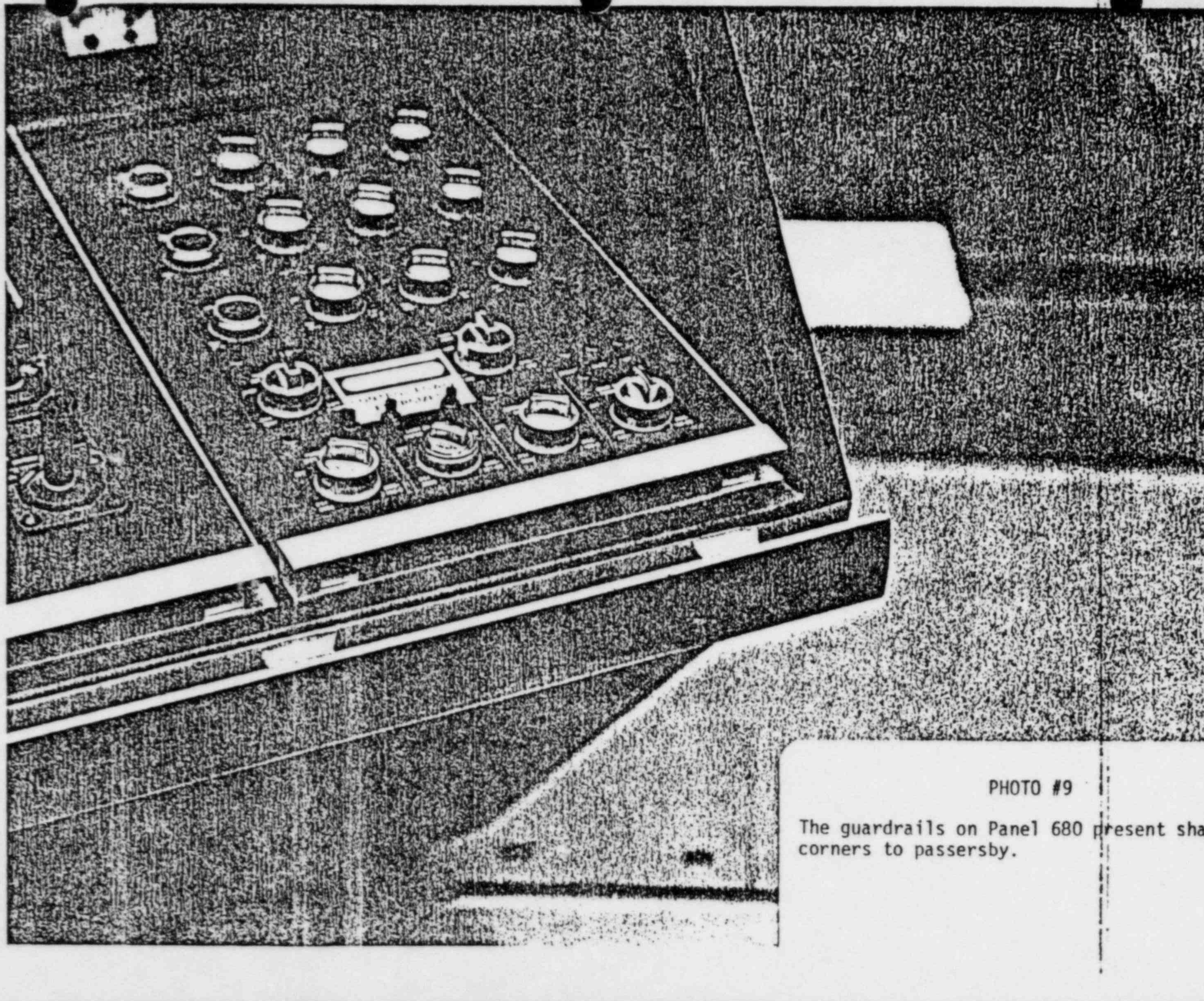


PHOTO #9

The guardrails on Panel 680 present sharp corners to passersby.

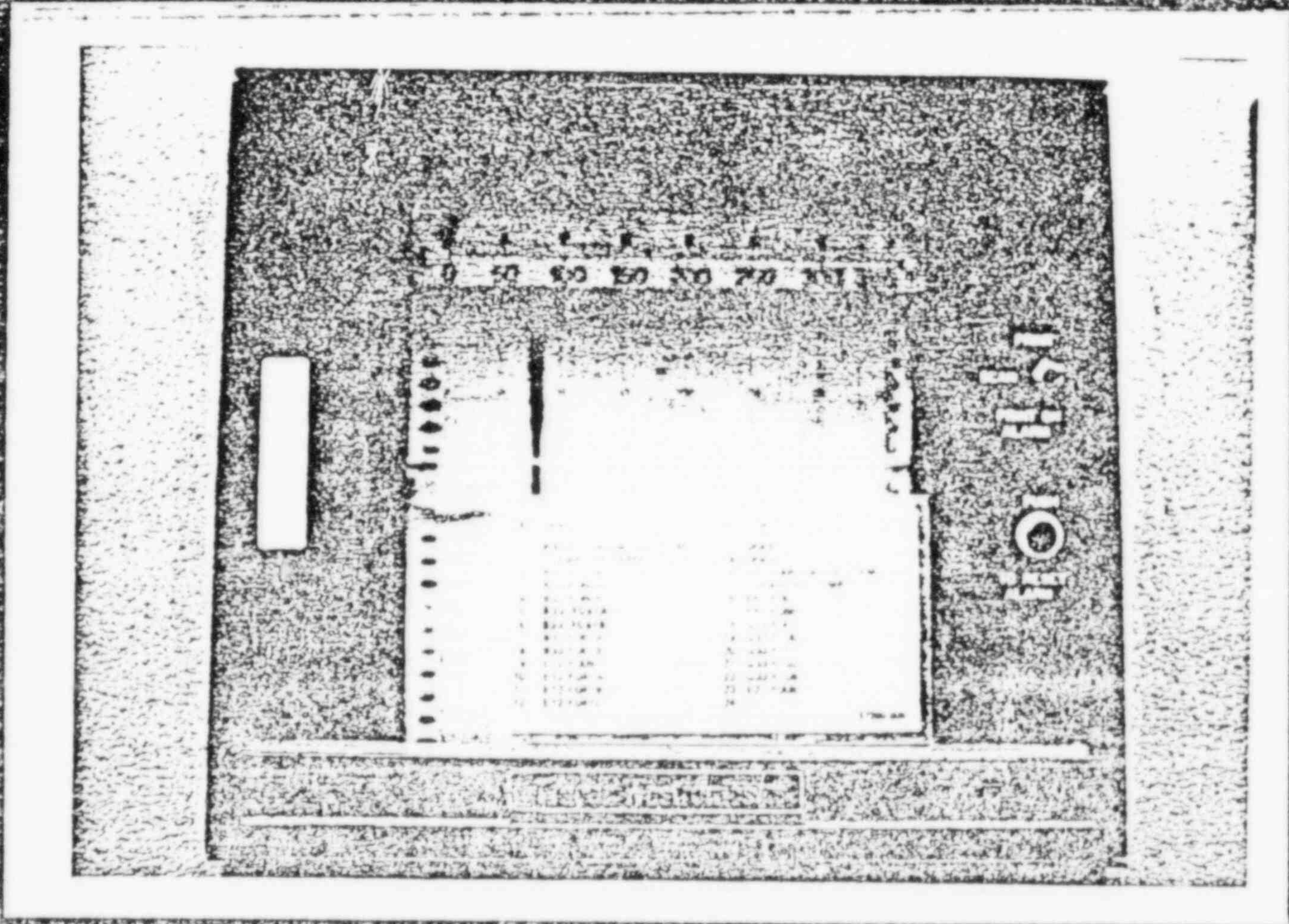


PHOTO #30

Frosted glass on recorder faces impairs the readability of the printout.

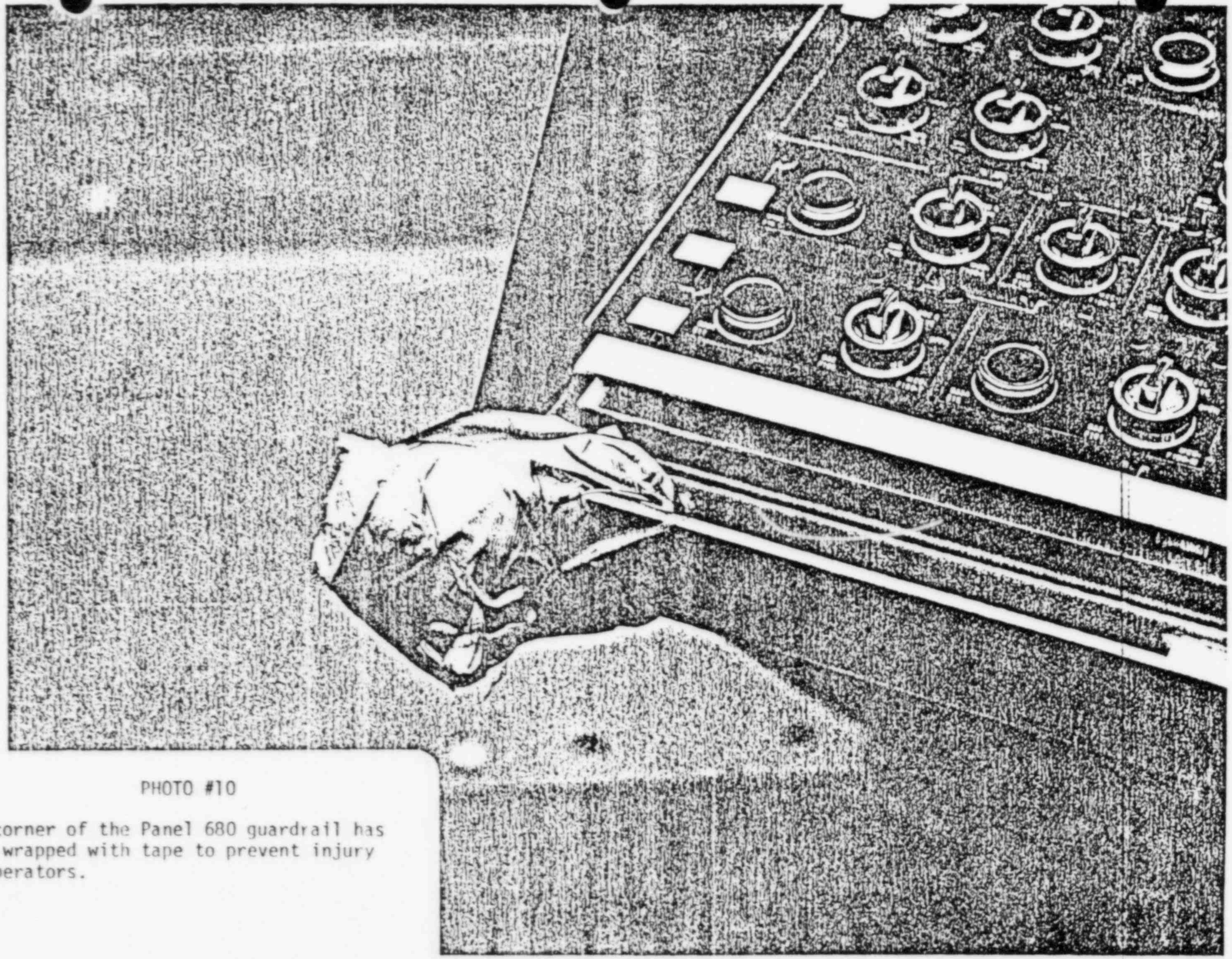
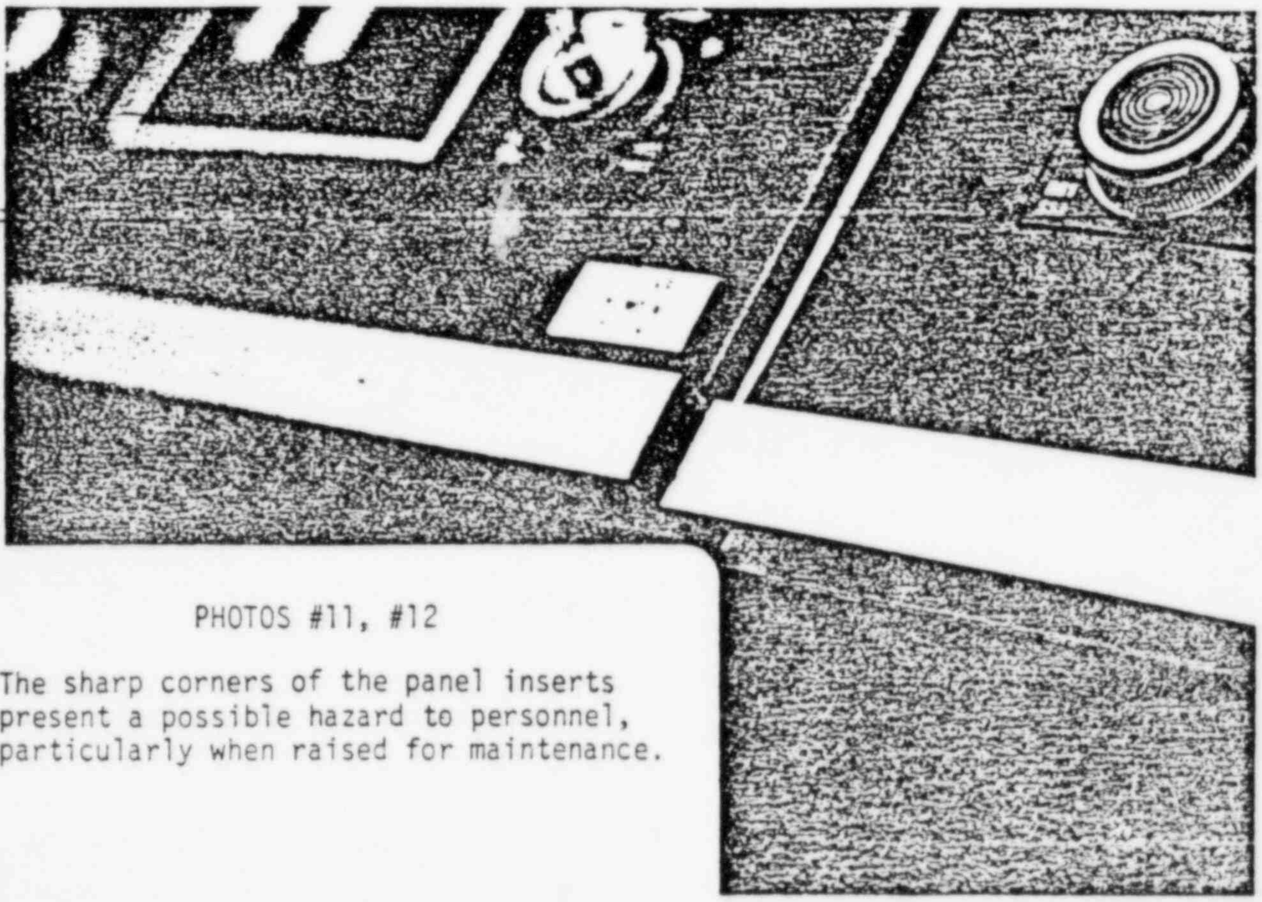


PHOTO #10

One corner of the Panel 680 guardrail has been wrapped with tape to prevent injury to operators.



PHOTOS #11, #12

The sharp corners of the panel inserts present a possible hazard to personnel, particularly when raised for maintenance.

