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Vol. I

Volume I - Control Room Evaluation Process

HUMAN ENGINEERING GUIDE TO CONTROL ROOM EVALUATION

Final Report

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Prepared by
K. Mallory, S. Fleger, J. Johnson, L. Avery, R. Walker, C. Baker, T. Malone

The Essex Corporation
333 N. Fairfax Street
Alexandria, VA 22314

Prepared for
Division of Human Factors Safety
U.S. Nuclear Regulatory Commission
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PROLOGUE

NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report, Short Term Recommendations," requires that Nuclear Power Plant Licensees:

> Perform comprehensive review of control room using NRC human factors design guidelines and evaluation criteria. Modify to correct significant deficiencies. Issue report describing methods of review, results of review, including bases for findings made, and implementation schedule. Applicants to be granted operating licenses prior to September 1981 must perform a preliminary assessment of their control rooms to identify and correct significant human factors and instrumentation deficiencies.
>
> Licensees and applicants will complete review and implement short lead-time revisions by September 1981 or prior to issuance of operating license, whichever is later. Long lead-time revisions will be completed by April 1982 or prior to issuance of operating license, whichever is later.

The two volumes of this document contain the NRC guidelines and evaluation criteria to be applied in performing control room reviews.

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FOREWORD

This document contains guidelines for a human engineering evaluation of nuclear power plant control rooms. These guidelines are intended to help in identifying potential human engineering problem areas in control room design, documentation, and operations and should *not* be construed to be NRC standards, criteria or regulations.

Volume I suggests a procedure for applying the guidelines (Volume II) to uncover potential human engineering problems, and for identifying critical problems by estimating the impact of the potential problems on safe control room operations. This procedure is suggested and should *not* be considered as an NRC requirement.

It should be recognized from the outset that hardware or procedures that fail to meet one or more of the guidelines are *not necessarily* in violation of NRC criteria or regulations. Only where operator performance of a safety-related task could be jeopardized should the hardware or procedure problem be considered serious.

Many of the guidelines in Volume II can be applied to control room design. However, many human engineering guidelines addressing design issues, and not evaluation, have been intentionally omitted from this document.

Finally, these guidelines and evaluation procedures were validated on nuclear power plants that were operating or ready for licensing prior to May, 1980. Thus, these guidelines and procedures may not be completely appropriate or sufficient for plants of a later vintage.

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1.0 INTRODUCTION

1.1 General

From the point of view of control room evaluation, human engineering seeks to locate and remove causes for operator error. While this definition depicts only a small part of the general discipline of human engineering, it focuses on the primary thrust of the information presented in the two volumes of this Guide — namely, to provide a means to locate and remove causes for operator error in nuclear power plant control rooms.

Many studies have been performed which attempt to quantify the effect of human error on nuclear power systems' safety and reliability. Results show that 15 to 66 percent of plant safety failures are attributable to human failure. For example, IEEE Spectrum (1) reports some of these findings to be: a) "Between 1/2 and 2/3 of hypothesized reactor accidents are caused by human error," b) "20 to 50 percent of all LER failures are due to human error;" c) "About half of the accidents that lead to any release of radiation are caused by human error;" and d) "In about one percent of the LERs (examined by the investigators), or about 35 a year, there are indications that a safety feature has been severely compromised or made unavailable by human error." Further, a report issued by the Aerospace Corporation (2) states that "personnel errors constitute 15 to 20 percent of all reportable occurrences in a nuclear power plant." Lastly, according to a report based on WASH 1400 (3), human errors in nuclear power plants present one of the most significant potential risks to public health.

Research has also been performed on the effects of human error on power plant outages. Results of these studies are in general agreement that upwards of 20 percent of plant outages are caused or contributed to by operator error (4). Representative statements include: "The single most important cause of the July 13, 1977, power failure was the failure of the system operator to take the necessary action," (5) and "A study of major power system disturbances found that human factors problems either initiated or compounded about 20 percent of the events" (6).

Reviews of nuclear power plants have repeatedly demonstrated that most of the control rooms designed prior to the TMI-2 accident were not in compliance with human engineering standards and principles (2, 7, 8, 9). Based on extensive military and aerospace experience with complex systems, operator error will be reduced if control panels and procedures are brought into agreement with human engineering practices. The procedures (Volume I) and guidelines (Volume II) that make up this Guide will assist the user in determining which components, labels, procedures, etc. are at variance with *established* guidelines and provide a means to determine whether or not this variance is likely to result in a significant operator error.

As part of developing this Guide, nine control rooms were examined for compliance with a large sample of human engineering guidelines and to test the control room and evaluation process covered in Volume I. Since no human engineering standards had been developed specifically for the nuclear power plant control room applications, military and aerospace guidelines were used. In most cases, these guidelines appeared to be valid since they are applied quite successfully to systems containing the same types of operational requirements, components, personnel and procedures.