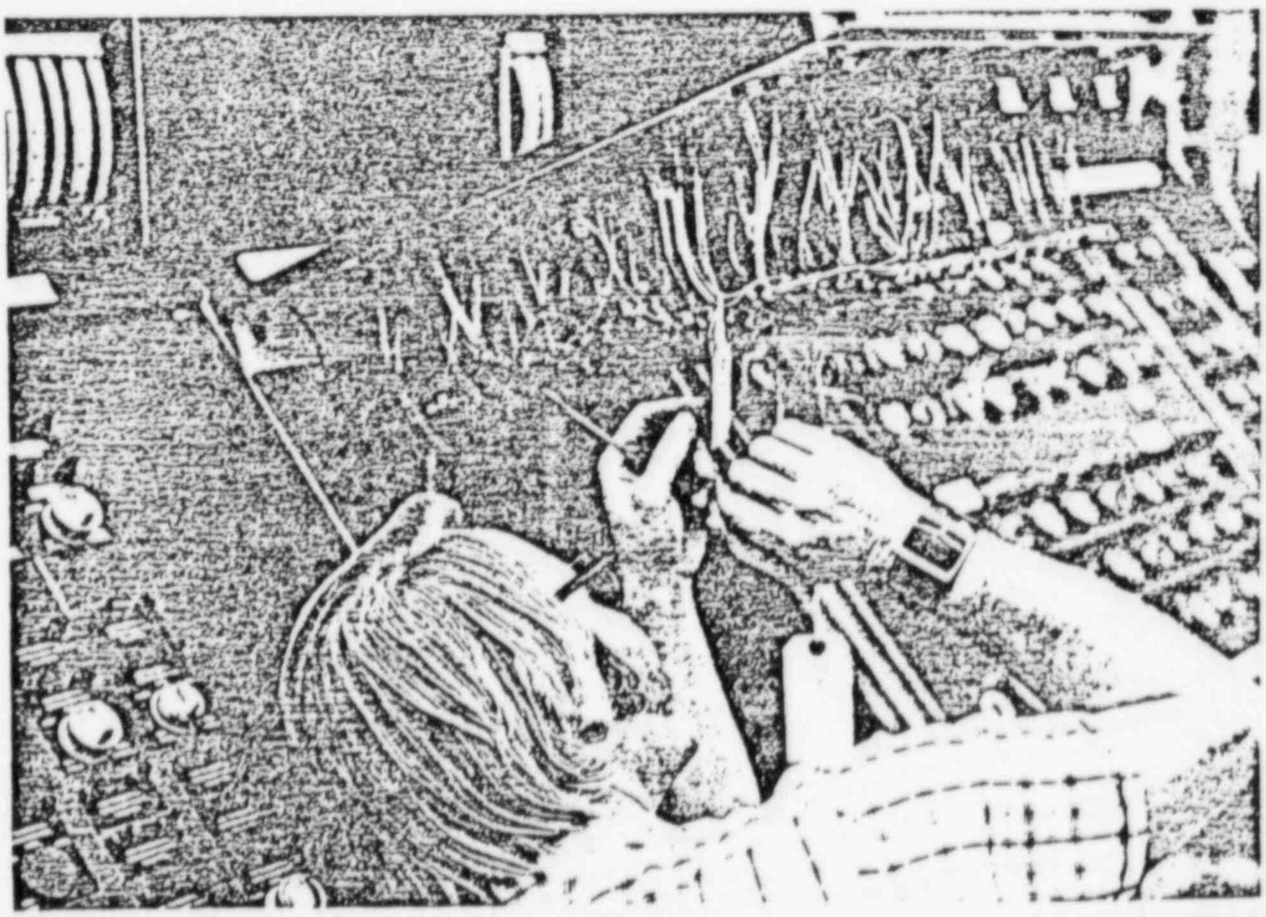
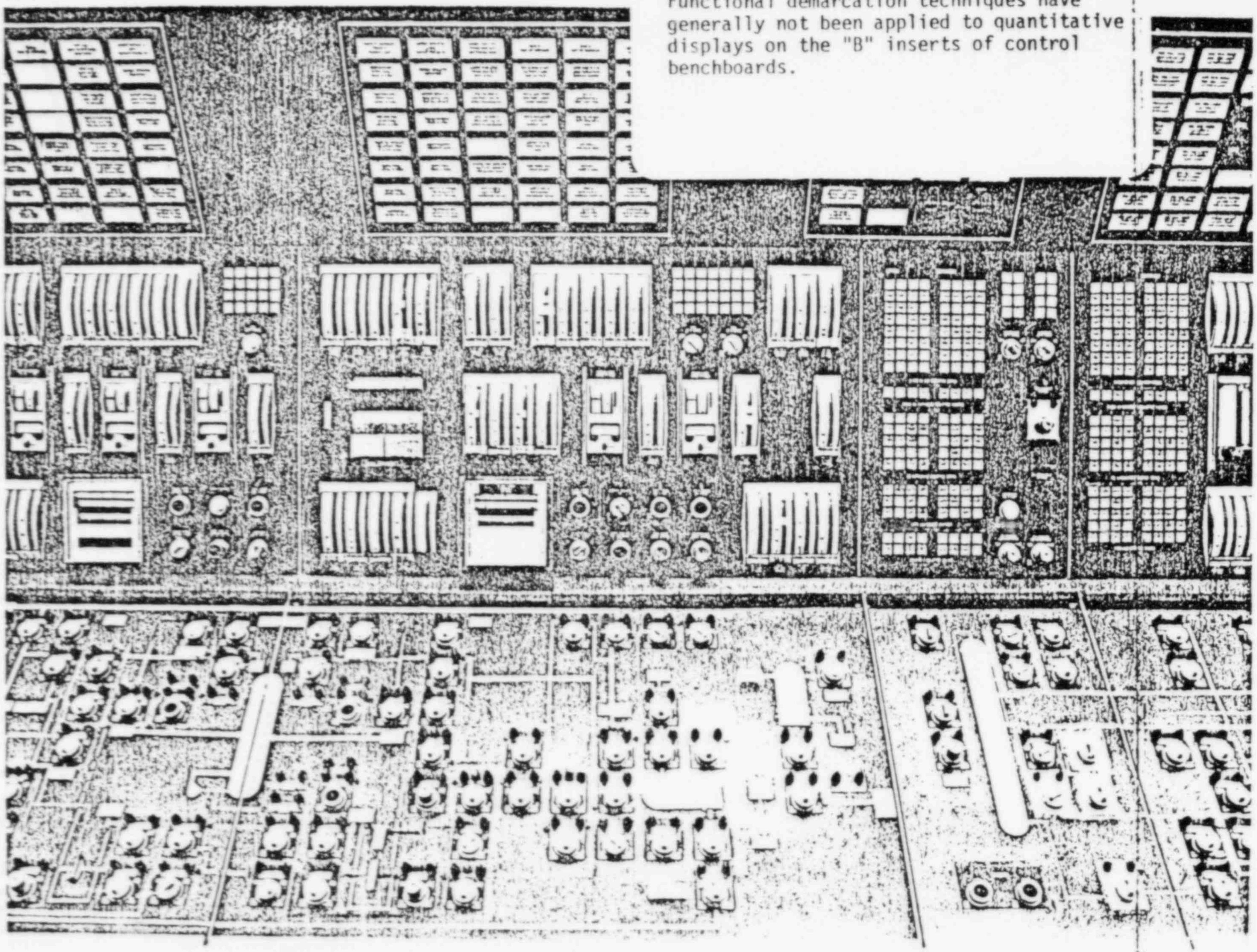


PHOTO #13



Functional demarcation techniques have generally not been applied to quantitative displays on the "B" inserts of control benchboards.

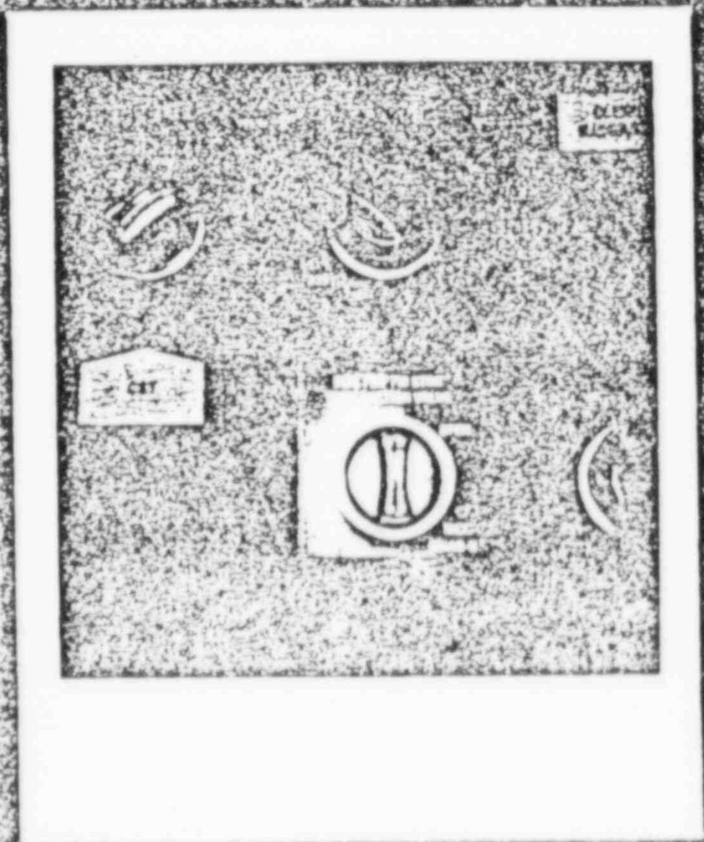


PHOTO #14

While component labels are usually very explicit, accuracy has often been obtained at the expense of succintness. (Panel 601-21)

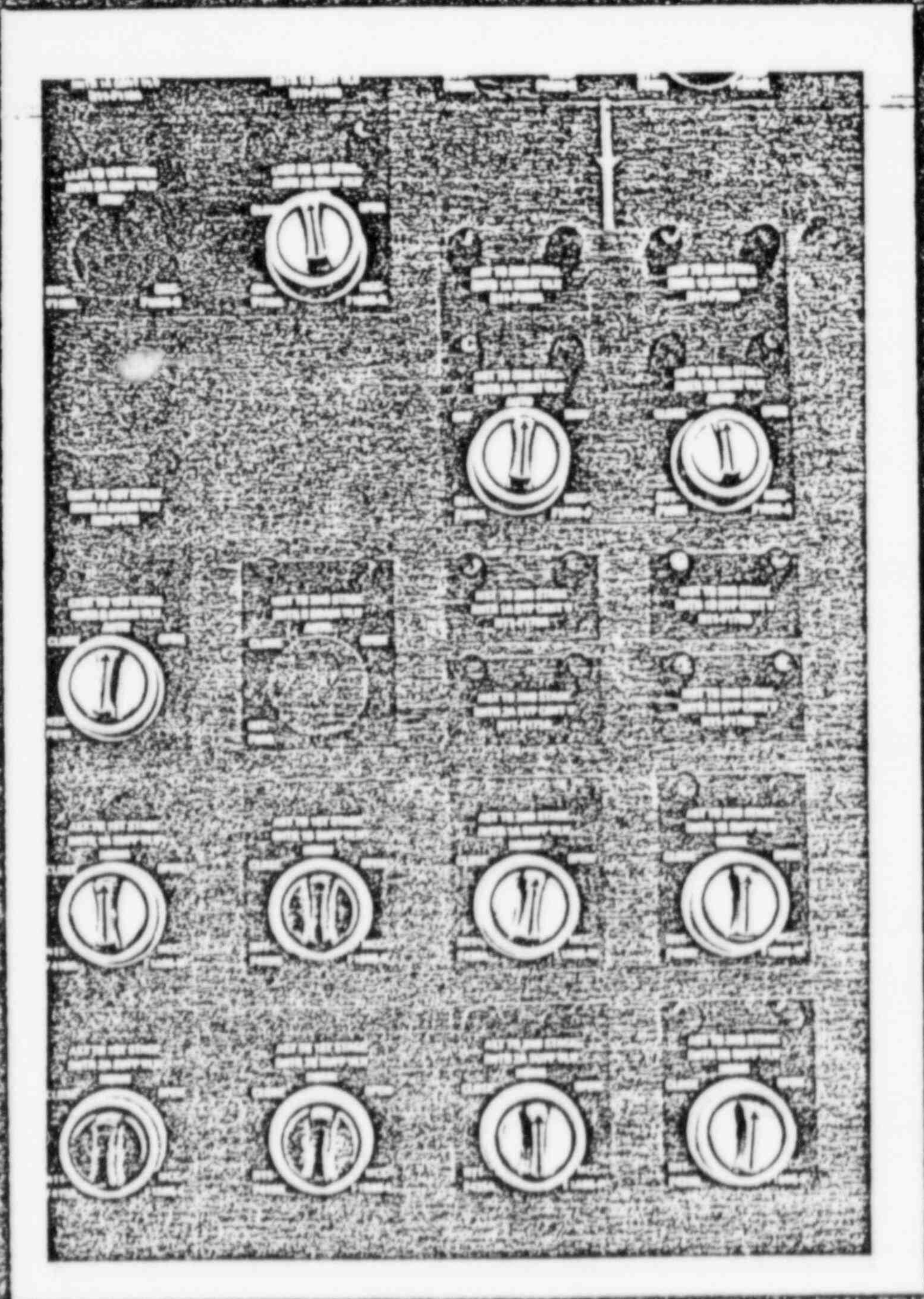


PHOTO #15

Many instances of repetitive labeling were noted. Institution of a hierarchical labeling system is recommended. (Panel 870-6)

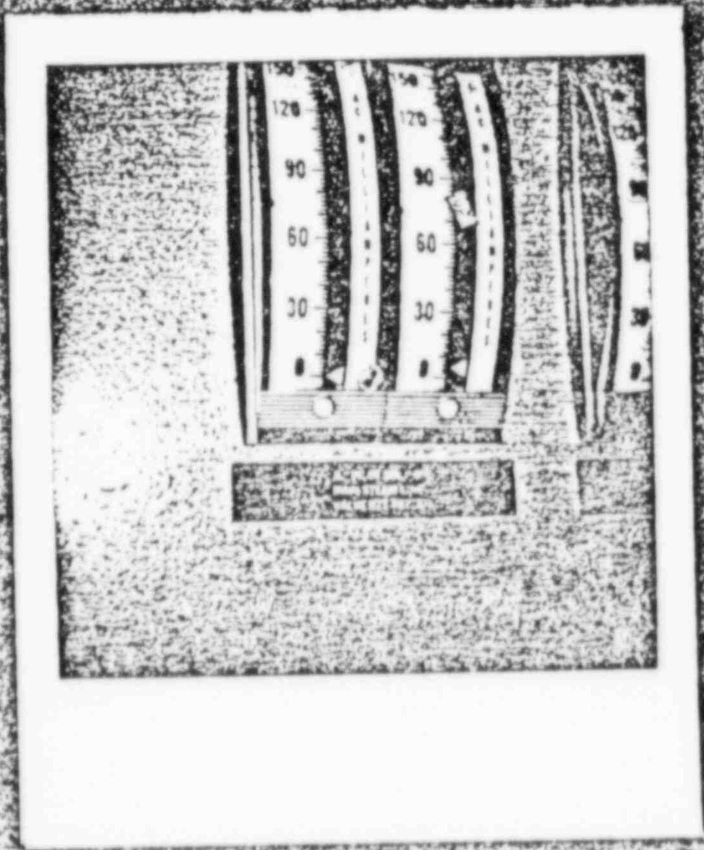
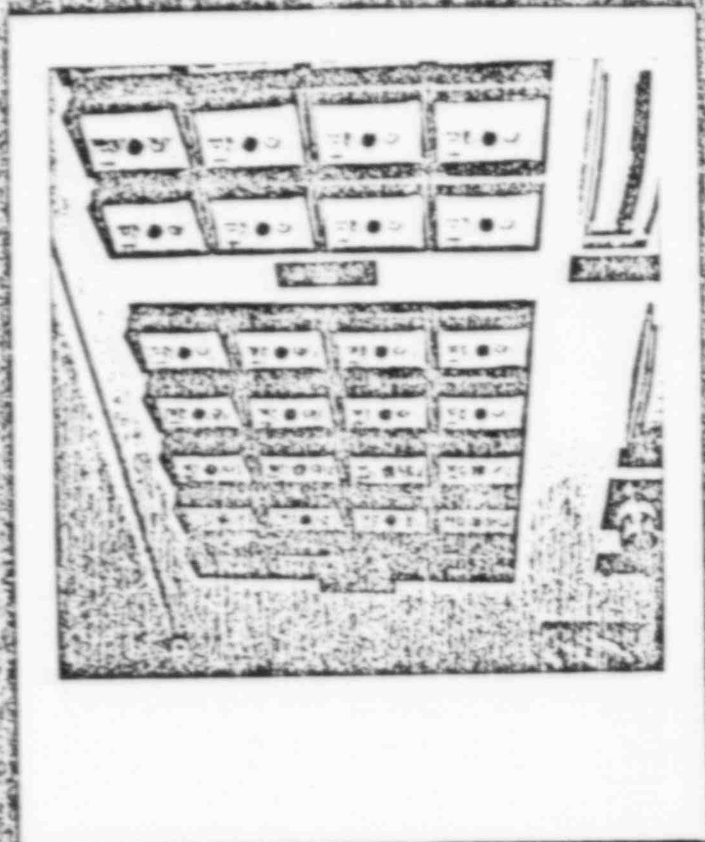
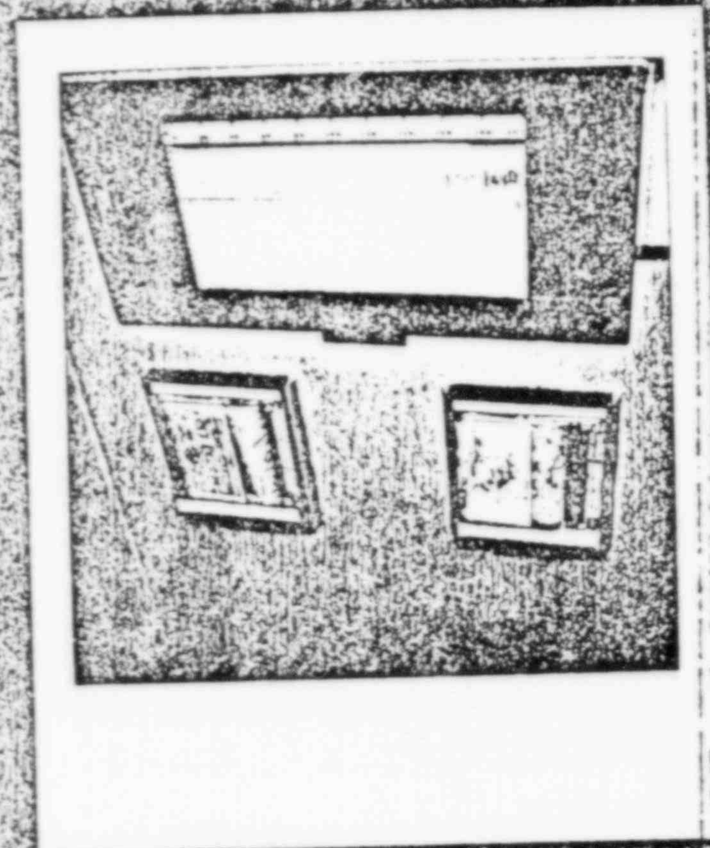


PHOTO #16

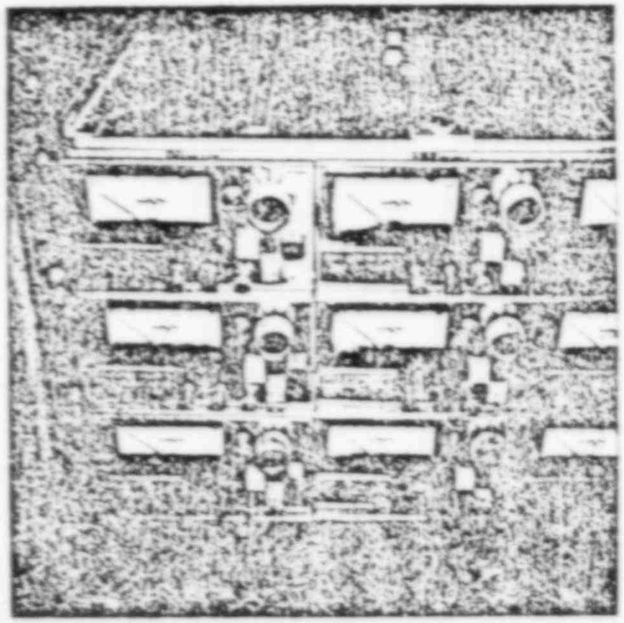
While attempts have been made at hierarchical labeling in some instances, the results are often not as effective as they might be. Labels should be gradated in size with summary labels spatially separated from component designations. (Panel 622)