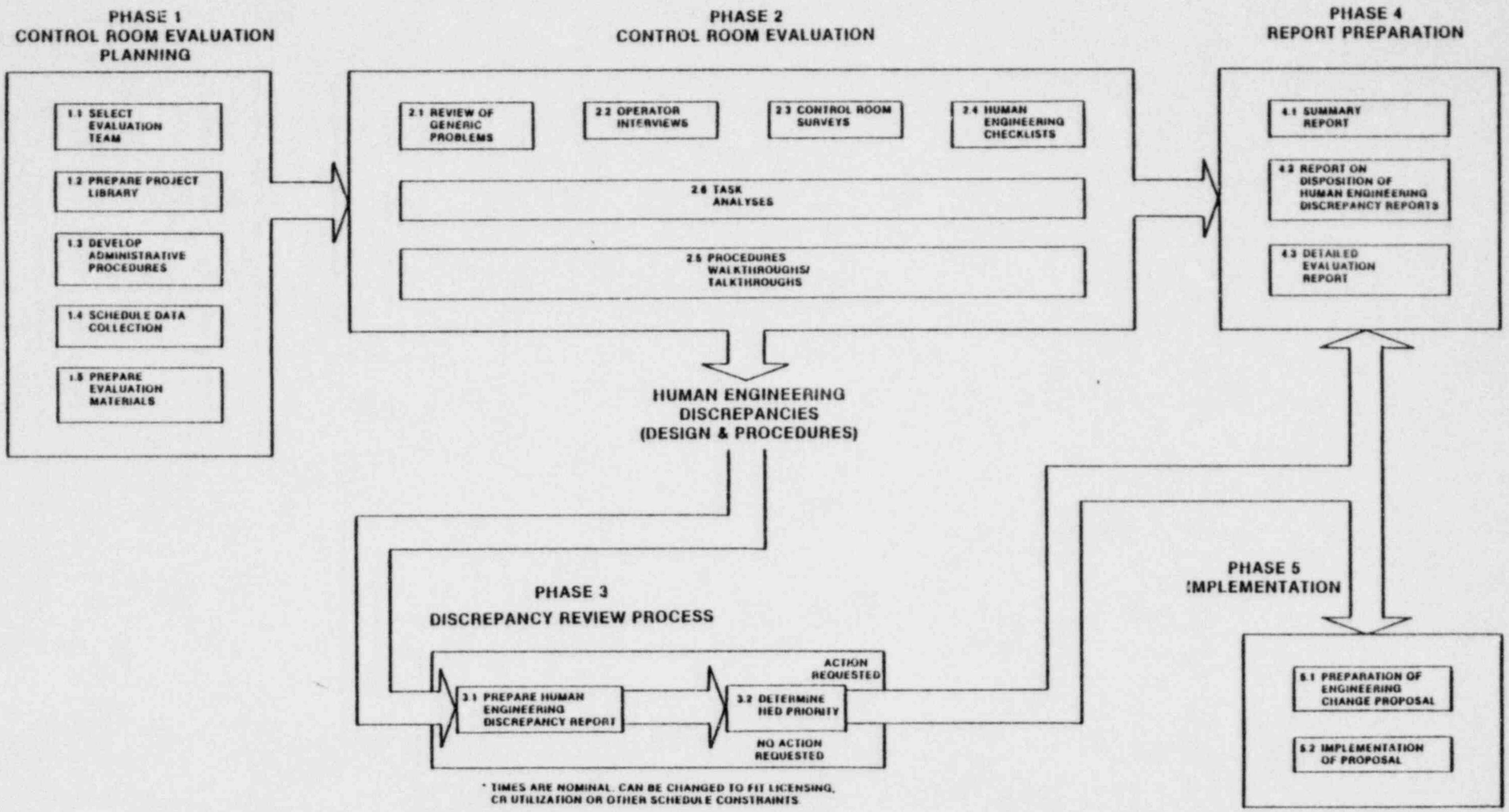
The control room evaluation process *suggested* in these volumes can be characterized in five steps (Figure I-1).

1. Plan the evaluation.
2. Locate *all* instances where the control room differs from the Human Engineering Guidelines.
3. Evaluate the impact of each instance on safety and reliability.
4. Prepare Evaluation Reports.
5. Develop means (engineering, procedures, etc.) to correct the high priority discrepancies.

The general objectives of each Phase are summarized below.

- Phase I
  - to gather all of the resources needed to complete the evaluation
  - to develop data collection and evaluation checklists, surveys, etc.
  - to schedule all subsequent activities and prepare management plans.
- Phase II
  - to locate and record all control room interfaces (e.g., controls, displays, labels) where design or operation do not meet human engineering guidelines
  - to suggest potential backfits.
- Phase III
  - to determine which of the interfaces cited in human engineering discrepancies have an impact on plant safety or reliability
  - to select most cost-effective backfits.

FIGURE 1-1. PROCESS FOR HUMAN ENGINEERING REVIEW OF NUCLEAR POWER PLANT CONTROL ROOMS



- Phase IV
  - to prepare reports documenting the scope, methods, objectives and results of the review.
- Phase V
  - to implement control room backfits that correct high priority human engineering discrepancies.

As pointed out by an EPRI study (7), backfits for human engineering discrepancies do not necessarily involve hardware modifications. Demarcation lines, special emphasis markings, relabeling, special training, etc. are often satisfactory in lieu of moving components. This being the case, each guideline in Volume II contains a range of backfits that *might* be satisfactory, depending on the specific circumstances. In fact, each guideline in Volume II gives:

- The evaluation guideline itself
- The type of operator error that can result from violation of the guidelines (e.g., inadvertent switch actuation)
- The source for the guideline (e.g., MIL STD-1472B)
- Backfits that may be suitable for correcting discrepancies (e.g., Switch guarding)

When this Guide is applied throughout the nuclear power industry needs for revised or new guidelines or evaluation procedures will be discovered. Such needs should be referred to the Division of Human Factors Safety, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

1.2 Human Error as a Function of Control Room Design

During the development of these guidelines Essex conducted a human factors engineering evaluation at nine plants. These were:

Crystal River - Unit 3
Zion - Unit 1
Dresden - Unit 1
Dresden - Unit 2
Indian Point - Unit 2
Diablo Canyon - Unit 2
Sequoyah - Unit 1
Salem - Unit 2
North Anna - Unit 2

A number of design discrepancies were identified during these surveys. These discrepancies were categorized by the types of errors that they could be expected to cause or contribute to. The taxonomy of errors is based on the following general categories:

- Control errors — errors in activating controls
- Display errors — errors in reading displays
- Annunciator errors — errors in reading annunciators
- Labeling errors — errors in reading labels
- Procedural errors — errors in reading or following procedures.