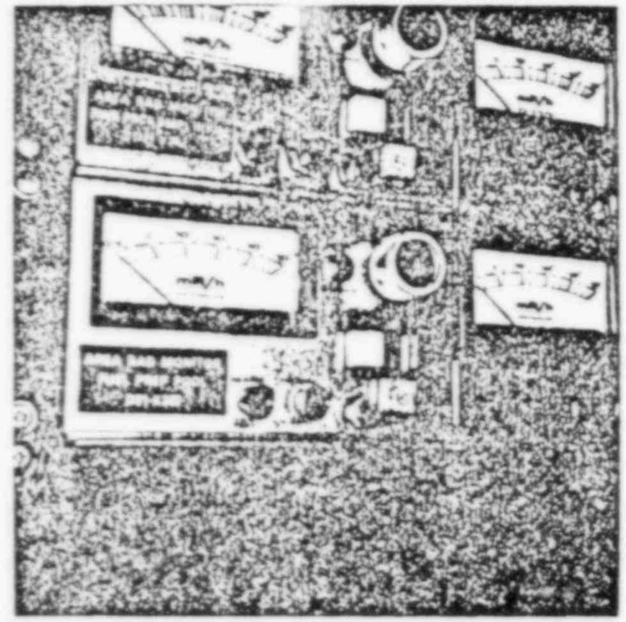




PHOTOS #17, #18

Labels below projecting vertical panel components are obscured when viewed from a standing position. (Panels 842 and 904)





PHOTOS #19, #20

Legends below projecting switches are obscured when viewed from a standing position. (Panel 902)

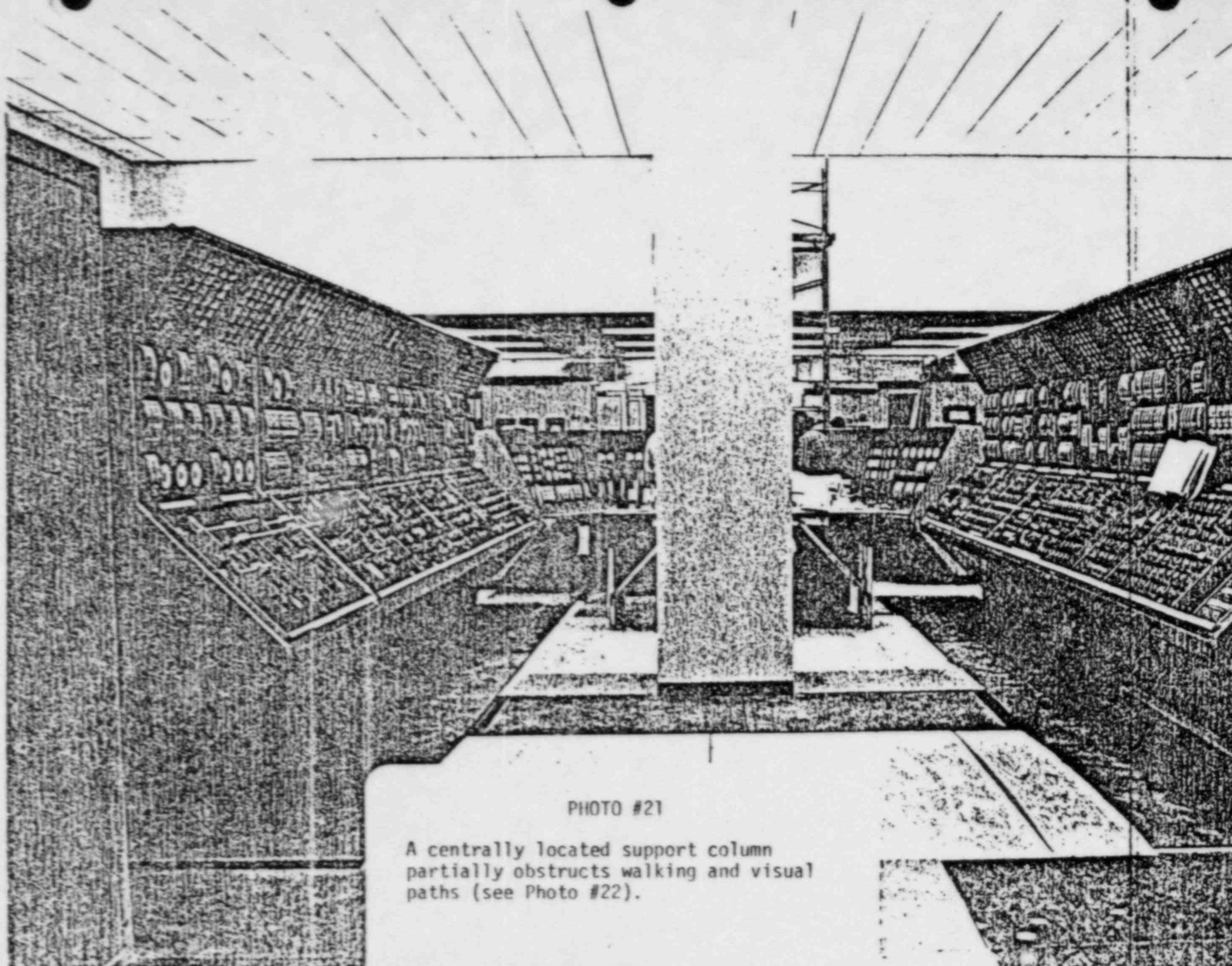


PHOTO #21

A centrally located support column partially obstructs walking and visual paths (see Photo #22).

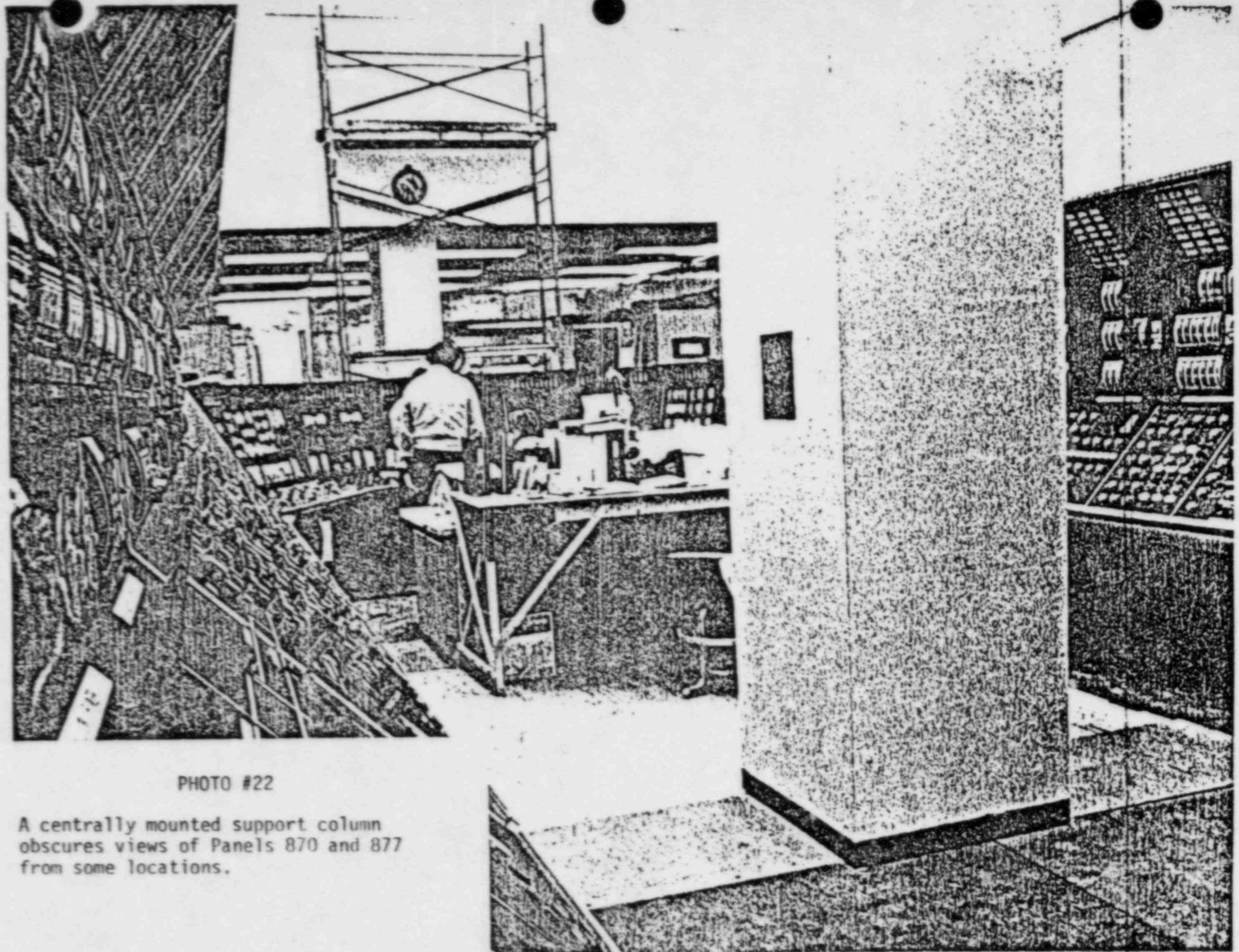


PHOTO #22

A centrally mounted support column obscures views of Panels 870 and 877 from some locations.

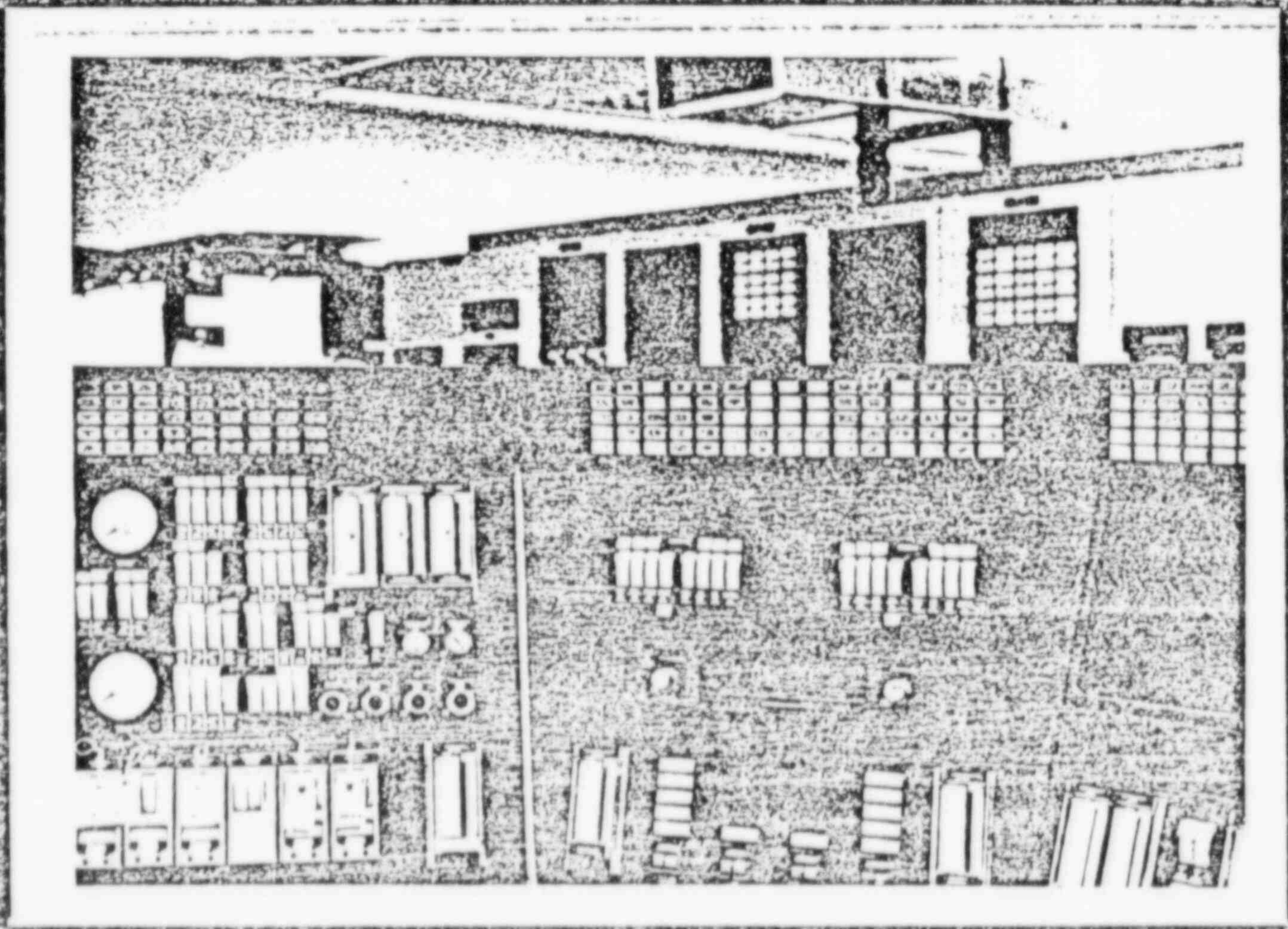


PHOTO #23

Panel 680 blocks views of the radiation monitoring panel (photo taken from a standing position).

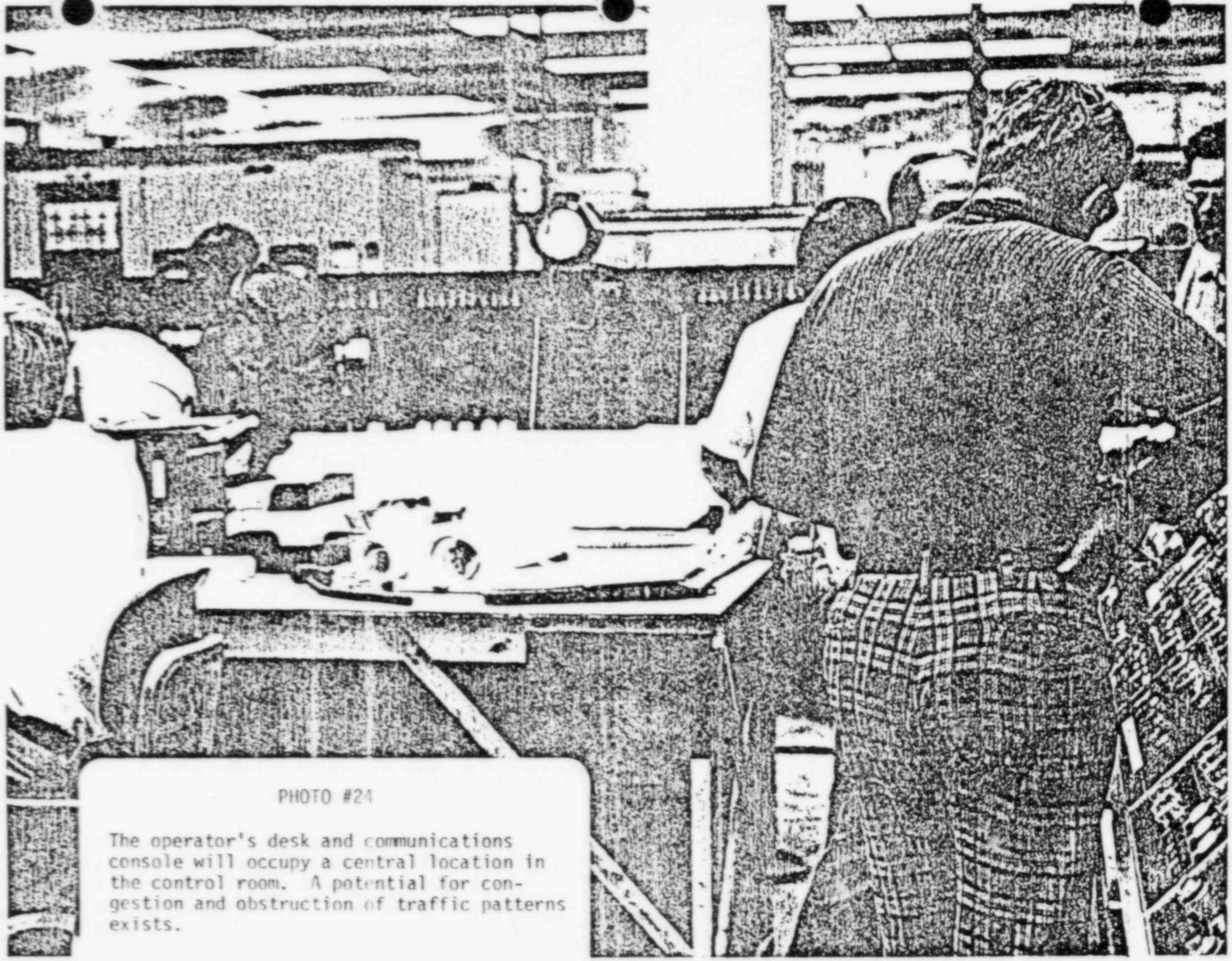


PHOTO #24

The operator's desk and communications console will occupy a central location in the control room. A potential for congestion and obstruction of traffic patterns exists.

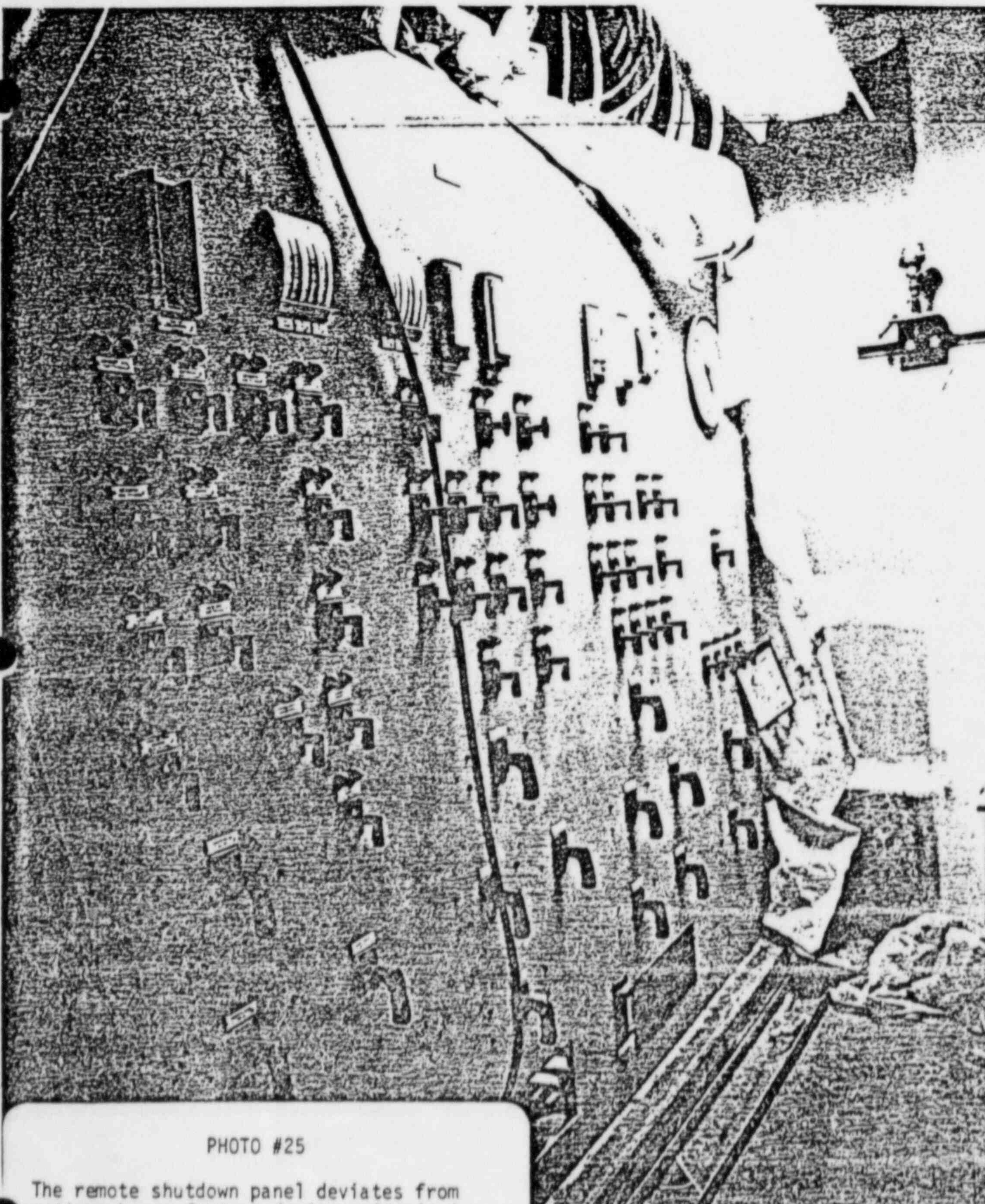


PHOTO #25

The remote shutdown panel deviates from optimum human factors design criteria in several respects. Lighting is substandard, functional demarcation techniques are not utilized, and components are placed above and below recommended heights.

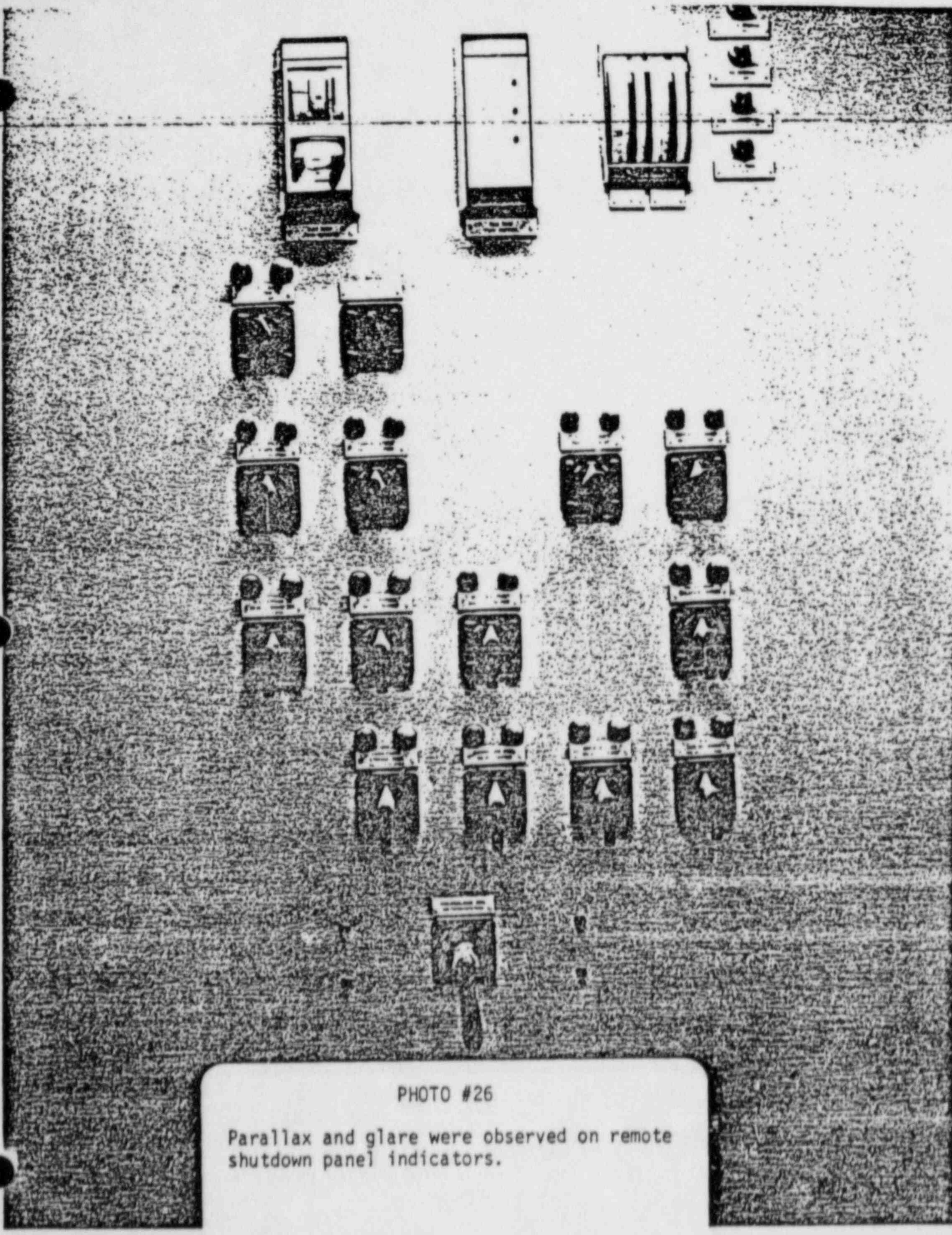
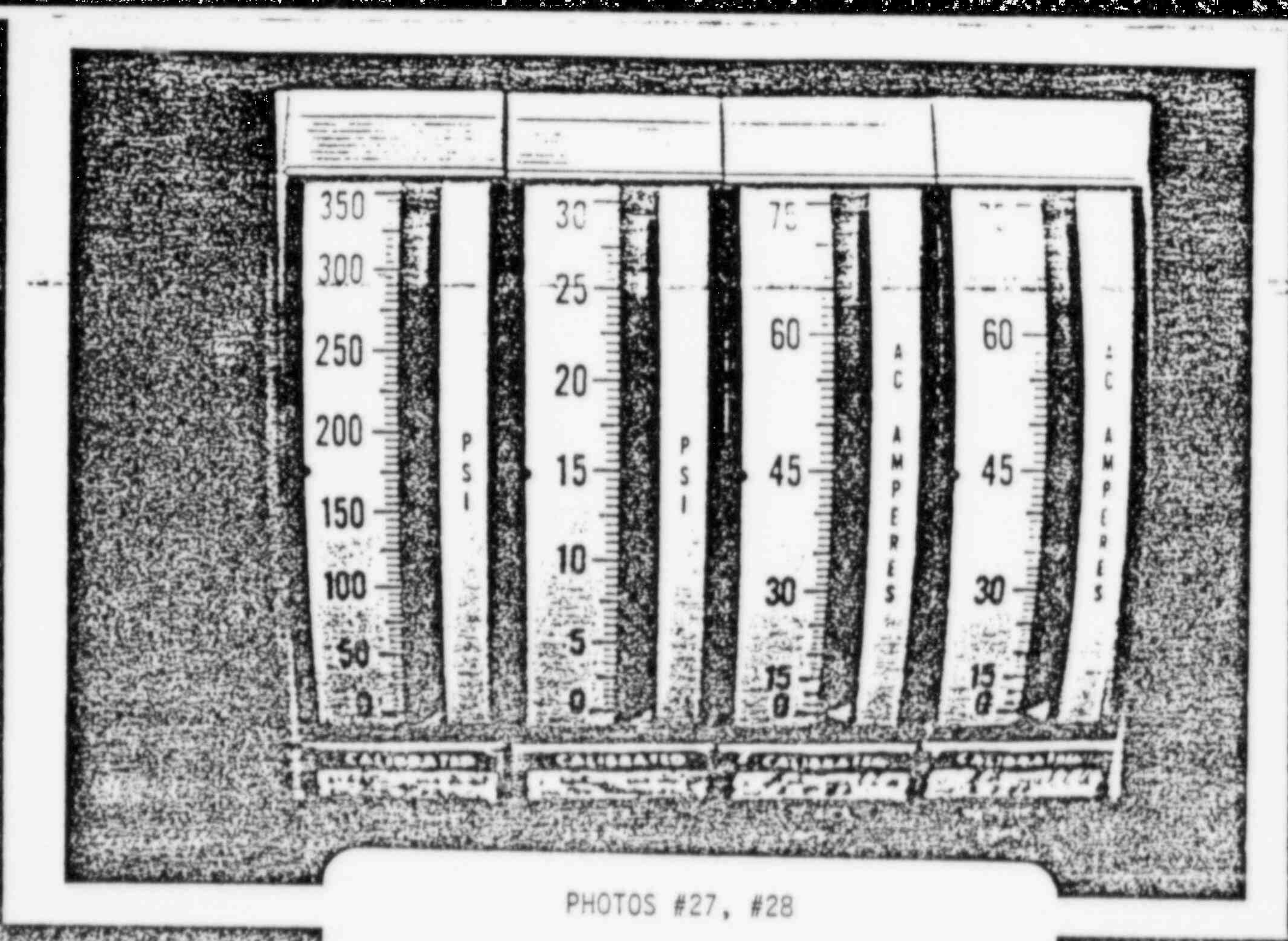


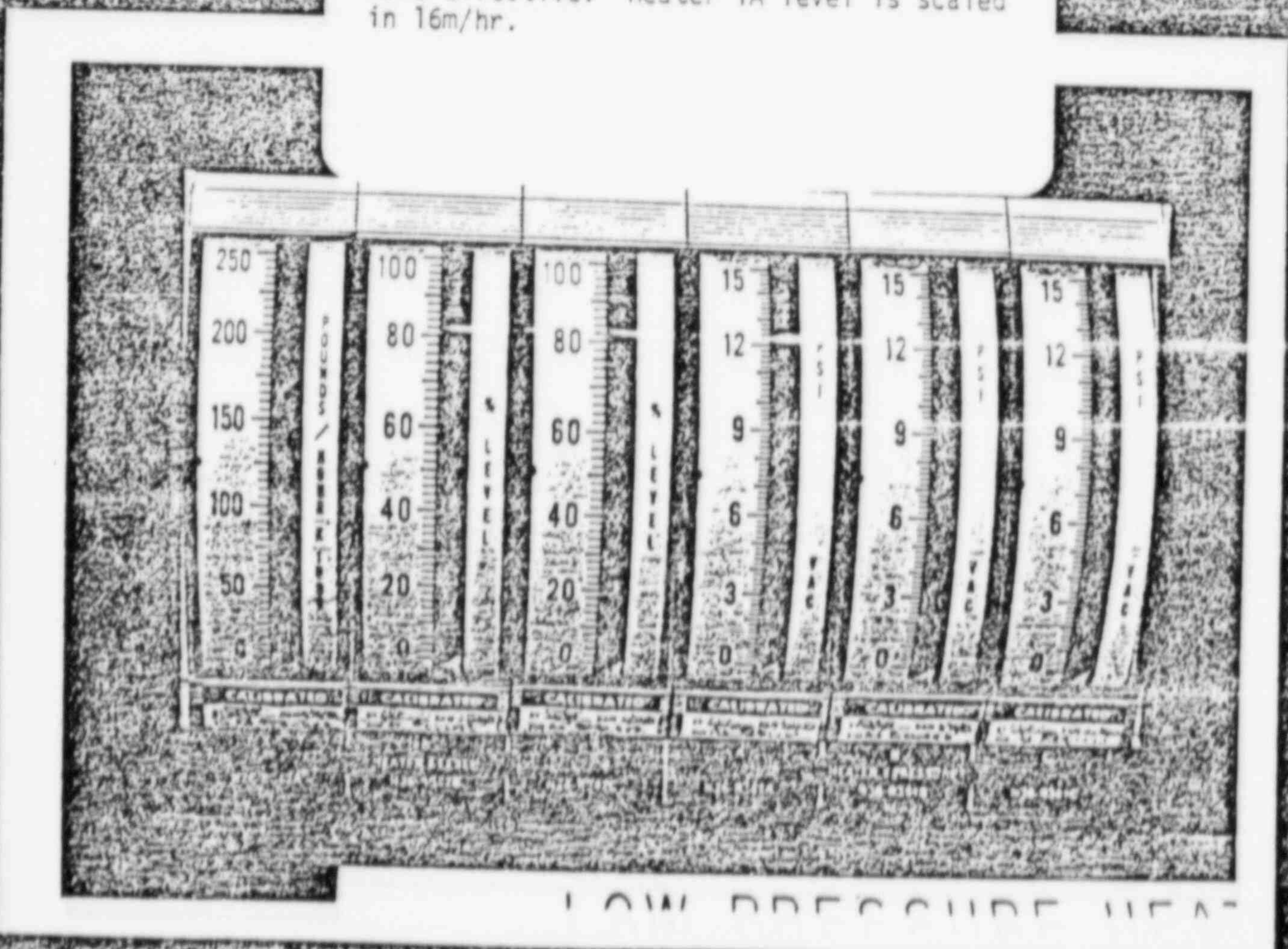
PHOTO #26

Parallax and glare were observed on remote shutdown panel indicators.



PHOTOS #27, #28

Examples of nonstandard indicator scales. Hierarchical labeling attempts could be more effective. Heater 1A level is scaled in 16m/hr.



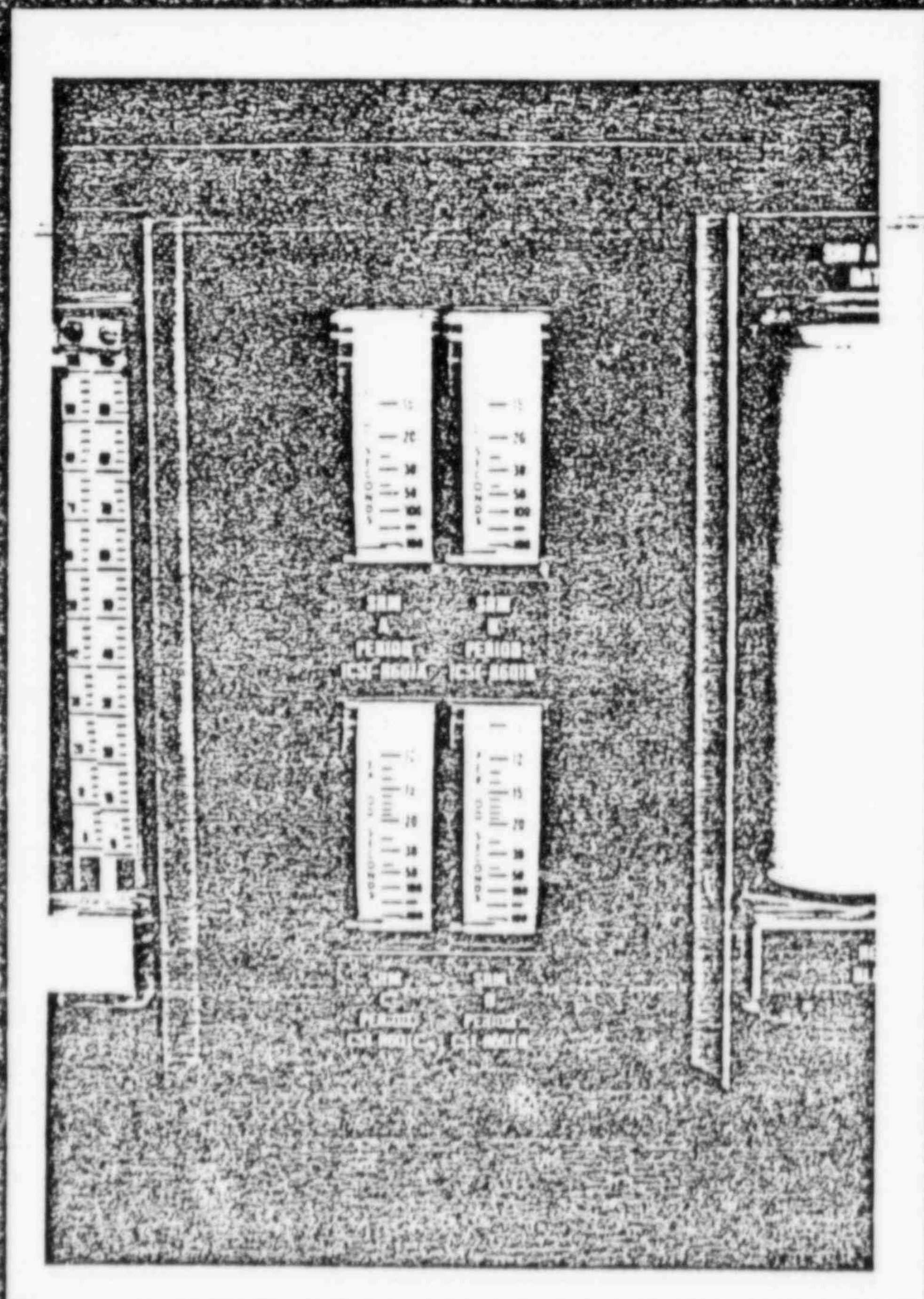


PHOTO #29

The normal control band on the SRM period indicators subtends a very small visual arc when viewed from a normal operating position.