The control room design features associated with general types of error are listed in Appendix I-c.

2.0 CONTROL ROOM EVALUATION PLANNING

Timely completion of a thorough human engineering control room evaluation can be aided by conscientious planning prior to actual data collection. Evaluation team members should be selected for the decisionmaking and judgmental skills as well as the technical knowledge and management status needed to identify, qualify, and correct human engineering discrepancies. A project library as well as data collection instruments (e.g., checklists) and instrumentation (e.g., video systems) tailored to the control room under review will be quite useful to the evaluation team. Finally, well-coordinated data collection schedules and administrative procedures for reviewing Human Engineering Discrepancy Reports (HEDs) prepared during data collection will help to assure that every man-system interface in the control room receives sufficient attention.

2.1 Select Evaluation Team

The first step in the CR evaluation process is to organize a team of technical specialists and managers. This team must be capable of performing a thorough job in the control room review and of making technically acceptable decisions with respect to prioritizing human engineering problem areas and developing acceptable backfits. The operator, through use of controls, displays and communications, interacts with virtually every plant system and organization; therefore, the evaluation team must be multidisciplinary. While human engineers can identify CR problem areas, engineering and operations personnel should participate in determining the priority of problems and in reviewing the technical and operational acceptability of backfits suggested by human engineers.

2.1.1 Objectives

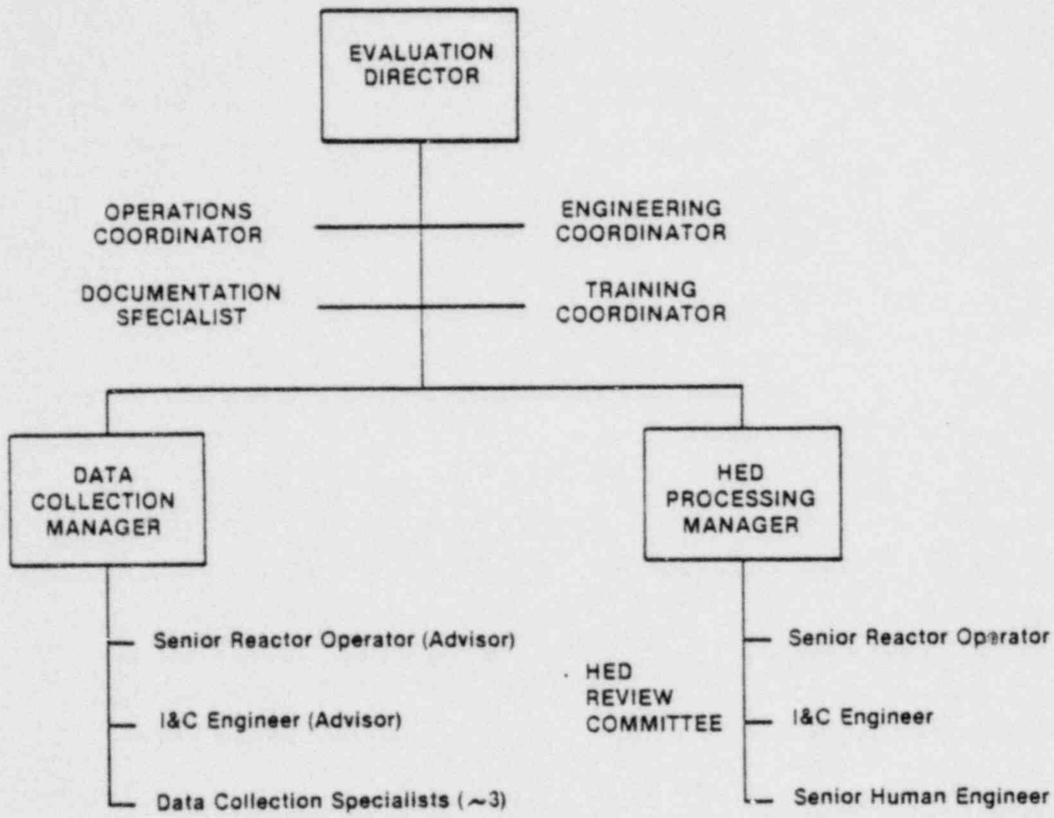
The objective of this first step in the evaluation process is to organize a multidisciplinary team capable of performing the control room human engineering evaluation.

2.1.2 Method

Before team members can be selected, the organization of the team must be specified along with the responsibilities (or functions) of each position in the organization.

Then, the qualifications for team members can be determined for each position. Figure 2-1 gives a typical organization with a sample of some position descriptions. A complete listing of descriptions for the positions named in Figure 2-1 can be found in Appendix I-a.

FIGURE 2—1
TYPICAL CONTROL ROOM EVALUATION MANAGEMENT PLAN



2.2 Prepare Project Library

Easy access to a variety of information sources will expedite the CR evaluation process, minimize dependence on memory and improve the quality of results with respect to plant safety.

2.2.1 Objectives

The result of this task will be a centralized project library suitable for use throughout all phases of the project by the entire project team.