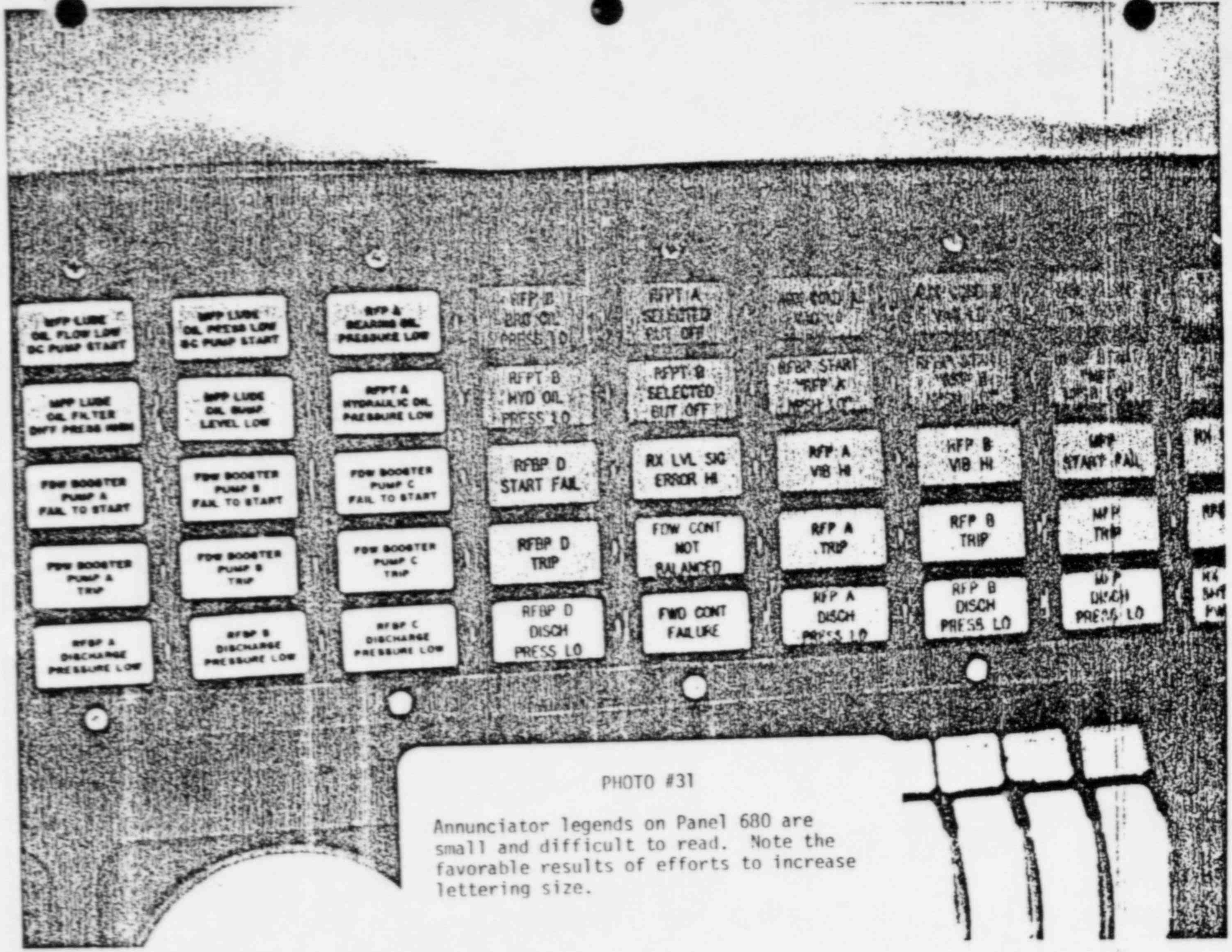


PHOTO #31

Annunciator legends on Panel 680 are small and difficult to read. Note the favorable results of efforts to increase lettering size.

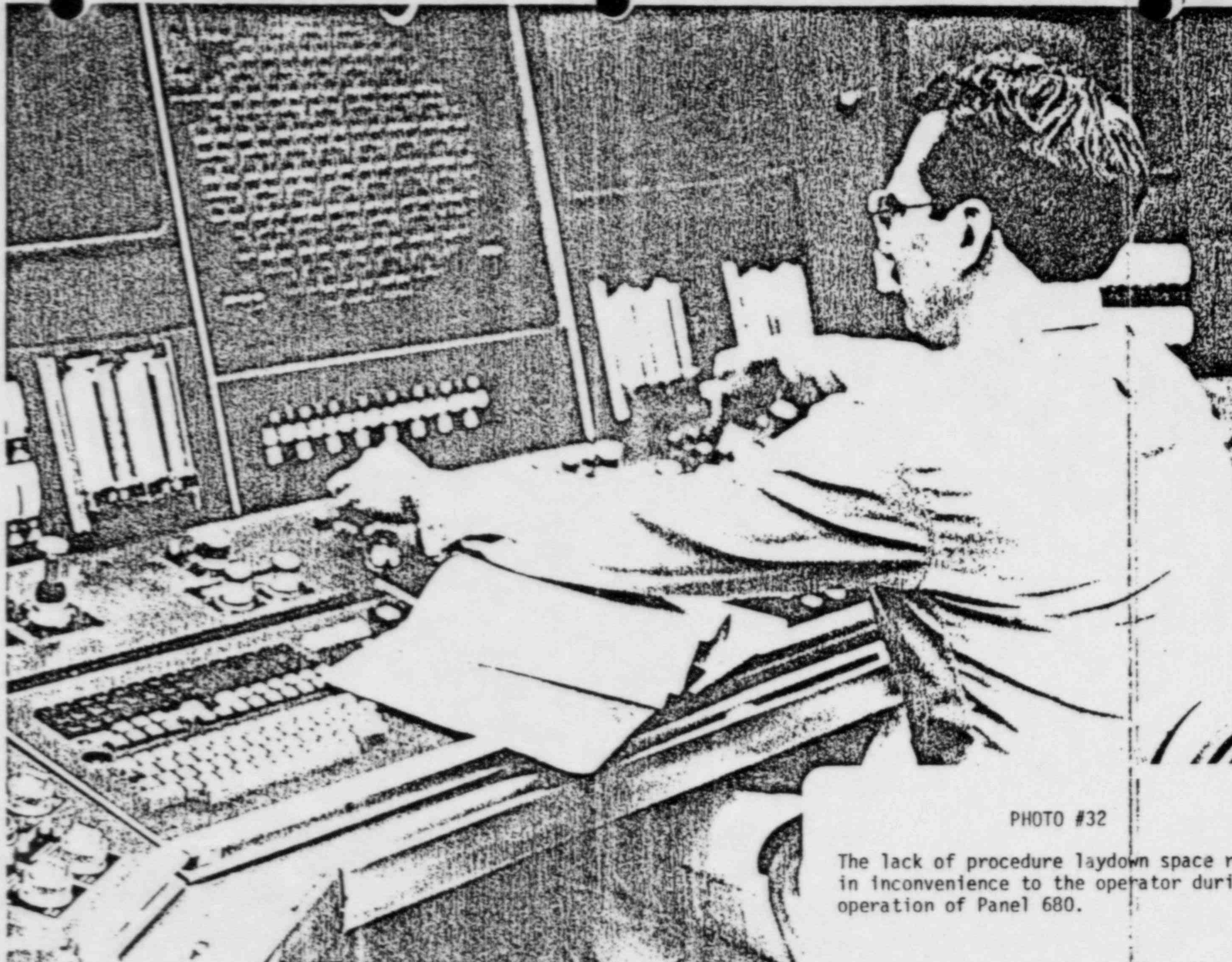


PHOTO #32

The lack of procedure laydown space results in inconvenience to the operator during operation of Panel 680.

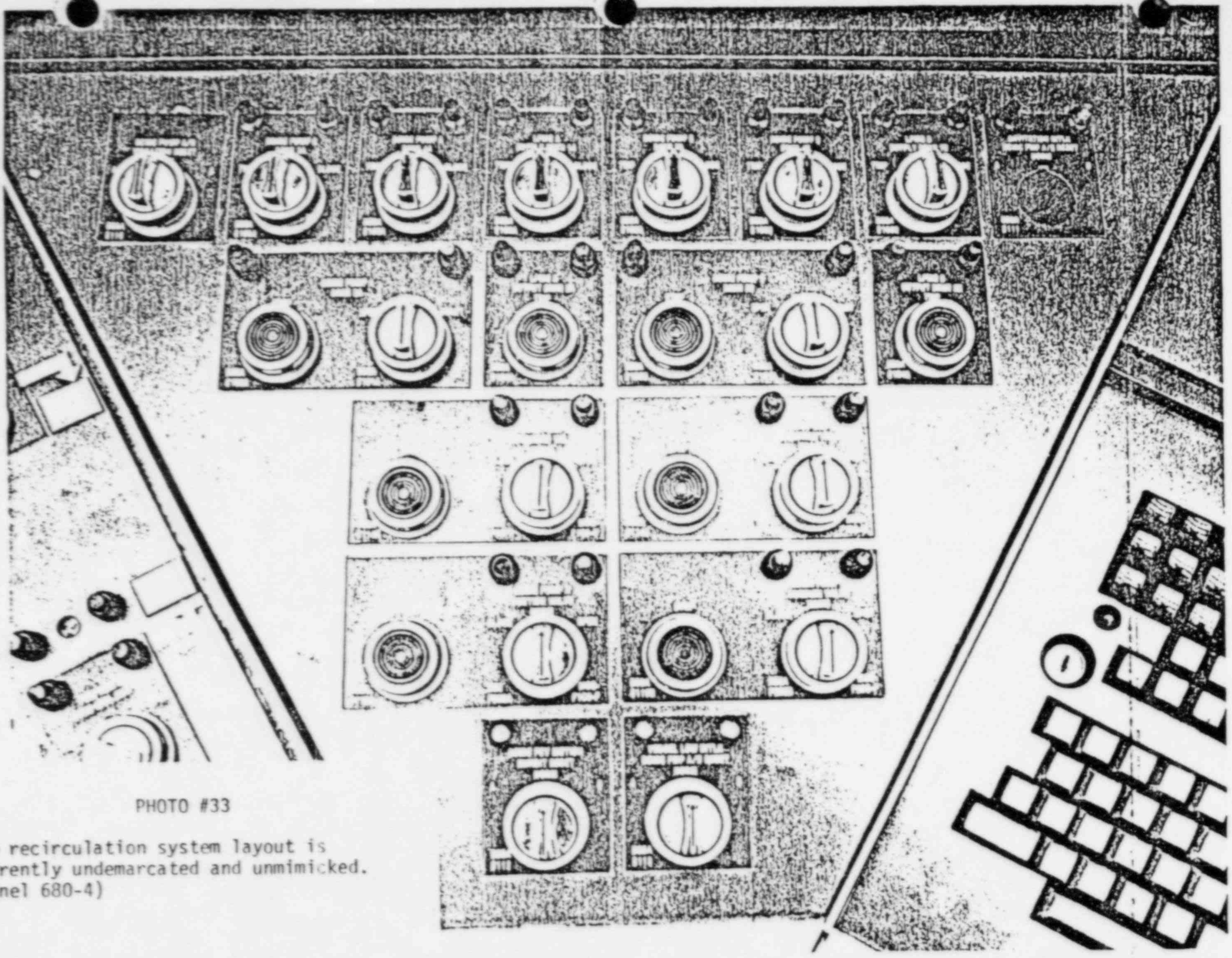


PHOTO #33

The recirculation system layout is currently undemarcated and unmimicked. (Panel 680-4)

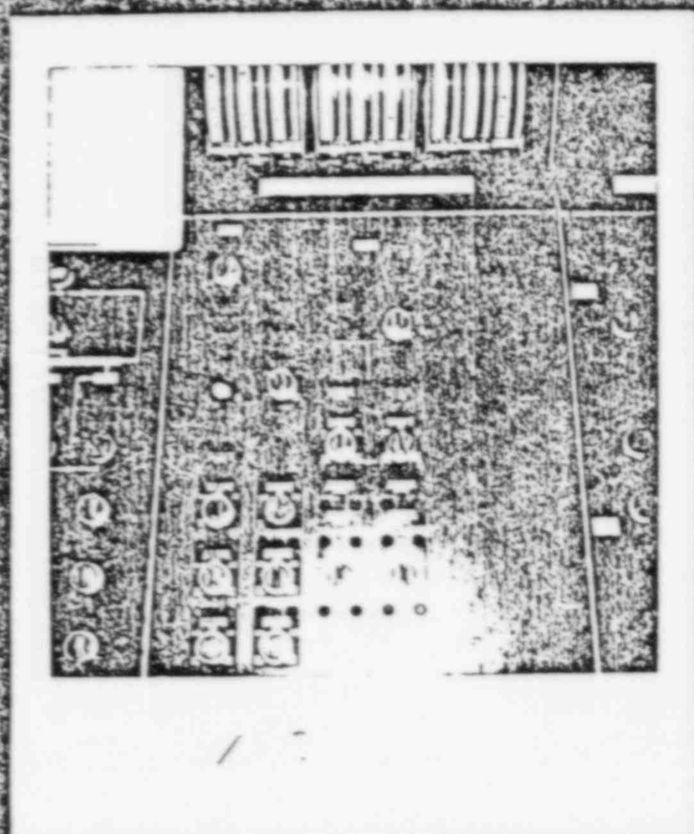


PHOTO #34

Dividing controls for main and auxiliary steam to reheater is one possible application of demarcation lines.

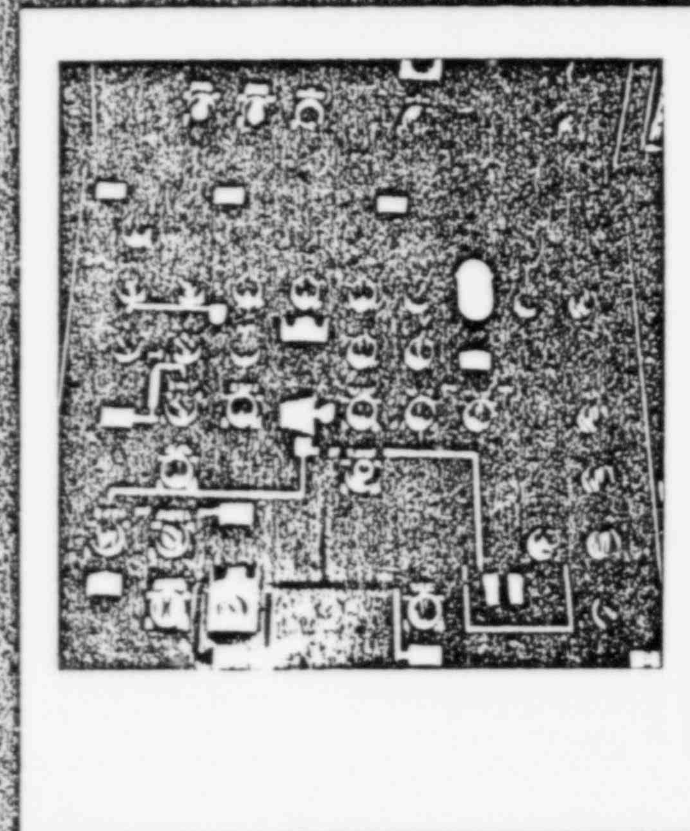


PHOTO #35

The division between RCIC and LPCS system controls is not clear on Panel 601. Suppression pool symbol is nondescript.

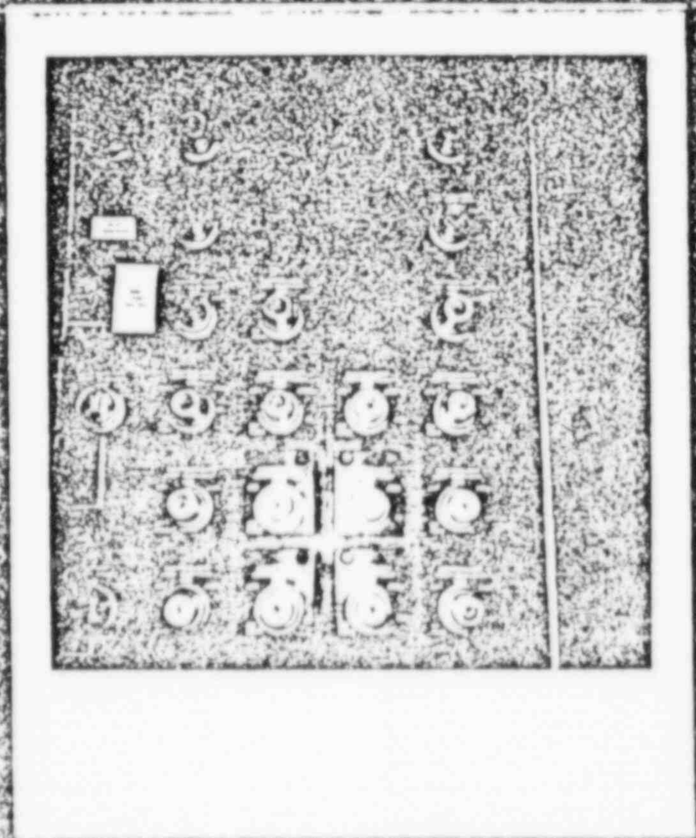
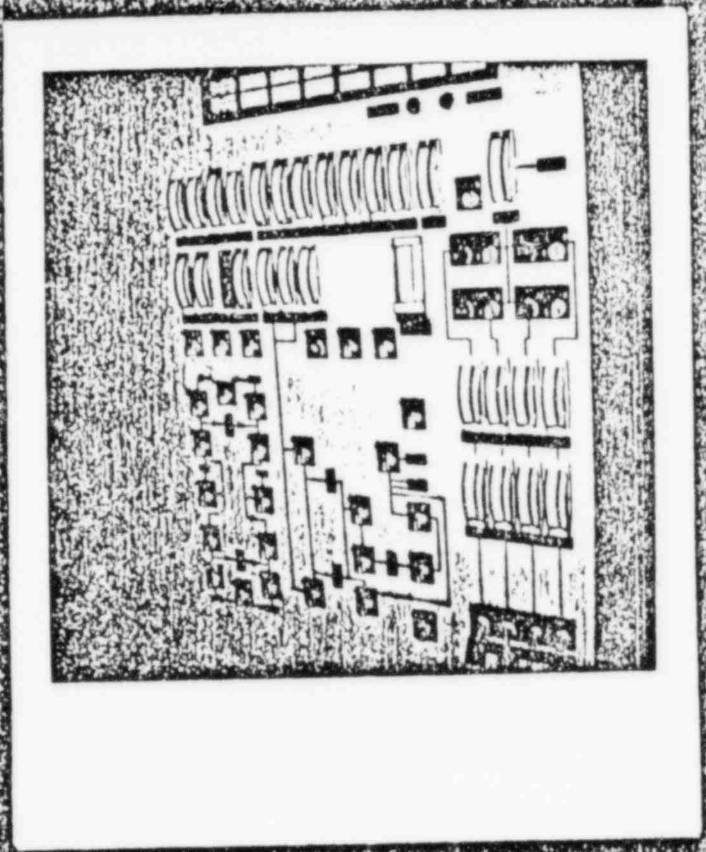
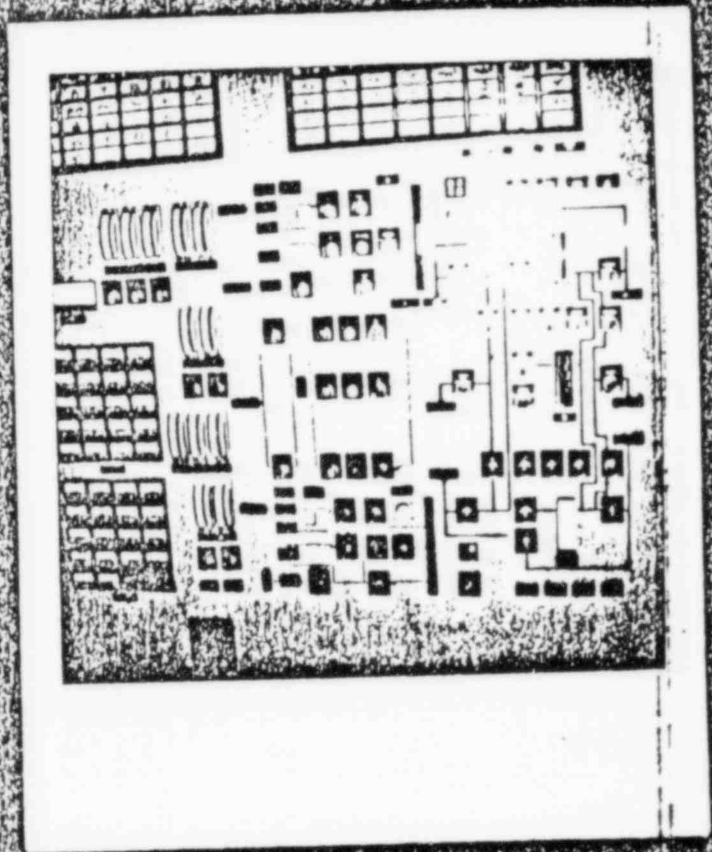


PHOTO #36

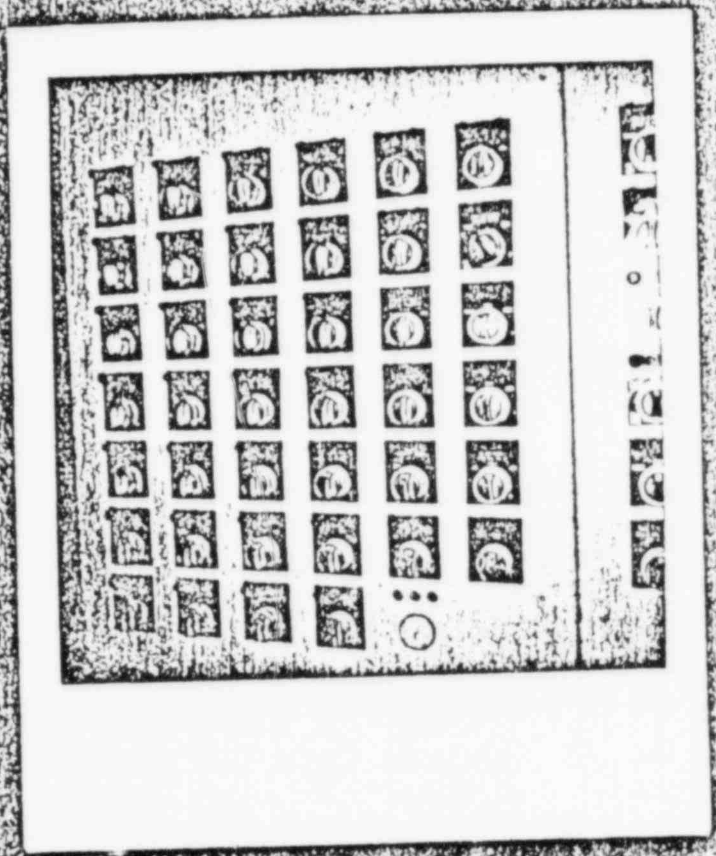
Relief valves are shown in series in this mimic on Panel 601-19.

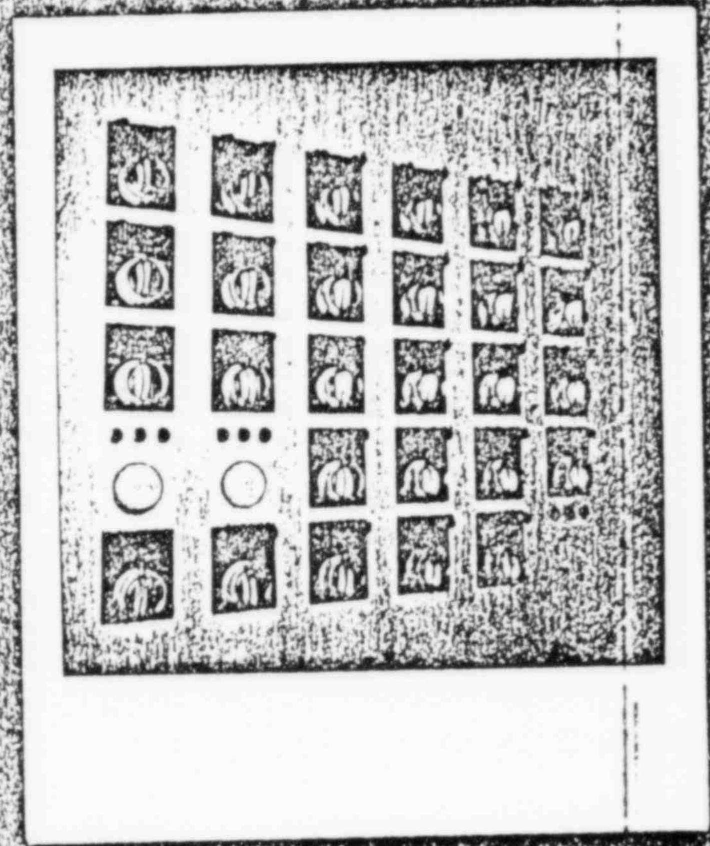




PHOTOS #37, #38

Demarcation lines could be used to clarify system divisions on Panels 970 and 904.





PHOTOS #39, #40

Undifferentiated matrices of controls are seen on Panels 881, 882 and 865.

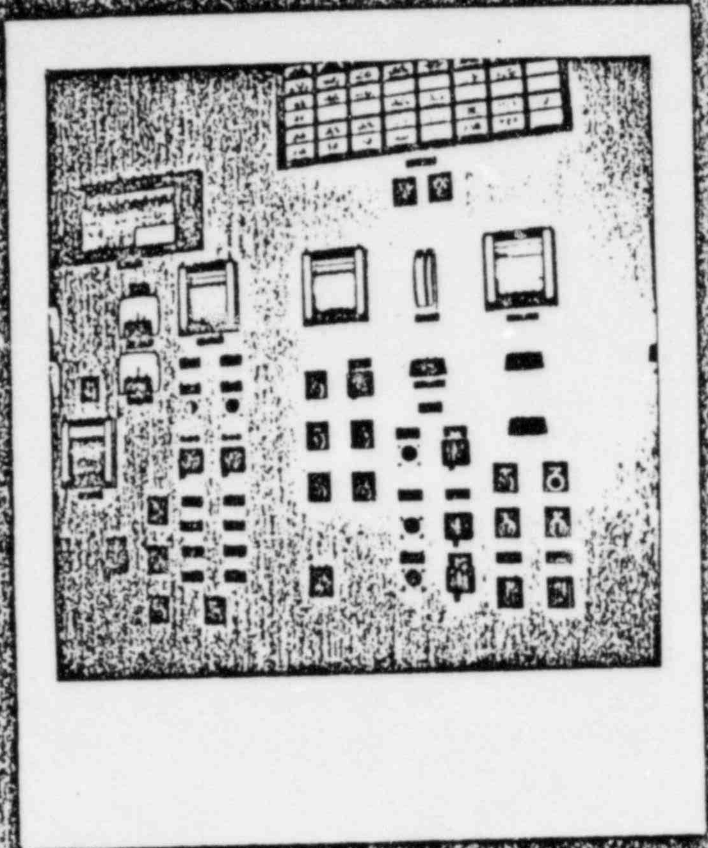


PHOTO #41

Demarcation lines could be used to subdivide Panel 845.

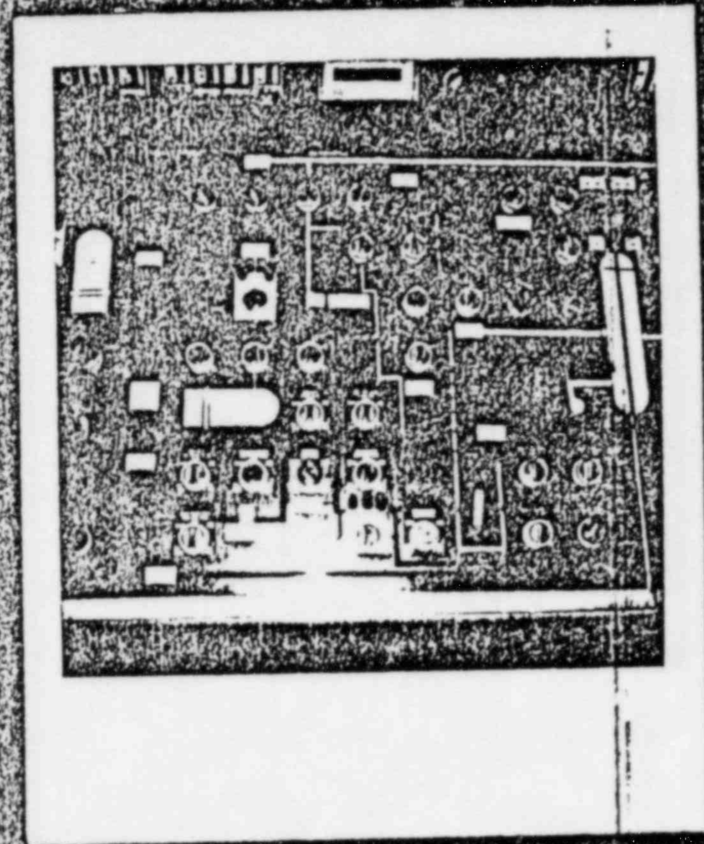


PHOTO #42

Operators found this mimic somewhat confusing. Blue mimic lines provide poor contrast against the dark panel background. Dotted white lines are used to represent both the containment and feedwater lines. The suppression pool symbol is nondescript.

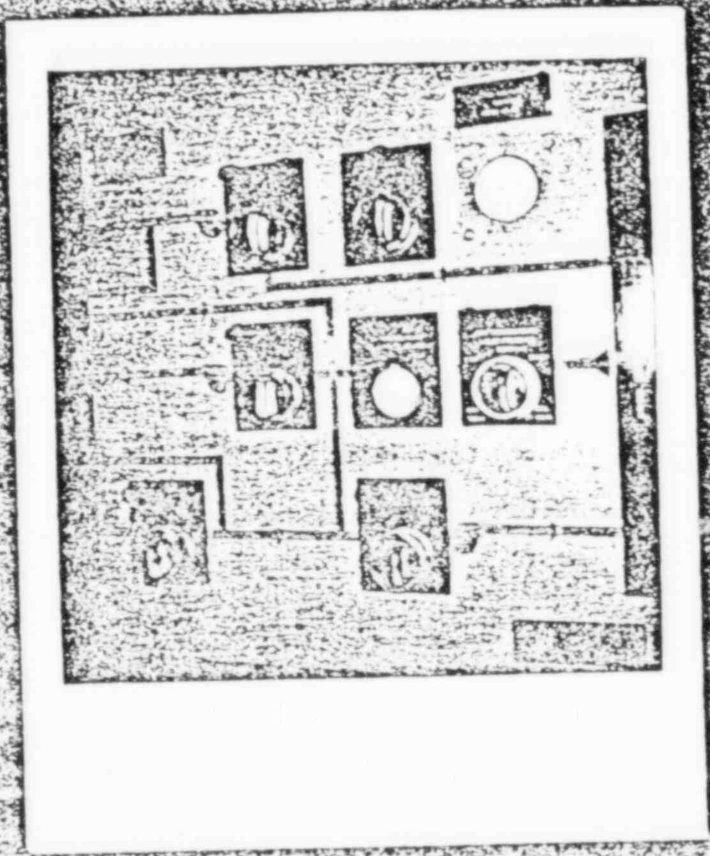
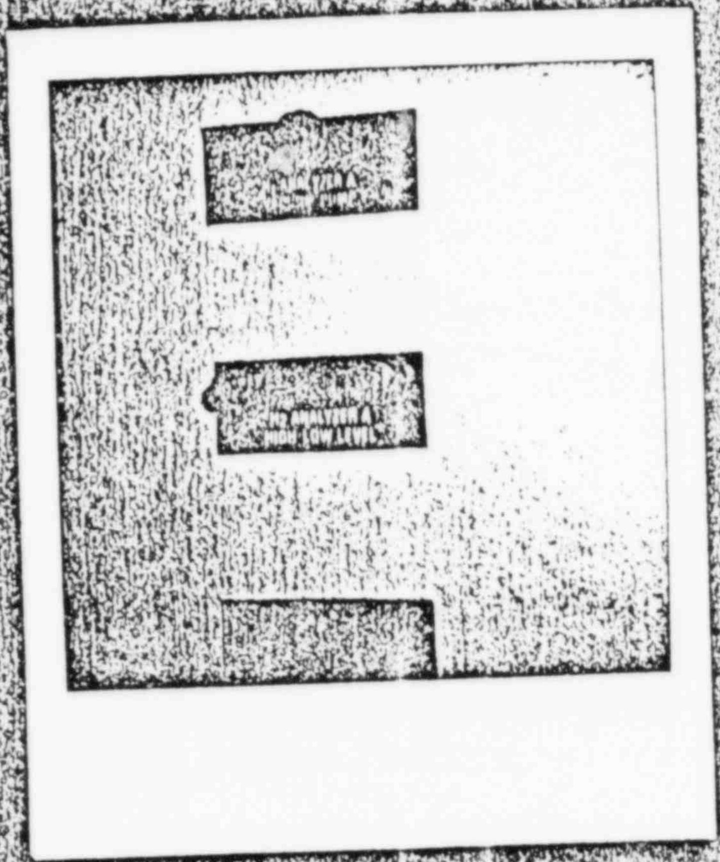
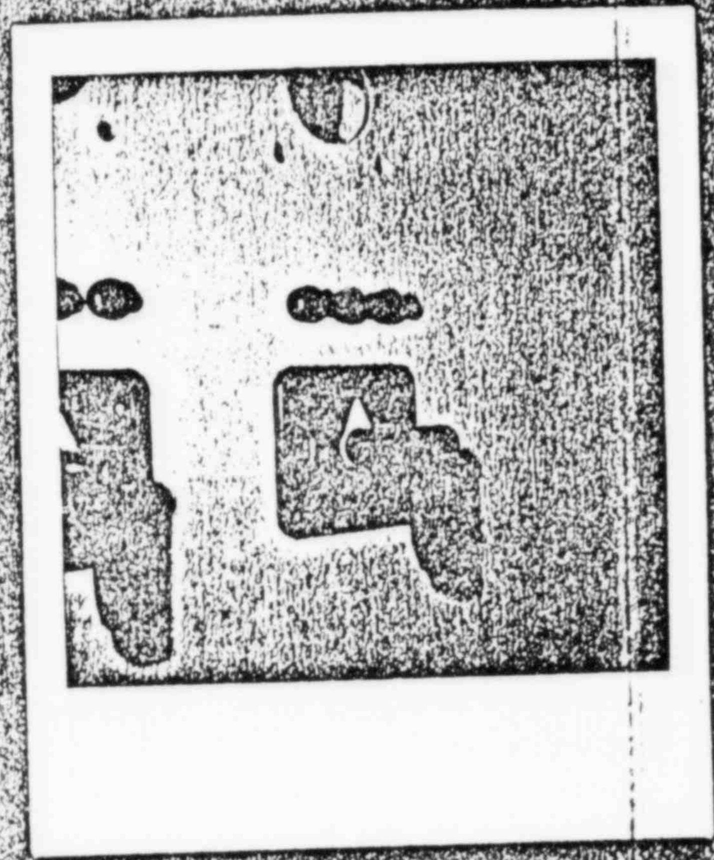


PHOTO #43

Additional use of flow arrows may be beneficial on Panel 904.





PHOTOS #44, #45

Labels do not clearly describe the function of these indicating lights on Panel 845.

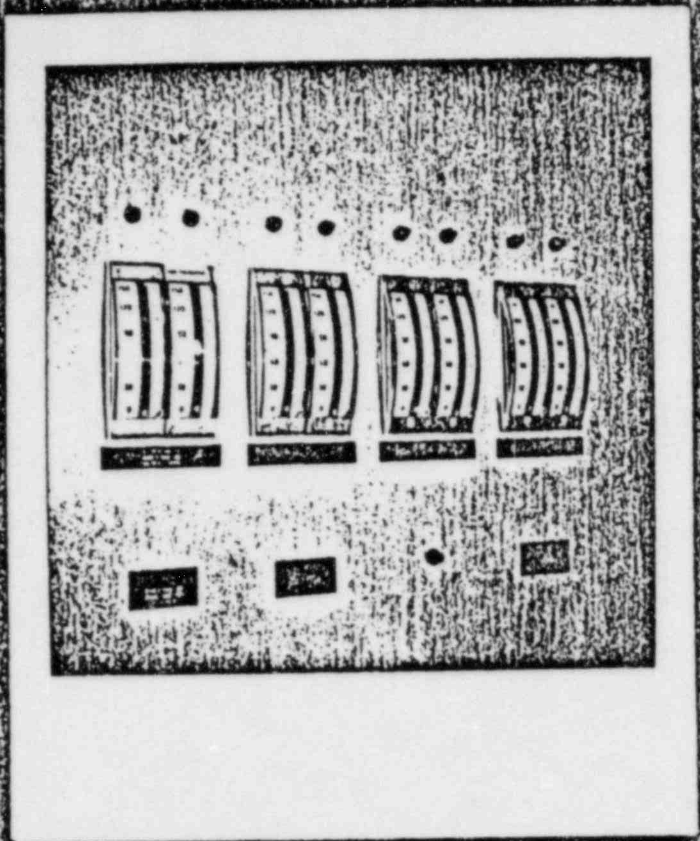


PHOTO #46

Unlabeled indicating lights on Panel 622.