2.2.2 Methods

The first step is to identify sources of information that might prove useful in identifying human engineering problems, prioritizing these problems, and evaluating backfits. Such a list might include:

- Licensee Event Reports
- System Descriptions
- Piping and Instrumentation Diagrams
- Procedures (emergency, operating, etc.)
- Software Descriptions
- Operator Comments on Panel Design
- Operator Training Materials and Aids.
- Final Safety Analysis Report
- Outage Analysis Reports
- Panel Layout Drawings
- Control Room Floor Plans
- Lists of Acronyms and Abbreviations
- Samples of Computer Printouts
- Annunciator Response Procedures
- Fault Trees and Failure Modes and Effects Analyses
- Photographs of Panel

2.3 Prepare Management Procedures

In many respects, the process and management organization presented in this Guide is only a framework or perhaps a point of departure for developing a specific organization and method for conducting the evaluation. Defining detailed data collection and HED review procedures at all levels of management will help to assure that each operator-control room interface is given adequate attention during evaluation, prioritization and backfit selection. Also, defining management procedures will help to clearly delineate the roles and responsibilities of each team member.

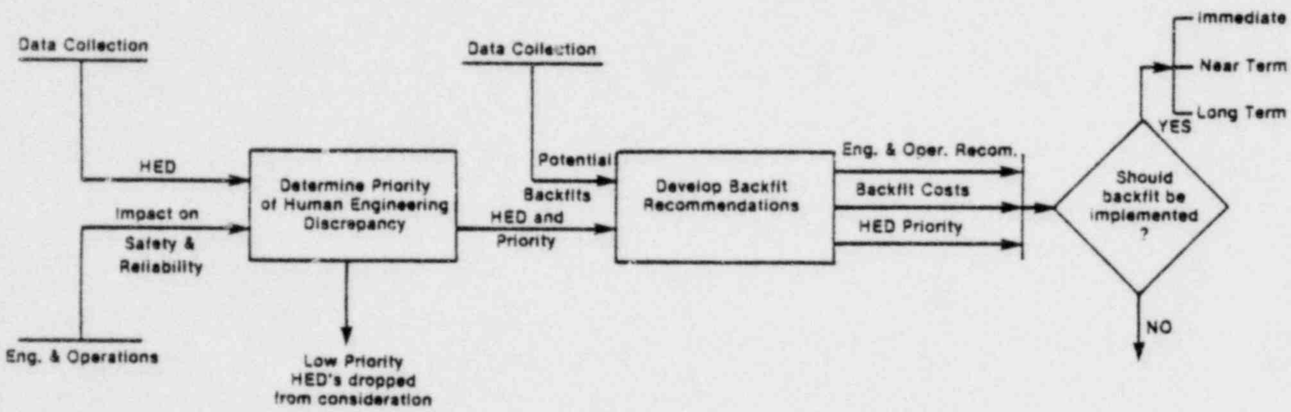
2.3.1 Objective

This step will produce a detailed flow chart of the entire human engineering review of the control room. Each function in the chart will be assigned to one position in the team organization (Figure 2-1).

2.3.2 Method

A time-based process for data collection and HED review should be designed for implementation by the evaluation team. This process identifies data collection; HED processing and reporting functions, decisions, the inputs to each function, the outputs from each function and the information needed to make each type of decision (Figure 2-2). The positions responsible for performing each function and decision will be identified.

FIGURE 2—2
EXAMPLE OF FUNCTIONS IN PLANNING PROCESS FLOW



2.4 Schedule Data Collection and Reporting Activities

Dovetailing evaluation activities with simulator and control room schedules will help to assure that all evaluation data are collected, processed and reported in a timely manner.

2.4.1 Objective

The goal of this task is to develop realistic schedules for all data collection, HED evaluation and reporting tasks to be performed throughout the evaluation.

2.4.2 Method

The flow chart prepared as a result of developing management procedures (2.3 above) provides the basis for the sequence of tasks to be scheduled. The time required to complete each task will depend on several factors, including:

- Number of man-system interfaces considered in the evaluation
- Number of personnel involved in data collection
- Human engineering guidelines considered to be applicable
- Numbers and types of situations and casualties considered in establishing HED priorities
- Amount of applied research performed in support of evaluation
- Breadth of procedural evaluations (e.g., emergency, abnormal, operational) as well as range of contingencies considered within each procedure.

The sequence and duration of tasks should be used in light of constraints to compile an end-to-end project schedule complete with milestones and specific responsibilities. Of course, scheduling constraints should be determined with respect to:

- Simulator availability
- Team commitments to other projects
- Control room scheduled and unscheduled activities.

Prior to revising the evaluation materials, a complete listing of all operator-control room evaluations should be made. One copy of the Human Engineering Evaluation Report (Appendix I-b) should be filed, by panel or procedures, for each interface. The surveys, checklists and walk-throughs contuined in Appendix IV, V and VII respectively should be reviewed for applicability to the interface and recorded on the HEER as appropriate. Interfaces could be:

- Individual components
- Environmental characteristics
- Groups of components operated together
- Systems or subsystems
- Features of the control room layout, etc.

2.5 Preparation of Evaluation Materials

Prior to performing the control room data collection, certain steps should be taken to streamline the data collection process by tailoring the general methodology to the specific control room under review:

- Examine generic problems and operator interviews for applicability to control room
- Develop human engineering surveys and checklists matched to the systems, layout and components of the control room

- Prepare for walk-throughs of plant-specific procedures
- Select and acquire necessary instrumentation
- Initiate task analyses.