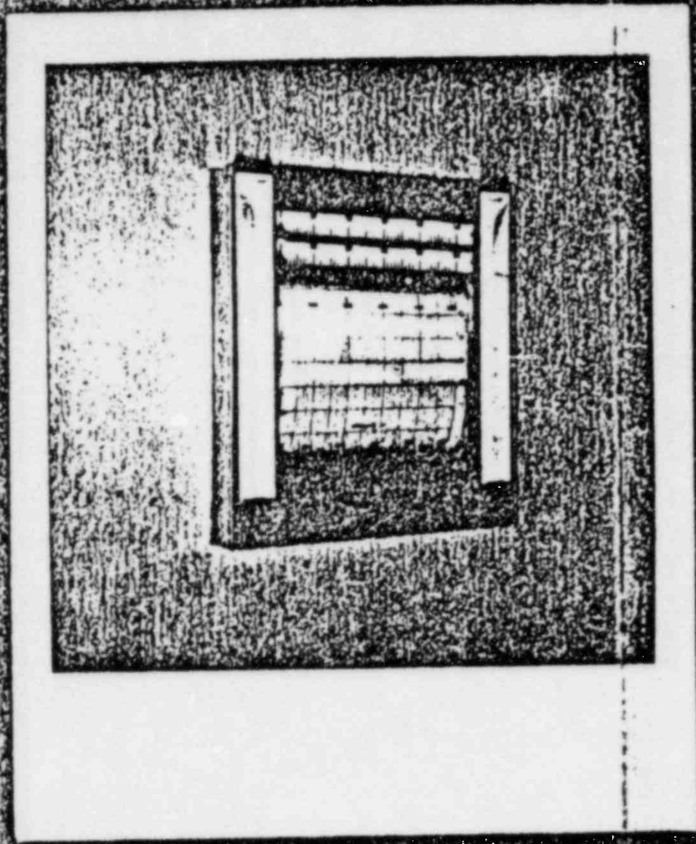


PHOTO #47

An unlabeled recorder on Panel 845.

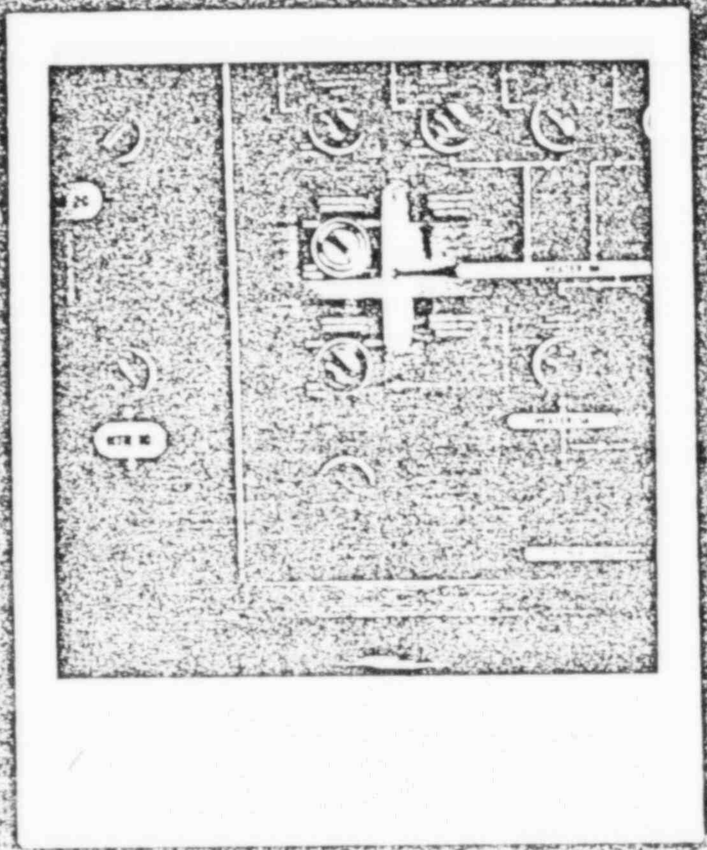
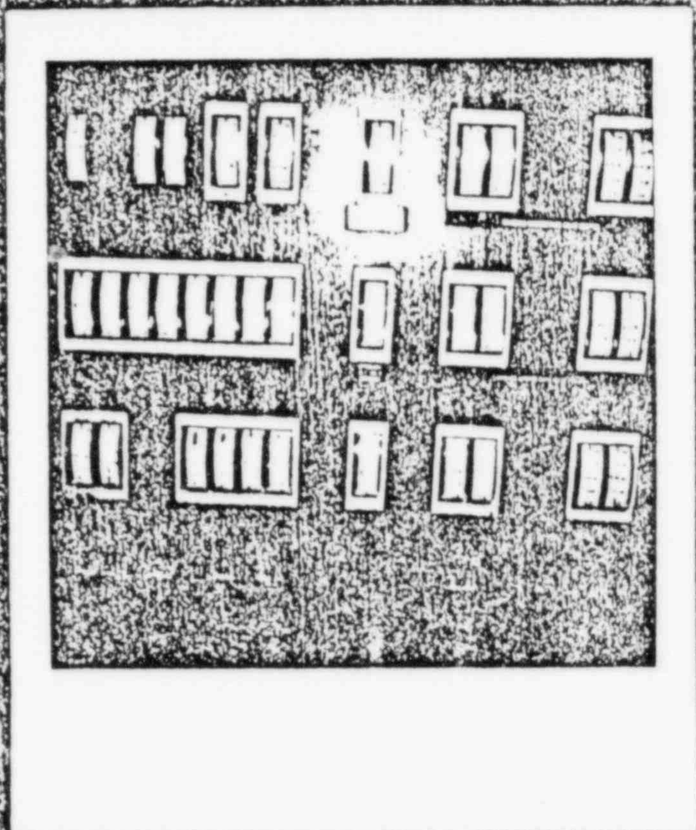
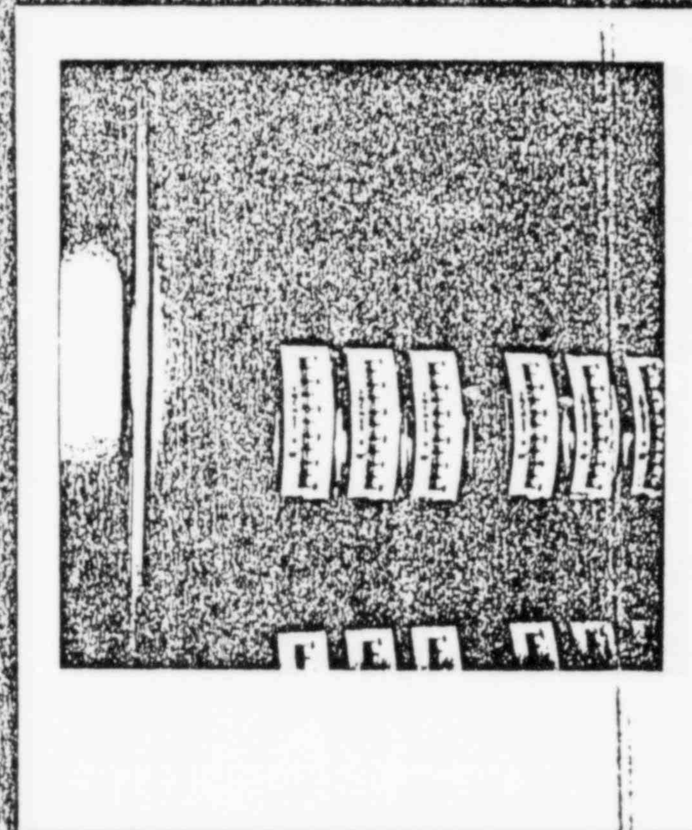


PHOTO #48

An unlabeled switch on Panel 870-5.





PHOTOS #49, #50

Unlabeled indicators on the right wing of Panel 680.

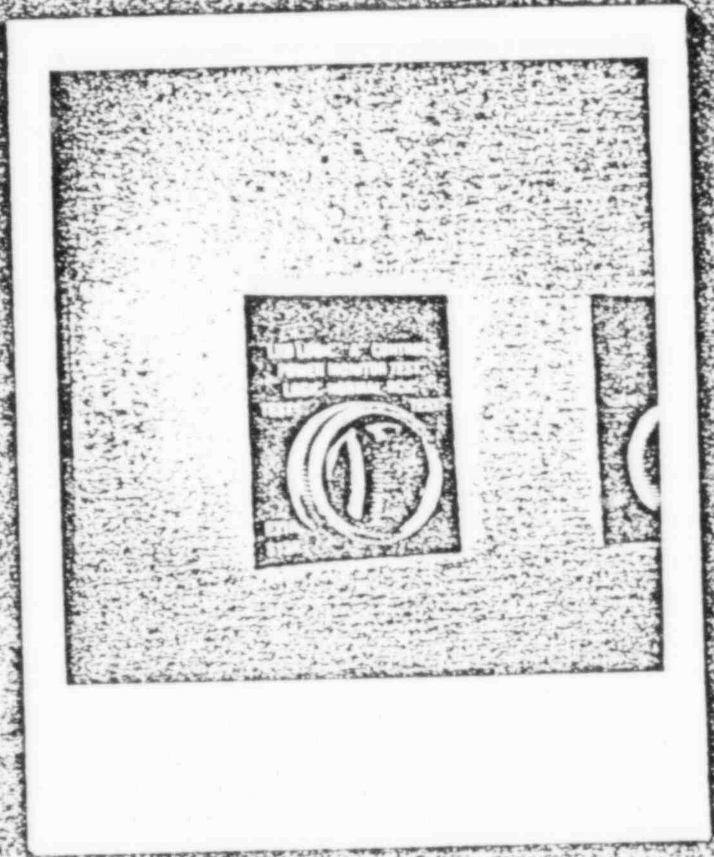


PHOTO #51

The center position marking on this switch appears to be part of the function label. (Panel 632)

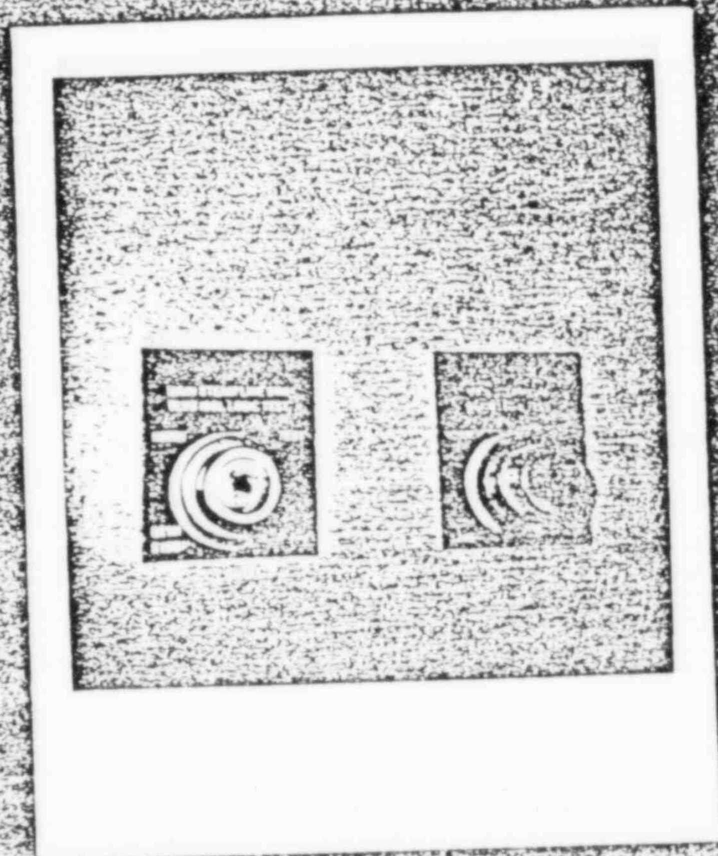


PHOTO #52

Two adjacent switches on Panels 691 and 694 have very similar labels.

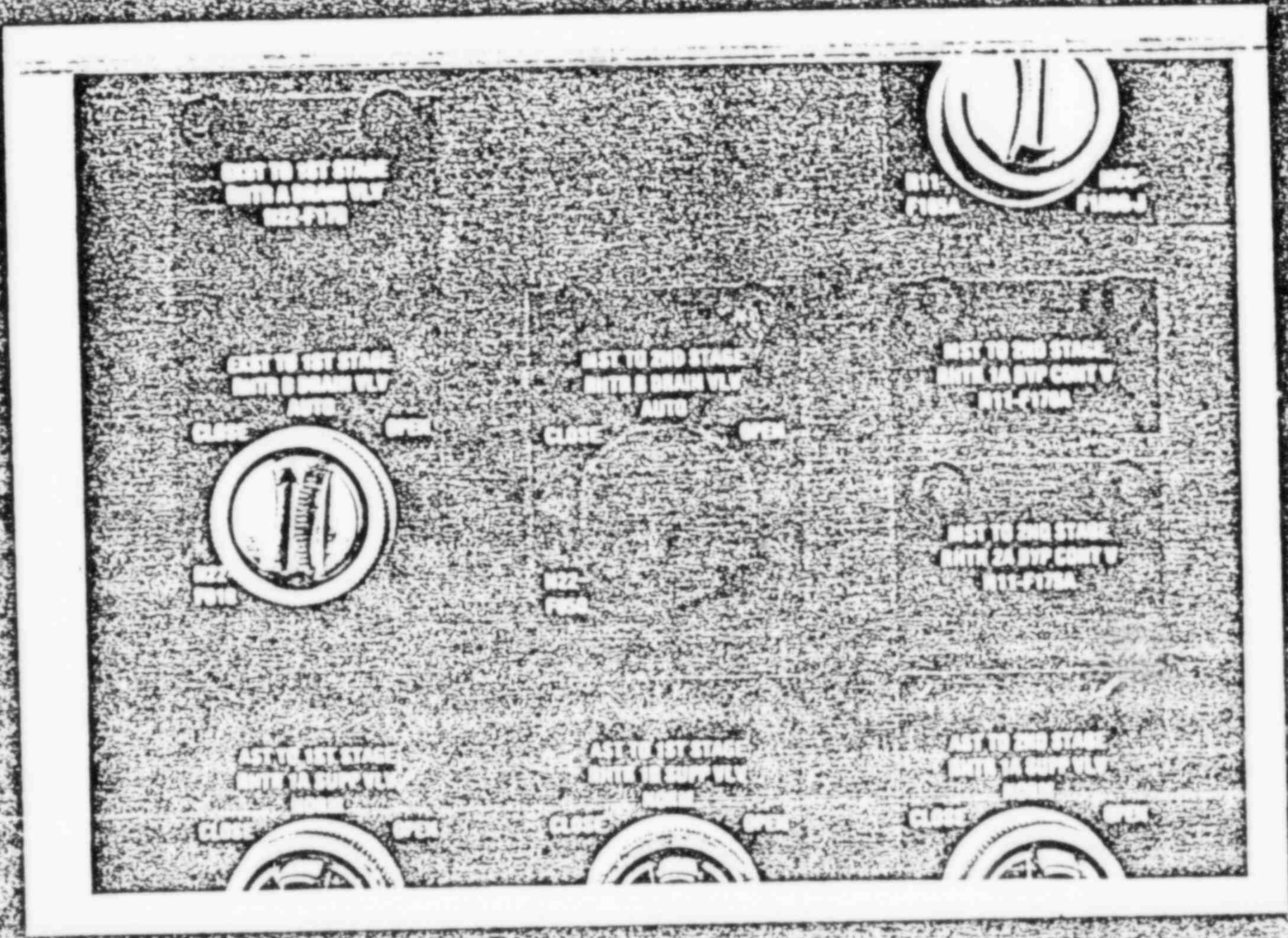


PHOTO #53

An unused switch escutcheon on Panel 870-6.

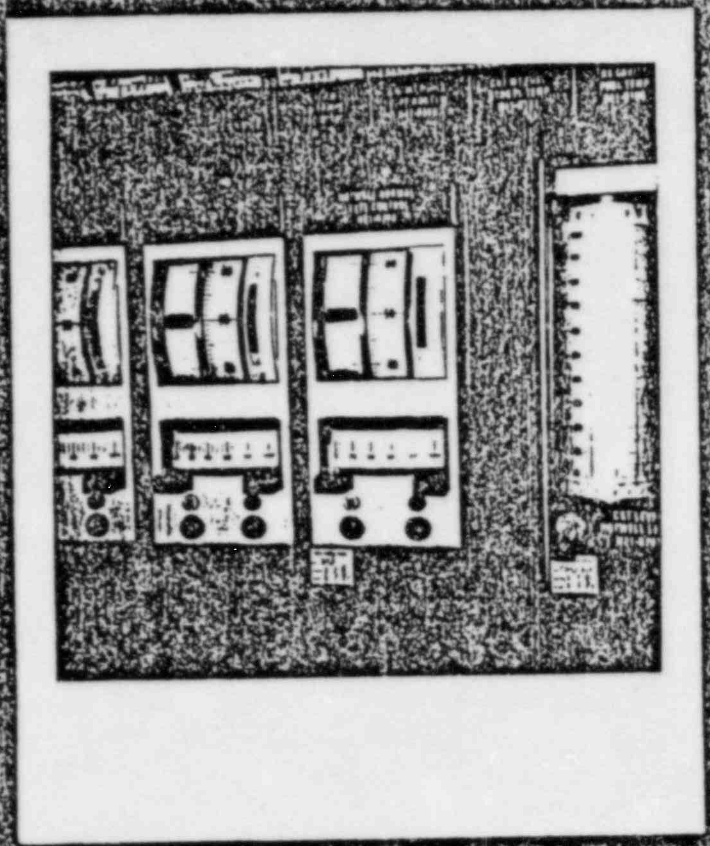


PHOTO #54

"0" on the hotwell level controller means the dump valve is full open and the fill valve full closed. "100" indicates the dump valve is full closed, the fill valve full open. At "50", each is 50% open.

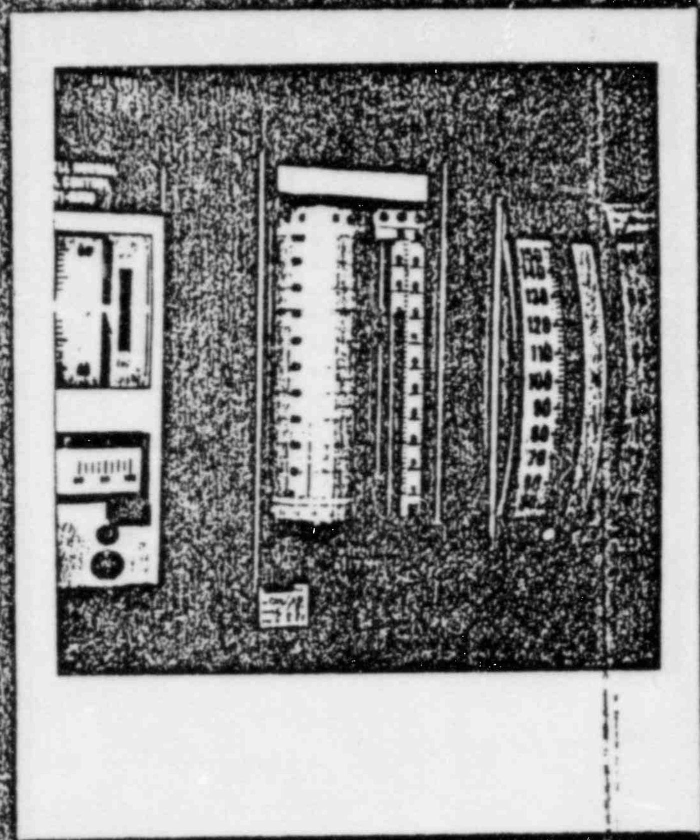


PHOTO #55

The condensate storage tank level indicator on Panel 870-2 is scaled 0-100%, but procedures specify level in gallons.