2.5.1 Development of Generic Problem Reviews and Operator Interviews

The first two steps in control room evaluation were selected to provide an immediate look at what could be some of the serious or more apparent human engineering problems. By comparing the control room design and operations to problem areas (called generic problems) characterizing a number of existing plants (Appendix II), some problems can be identified quickly for immediate action by the HED review committee (Section 2.1).

Operator opinion has been used widely as a design aid, and to identify engineering and procedure problems during operation. A rather extensive operator interview, included as Appendix III, assures that shortcomings known to the operators will be considered for backfit early in the process.

2.5.1.1 Objectives — The results of this task will be a list of generic problems and operator interviews directly related to the design and operation of the plant under review.

2.5.1.2 Methods — The list of generic problems (Appendix II) and the standard operator interview (Appendex III) should be reviewed by Instrumentation and Control Engineering and Operations Specialists. During this review generic problems not related to the plant (if any) would be purged from the list, and inappropriate questionnaire items (if any) would be dropped or modified.

Generic problems and operator interviews should be revised, together with their instructions for use, for application during Data Collection.

2.5.2 Development of Surveys

The surveys combined in Appendix IV cover aspects of the control room not well suited to checklist evaluation. For example, noise, illumination, and use of design conventions throughout the control room.

Since surveys can be performed quickly to identify human engineering discrepancies, they are scheduled for early in the data collection phase.

2.5.2.1 Objectives — The objective of this task is to tailor the survey items to the specific configuration of the control room review.

2.5.2.2 Methods — While the sample surveys included in Appendix IV have been designed based on reviews of several plants, there may be some items that are inappropraite for a particular control room. Instrumentation and Control Engineers and Operations Specialists should recommend survey changes to the Data Collection Manager (Section 2.1). In turn, the Data Collection Manager should review, discuss and, where appropriate, implement these changes.

In some cases, the Data Collection Manager may be required to develop specific survey items (Figure 2-3) from the guidelines (Volume II).

2.5.3 Development of Checklists

Checklists are probably the most widely used tool for human engineering evaluation. When properly designed and systematically and thoroughly applied throughout the control room, checklists will enable the evaluator to pinpoint specific operator-control room interfaces that do not agree with the human engineering guidelines (Volume II). In turn, these discrepancies become candidates for backfits.

2.5.3.1 Objectives — The results of this task will be several checklists which, when applied collectively, thoroughly compare the control room to the guidelines in Volume II.

2.5.3.2 Methods — The checklist samples given in Appendix V will often serve "as is" for control room evaluations. However, to identify any inappropriate items, Instrumentation and Control Engineers and Operations Specialists should review all checklist items with respect to control room design and operator procedures. Figure 2-4 illustrates how to develop a checklist item from a guideline.

Some characteristics of a control panel component need be examined for only one component and then the results can be assumed for all components of the same type. For instance: handle dimensions, size of legend pushbuttons, size of lettering on switch position labels. For these parameters, one measurement on a typical component will suffice for the entire control room. Other measurements, such as the push force on a "Pull-to-Defeat" J-handle switch, may require several measurements of components to determine both the means and variance of the force across switches. Finally, many checklist items must be applied to every component of the type indicated. For instance, the distance between controls and related displays may change remarkably from control to control.

FIGURE 2-3 DEVELOPMENT OF SURVEY QUESTIONS FROM GUIDELINES

GUIDELINE

A. TITLE: CODING—WARNING, CAUTION ANNUNCIATORS

B. GUIDELINES: Objectives—Coding techniques shall be used to facilitate:

1. Discrimination between individual displays.
2. Identification of functionally related displays.
3. Indication of relationship between displays.
4. Identification of critical information within a display.

Techniques—Displays shall be coded by color, size, location, shape, flash rate, alphanumerics, brightness, motion, or inclination, as applicable.

1. Only one kind of information should be coded by one method. Compound coding for only one kind of information usually is less satisfactory than single coding if the single code used is the best available.
2. If two or more kinds of information are to be coded, the same number of coding methods should be used; do not use one coding method to code two or more kinds of information.

POTENTIAL SURVEY QUESTIONS

Are annunciators prioritized in some way? If yes, please describe.

Are annunciators grouped, say by system? If yes, please show arrangement.

Are annunciators above the system they monitor?

FIGURE 2-4 DEVELOPMENT OF CHECKLIST ITEMS FROM GUIDELINES

GUIDELINE

A. TITLE: TOGGLE SWITCHES AND PREVENTION OF INADVERTENT ACTIVATION—

B. GUIDELINES: When it is critical to prevent inadvertent activation of a toggle switch, a guard should be provided. This guard may be a lift-to-unlock mechanism, a safety cover or any equivalent method. If a lift-to-unlock mechanism is used, resistance should not exceed 48 oz. If a cover guard is used, its location should not interfere with the activation of the guarded control or any adjacent controls.

C. HUMAN ERROR: Inadvertent activation of a critical control, inability to activate a control within a given time limit.

D. DOCUMENTATION: 1472B (1974); 1472C (1980); Woodson (1964)

E. TYPICAL BACKFIT: Installing an appropriate guard, replacing a guard with appropriate guard.

POTENTIAL CHECKLIST ITEMS

TOGGLE SWITCHES

Evaluation Guideline	Check
1. Are critical toggle switches provided with guards to prevent accidental activation? 2. Does the guard interfere with the activation of the guarded control or any adjacent controls?	

It is suggested that the basic arrangement of checklist items in Appendix V be maintained even if the contents are changed somewhat. This will minimize the time and effort required to complete the checklists.