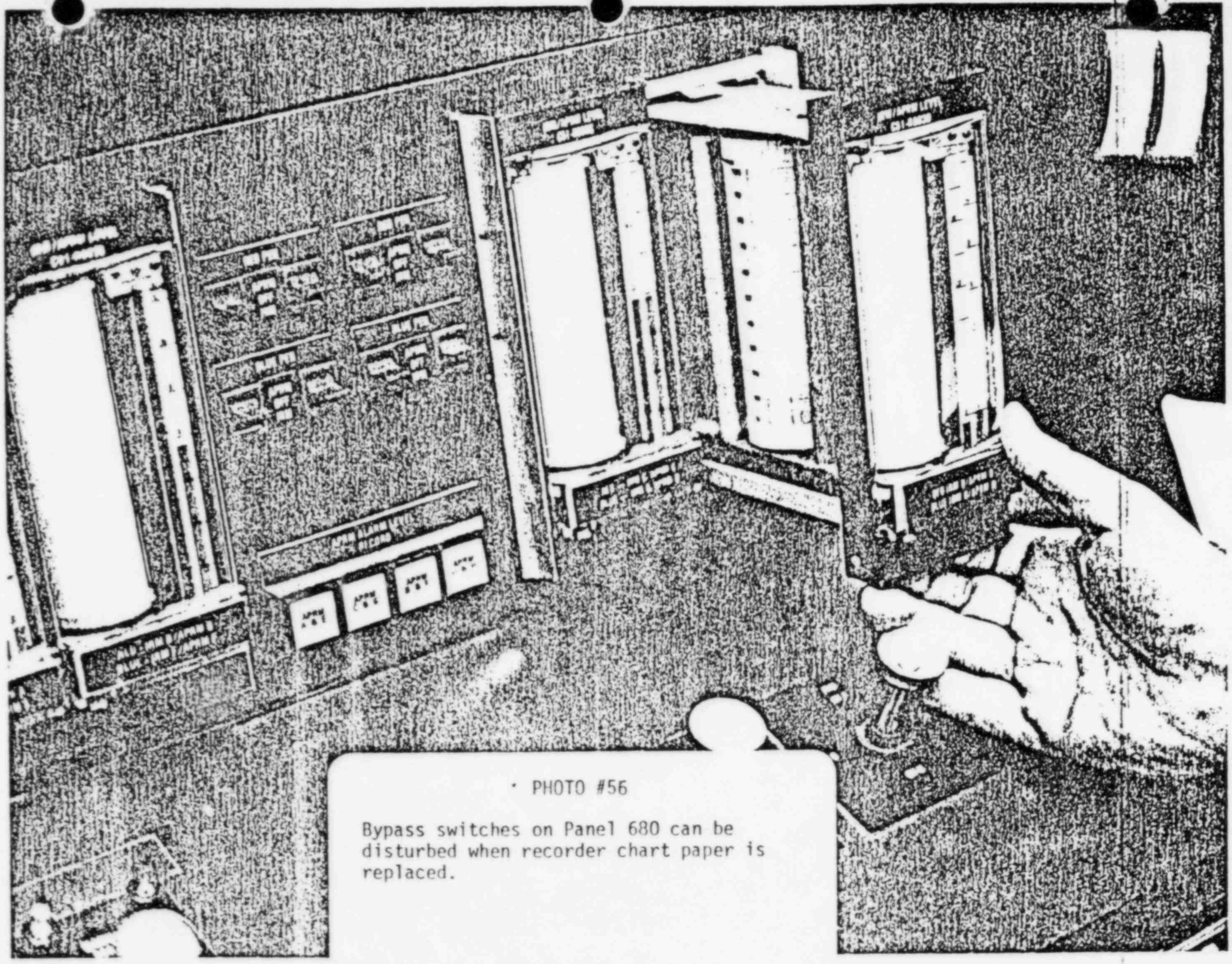


PHOTO #56

Bypass switches on Panel 680 can be disturbed when recorder chart paper is replaced.

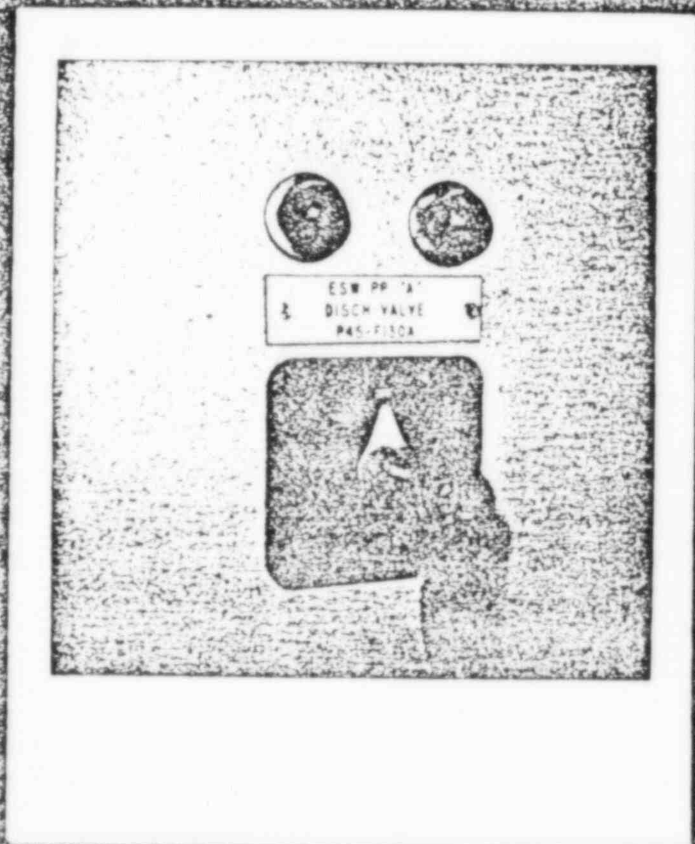


PHOTO #57

Switch escutcheons on Panel 001 list incorrect position options.

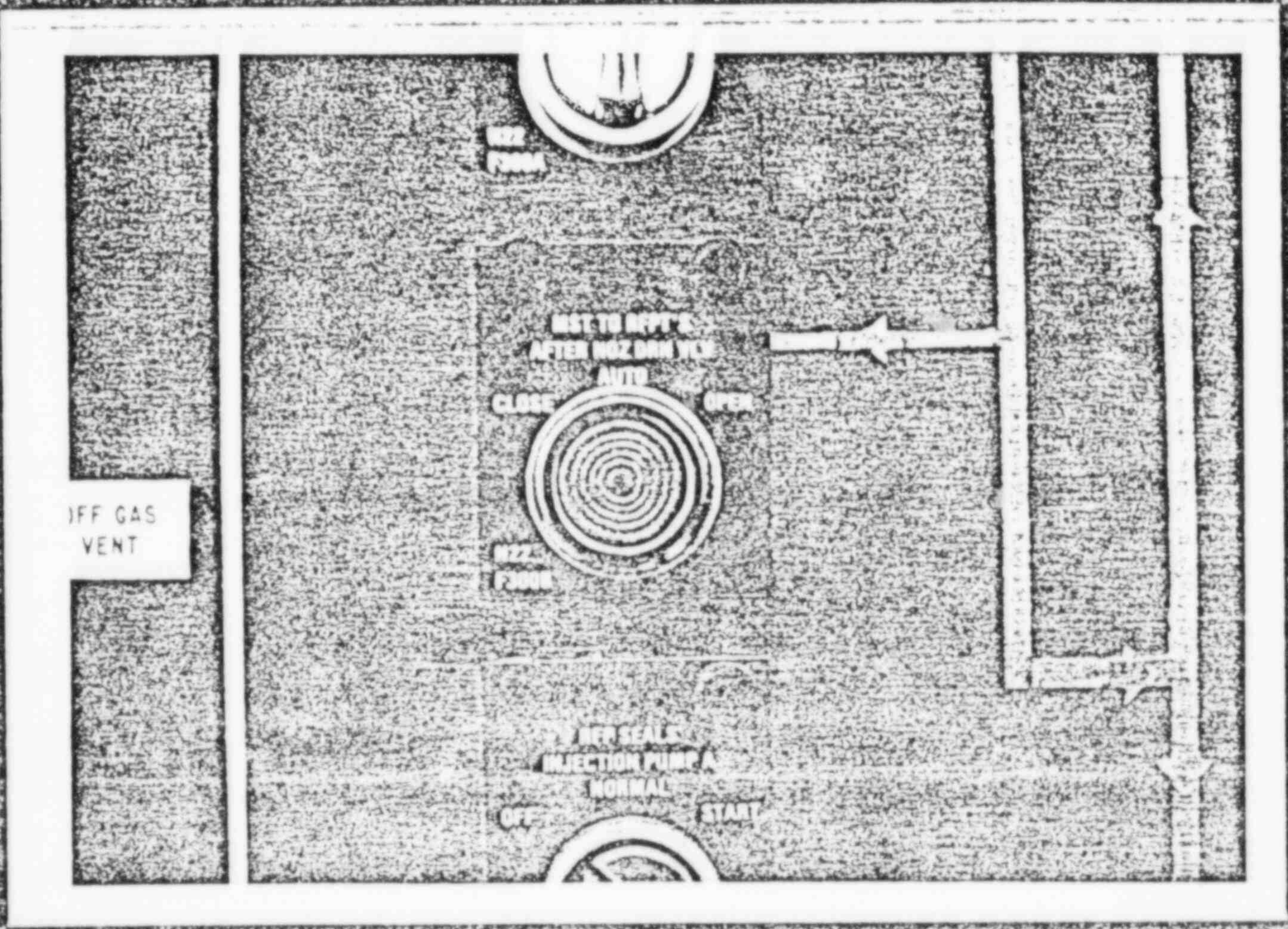


PHOTO #58

A rotary switch escutcheon is used for this pushbutton switch.

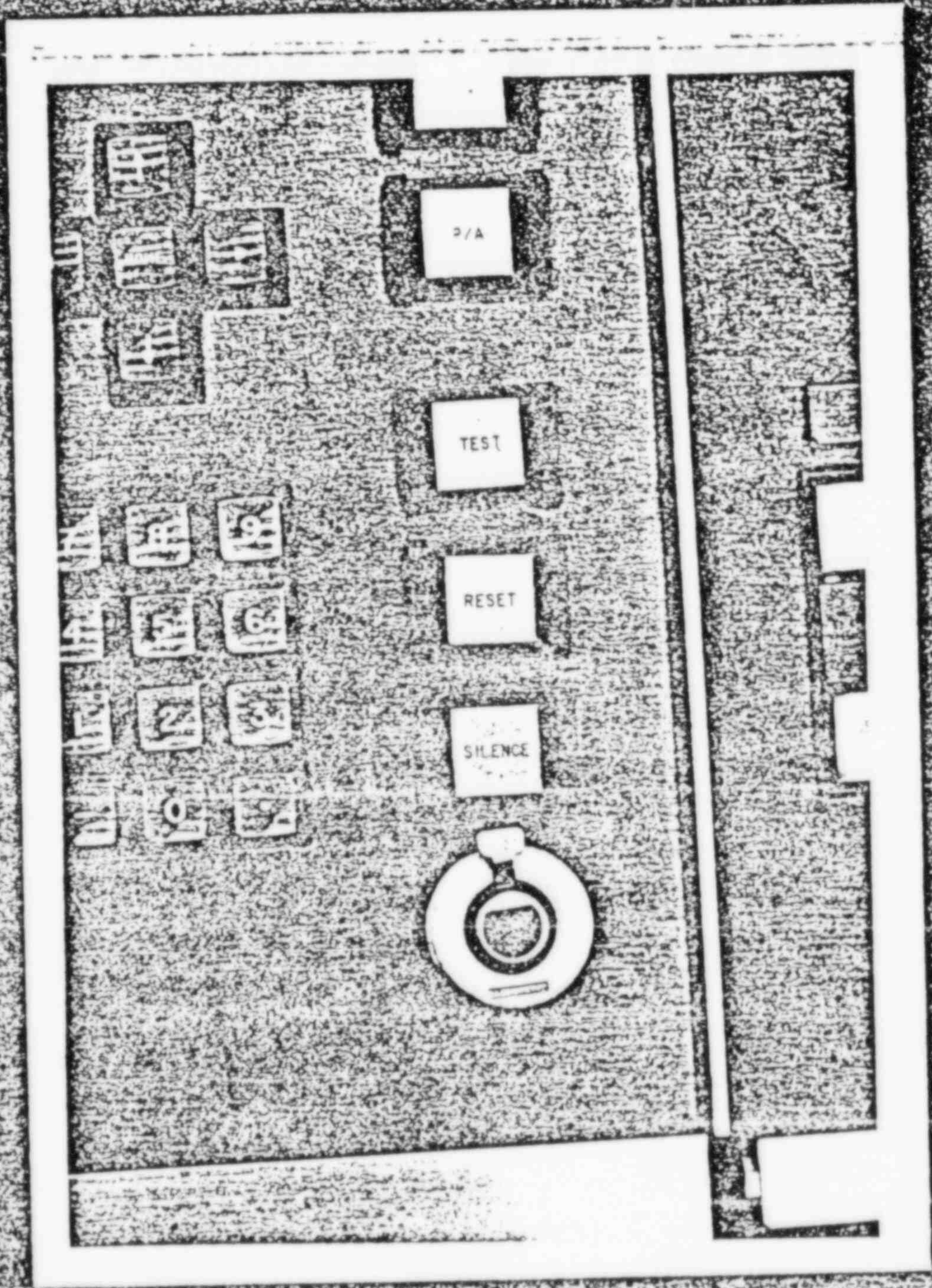


PHOTO #59

One set of annunciator response buttons on Panel 680 is configured differently from all others (compare to Photo #60.)

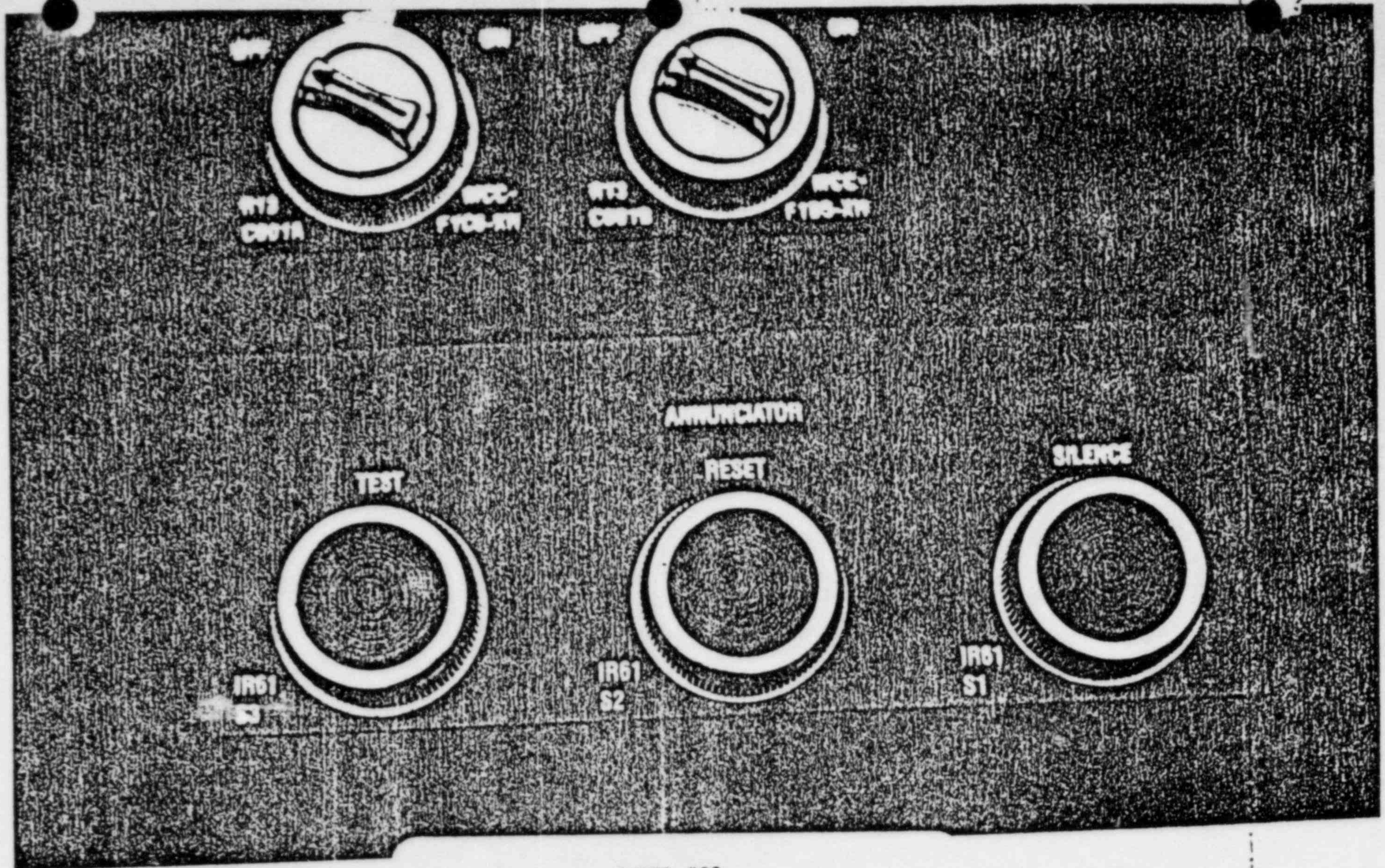


PHOTO #60

The standard configuration for annunciator response buttons.