2.5.4 Preparation of Procedures for Walk-Throughs

Surveys and checklists treat the engineering aspects of the control room. The operational aspects are examined through walk-throughs of emergency, abnormal and operating procedures using normal complements of trained and licensed operators. Operational features that can induce error include:

- The time between reading a meter and taking an appropriate action
- The number of personnel reading and sequencing actions
- The nature and structure of verbal (and nonverbal) communications between operators
- The sequence of operations with respect to panel arrangement.

The purpose of conducting videotaped procedures walk-throughs is threefold. One objective is to validate the completeness of task analyses of operating procedures. Another is to gain data on the use of particular control/display components during normal and emergency operations. The frequency and criticality of use will influence and validate the importance of human engineering discrepancies identified through the application of surveys, checklists and operator interviews. The third objective is to identify/tape procedural and operational factors which may lead to human error.

2.5.4.1 Objective — The purpose of this task is to select procedures, to develop casualty scenarios for emergency procedures to be used in walk-throughs, and to select operators for walk-throughs.

2.5.4.2 Method — Procedures selected for walk-throughs should include all emergency and abnormal procedures which require CR operator response as well as sample normal operation procedures. Normal operations sampled should include startup and shutdown procedures, specific systems operation procedures, and those operating procedures identified by operators (in the operator interview portion of this evaluation) as problematic.

Once procedures have been selected, scenarios should be developed for each procedure. For emergency procedures, scenarios should be developed where the operators' responses differ. For example: for a Loss of Coolant Accident procedure, scenarios should be developed which address actions taken during a small, slow leak; those taken during a large break; and, if the operator response differs, during a leak of intermediate size. For each set of automatic actions (for example, one set would be those automatic actions which occur any time a reactor trip occurs), at least one scenario should be developed which assumes that the automatic functions fail to actuate and the operator must take corrective manual action.

A team of operators must be selected to perform the walk-throughs. A full complement of operators should be chosen to represent normal staffing levels. This team should be composed of SRO and RO licensed personnel as would normally staff the CR, and should include experienced and knowledgeable operators.

2.5.5 Instrumentation Requirements

Human engineering evaluation of just about any complex system will involve some use of specialized instrumentation. Light levels, sound pressure levels, spot brightness, force and torque are frequently measured during an evaluation, since many human engineering guidelines are written with physical measurements as a basis.

2.5.5.1 Objective — The objective of this section is to provide the evaluation planner and conductor with guidance for selecting appropriate measuring instruments for the control room human engineering evaluation.

2.5.5.2 Method — Certain evaluation procedures require the physical measurement of a parameter. The control room evaluation planner should determine in advance what instruments are required and take steps to procure them. The following table (Table 2-1), in conjunction with the instrumentation paragraph of the specific procedures (Section 3.0), should be used to select the necessary instrumentation. The instrumentation should have been calibrated, if required, within the past year.

TABLE 2-1: INSTRUMENTATION FOR HFE EVALUATIONS

	Parameter to be Measured	Instrument Type	Range/Accuracy/ Characteristics
1.	Ambient Illumination	Photometer	1 to 300 ft. Candles
2.	Luminance Contrast	Spot Brightness Meter	1 to 300 ft. Lamberts; Focus Down to $1/2^{\circ}$
3.	Distance, Panel/ Room Dimensions	Tape Measure - Nonmetallic	Up to 20 feet
4.	Control Size, Separation	Ruler - Nonmetallic	Up to 5 inches
5.	Control Resistance (Force Required to Activate)	Spring Gauge (Push-Pull) Torque Gauge	Up to 5 lbs
6.	Control Displacement	Ruler - Nonmetallic Protractor	Up to 5 inches Up to 180°
7.	Sound/Noise Levels	Sound Level Meters	50 to 120 dB with Flat Response, A Weighting and C Weighting

2.5.6 Prepare and Develop Task Analyses

What specific information will the operator need and what control must be provided to maintain the systems and plant in balance? How much time do the systems allow the operator to collect information and make decisions? How many mental and physical tasks must be performed simultaneously?

These questions, and others, are answered through a process called "task analysis." While all of the evaluation's Data Collection Tasks should be performed by human engineering specialists, the task analyses must be performed by (or at least managed by) human engineers experienced in task analysis on complex systems.

2.5.6.1 Objective — The objective for developing task analyses of operator activities under emergency and normal operating conditions is to create a basis for the evaluation of panel and workspace layout. With a detailed analysis of all operator tasks and clearly defined performance requirements, design problems and potential human errors can be identified.

2.5.6.2 Method — Task analyses will be conducted on all emergency procedure operations and sample normal operations (hot startup, reduction in power, etc.). Control room operator functions will be listed in sufficient detail in a format like the sample form in Figure 2-5. Analyses will focus on the following characteristics:

a. Task — task designation

b. Activity — action(s) required by the operator to complete a task

c. Time — estimated or observed time required to complete each activity

d. Frequency (f) — frequency of each activity

e. Information — information required by the operator to complete an activity (i.e., signal to initiate activity, indication that activity is progressing as required, feedback that activity has been successfully completed)

f. Control — control capabilities required by the operator to complete the activity

g. Indication/Display — feedback of system response to operator actions

h. Concurrent/Shared tasks — tasks which must be performed simultaneously to the subject task or tasks requiring assistance from one or more other operators, including field operators

i. Potential errors — errors which may occur during the conduct of the activity (e.g., reading errors, control errors, sequence errors, etc.)

j. Error impact — affect of potential error on task or system performance.

Data required to complete task analyses will be collected using four complementary methods:

a. Review of emergency and normal operating procedures

b. Interviews with experienced control room operators

c. Review of videotaped walk-throughs of procedures

d. Where possible, observation of actual task performance.

An appropriate format should be selected which will insure complete and detailed data collection. The form provided in Appendix VI, or a similar form, is recommended. Experienced and knowledgeable operators should be selected and briefed on their role as

FIGURE 2-5 EXAMPLE OF CONTROL ROOM OPERATIONS TASK ANALYSIS

CRUNIT: Nuclear Plant - 1

ANALYSIS: J. Smith, R. Brown

PROCEDURE: Loss of Secondary Coolant, EP-4

TASK	ACTIVITY	EST. TIME (MIN)	I	INFORMATION/ COMMUNICATION REQUIREMENTS	CONTROL	INDICATION/ DISPLAY	CONCURRENT/ SHARED TASKS	POTENTIAL ERROR	ERROR IMPACT
Diagnose Condition	Recognize Symptoms	.5	I	Annunciators:					
				LO PRZR PRESS		PRZR PRESS	Task of diagnosis shared by ROs and SRO in CR	Incorrect diagnosis	Equipment damage
				LO PRZR LVL		PRZR LVL		Failure to take proper action	Loss of core integrity
				LO-LO REACTOR T-AVE		T-AVE			Inadvertent release of radioactivity
				HI CNTMT PRESS		CNTMT PRESS			
				HI CNTMT TEMP		CNTMT PRESS			
				HI CNTMT RECIRC SUMP LVL		STEAM FLOW			
				STEAM FLOW/FW FLOW MISMATCH		FW FLOW			
				LO STEAM LINE PRESS		STEAM LINE PRESS			
				LO SG WTR LVL		SG WTR LVL			
				HI STEAM FLOW		FW PUMP DISCHARGE PRESS			
				LO FW PUMP DISCHARGE PRESS					
Verify Reactor Trip	Check Reactor Trip indication, manually initiate if not activated	.5	I		Rod position control	Rod status indicators Rod bottom lights Reactor Trip annunciator		Failure to verify incomplete automatic action	Failure to shut-down system Loss of core integrity Inadvertent release of radioactivity

reviewers. Operators will be expected to verify the completeness of the data listed, supplying information regarding steps or information requirements not listed in the procedures. Operators will also provide information concerning potential human error and its affect on task or system performance. Potential error and its impact must be detailed for every operator action.

2.5.7 Photographic Support

2.5.7.1 Objective — The objective of compiling a photo log is twofold. First, it will provide the evaluation team with photographs for mockup construction and verification of control, display and panel configuration without physically returning to the control room. Second, it will provide a photograph for each Human Engineering Discrepancy Report. Photographs also offer a record of panel changes and corrective measures taken.

2.5.7.2 Instrumentation — The following camera equipment and supplies will be required for completion of the photo log:

- 35mm camera
- 50 to 55mm normal lens
- 24 to 28mm wide angle lens
- Tripods, one standard sized and one small (12" to 18" range)
- Tape measure
- One (1) inch stick on dots
- Film, Plus-X-ASA125-Black and White, and ASA400 Color Slide would be suitable.

2.5.7.3 Method — The control room photography should be performed in three phases. The first phase consists of general control room and generic problem photographs. The second phase consists of a detailed mosaic of the control room panels. The final phase consists of photographing an example of each Human Engineering Discrepancy Report. The photographer should shoot a test roll of each type of film to determine camera settings necessary to compensate for lighting peculiarities in the control room. The use of a flash is not recommended due to reflected glare. All items photographed should be shot in color and black and white except the mosaic. During the evaluation, every photograph and slide taken should have a designation to insure identification later. Each designation and subject matter should be logged into a master list of photographs. A method should be devised for storing, cataloguing and retrieving all negatives and photographs.

2.5.7.3.1 General Control Room and Generic Problems — Color slides should be taken in this phase which includes the following types of photographs:

- Control room panoramas
- Procedure and document storage facilities
- System and panel shots
- Items the operators report as problematic
- A sample of each type of contro' splay and label
- Any generic problems identifie.

The slides should be taken from as close as possible. Visual cues such as hands, rulers and coins should be included in the slides to supply a size reference. If any control and display relationships are identified as problems, operators should be used to illustrate these problems. Any alteration, addition, or retrofit change to the control room during the course of the evaluation should be photographed, documented, and stored.

Photographs should be made documenting variations existing between control room and simulator panels (assuming plant specific simulator) or between panels of similar but not identical units.

2.5.7.3.2 Mosaic — The mosaic (used to support checklisting and HED evaluation) should be shot with black and white film, a tripod and a normal lens. The camera, during photography, should be kept perpendicular to the panel surface. All panels and systems normally used by the operator should be photographed. A grid of easy on and off dots should be applied at predetermined coordinates on the panel surface numbered as reference points for each mosaic segment. These should be placed about every 20" vertically and 24" horizontally. Each of the mosaic segment rectangles should be photographed with the dots well in the viewfinder to provide overlap. Each photograph should be logged into the master file. It is very important that every label in a segment photograph be readable. Once developed, the negatives should be printed full frame on 8" x 10" paper.

2.5.7.3.3 Human Engineering Discrepancy Reports — Near the end of the data collection phase. a photograph of each Human Engineering Discrepancy Report should be taken. The photograph should provide enough detail to clearly read all labeling and easily identify the nature of the problem. Once again, each photograph, when taken, should be entered into the master log.

3.0 CONTROL ROOM EVALUATION

The following sections detail the data collection procedures necessary for the control room HFE evaluation. The order of data collection methodology should be as follows: review of generic problems, operator interviews, surveys, checklists, and procedure walk-throughs. By followng this order, the evaluator can progress from a general understanding of the control room to a detailed understanding of each system and component. Also, human engineering discrepancies will be identified throughout the data collection process, thus enabling orderly prioritization and backfit decisionmaking.

3.1 Review of CR Design Against Generic Problems

A number of human engineering design and procedural problems have been identified as common throughout the industry (Appendix II). Comparing the control room to these generic problems will enable the reviewer to determine quickly whether some important aspects of control room design and operations are in agreement with the human engineering guidelines.

3.1.1 Objective

The objective of this review is to determine if the control room manifests human engineering shortcomings characteristic of same-vintage nuclear power plants.

The objective in reviewing the issues listed as generic industry problems is to provide the reviewer with a point of reference; a broad, general review of the control room with emphasis on identifying major issues which are highly likely to occur based on reviews of same-vintage plants. Problems identified in the generic problem review should be given further scrutiny applying relevant surveys and checklists.

3.1.2 Method

Using the list of generic discrepancies in Appendix II, conduct a panel by panel and system by system review. Note by label or description, every control, display, equipment item or CR characteristic which violates human engineering practices listed in Appendix C. Complete a Human Engineering Discrepancy Report form for each and refer to appropriate guidelines for evaluative and backfit data.

3.2 Conduct Operator Interviews

The operator interview questionnaire is designed to solicit qualitative comments from control room operators. Those who operate the plant and interface with the control room on a day-to-day basis offer the best sources of identifying systems or components where human error does occur. Operators should provide information on design and operation problems in the CR as well as recommendations for improvement.

3.2.1 Objective

The objective of the operator interviews is to provide an opportunity for anonymous input regarding CR workspace and panel design. The questionnaires will document operator reports and the frequency with which a particular problem is reported.

3.2.2 Instruments

The Operator Human Engineering Questionnaire provided in Appendix III may be utilized as presented or revised (Section 2.5.1) to reflect specific concerns for the particular CR design.

3.2.3 Method

Every licensed operator employed by the plant should be interviewed individually concerning design and procedural problems impacting effective normal and safety plant operations.

Operators should be briefed before starting the questionnaires as to their content, purpose and use. More complete and objective responses will be received if participants are assured of anonymity.

Briefings should be conducted by personnel familiar with interview techniques and control room design. All comments should be recorded in writing, with the interviewer repeating the written comment for concurrence by the operator. The operator should be given as much time as needed to report each problem.

3.2.4 Data Reduction

Problems or potential for human error reported by operators should be listed by system, component, component type or environmental feature. A count should be made of the frequency with which each problem is reported and those reported by two or more operators should receive further review. Relevant checklists and surveys should be applied. The impact of human error, noted on a Human Engineering Discrepancy Report, should be recorded.

3.3 Control Room Survey Procedures

Control room surveys are performed for two purposes: to evaluate control room environmental features against human engineering guidelines; and to provide information required to complete the human engineering checklists (Appendix IV). Environmental surveys include Ambient Illumination and Noise. Design Convention and Emergency Garment Surveys provide baseline data to the checklists.

3.3.1 Noise Survey

3.3.1.1 Objective — The objective of this survey is to measure the ambient noise levels in the control room from various operator positions and to assess its impact on the operators' ability to verbally communicate and/or discriminate audible signals.

3.3.1.2 Instrumentation — The performance of this study requires the use of an appropriate sound level meter, selected to conform to the requirements established in Section 2.5.5.2.

3.3.1.3 Method — The performance of this evaluation requires the consideration of not just normal control room noise but any factors that can add to the overall noise level. Included in this are the occassional noises of very short duration that can cause high peak levels.

a. Noise Conditions — The noise survey should start with a basal noise level. This is the ambient noise without alarms, typers, or communications equipment contributing. Once this measurement has been taken, each potential noise source should be integrated into the ambient environment. The following are potential noise sources:

- Audible alarms
- Typers and printers
- Communications equipment (ringing telephones, P.A.s, radios)
- Emergency or atypical environmental control systems (air conditioning, exhaust fans)
- Loud conversation

- Adjacent control room alarms
- Open doors leading out of the control room.

b. Survey Conduct — Noise measurements should be taken at each operator position that requires verbal communication and/or auditory discrimination of a signal. This will include, at a minimum, the Reactor Operator's desk position, the Senior Reactor Operator's desk position, a point near the center of each panel/board, and any position at back panels requiring communication. Three measurements should be taken at each position, one with the microphone directed towards the major noise source, one with the microphone directed towards the panel surface and one with the microphone directed towards the furthest operator's position that would require communications. Measurements should be taken flat (dB), in A weighting (dB"A"), and in C weighting (dB"C"). Any instances of extreme peak values should be noted and the source located. The result for each position should be recorded on a form similar to Appendix IV-a. An example of a completed form is given in Table 3-1.

3.3.1.4 Data Reduction — The collected data should be compared to the appropriate guidelines contained in Volume II. Values that exceed the established limits should be noted and a Human Engineering Discrepancy Report should be completed.

3.3.2 Lighting Survey

3.3.2.1 Objectives — The objective of this evaluation is twofold. One is to measure the ambient illumination in the control room and to assess its impact on the operator's ability to read and interpret displays, controls, labeling, and printed matter such as drawings and procedures. The second is to measure the brightness of display and calculate the luminance contrast values to determine the adequacy of display lighting.

3.3.2.2 Instrumentation — The ambient illumination should be measured using an appropriate photometer. The display illumination measurements should be taken with an appropriate spot brightness meter. Both instruments should conform to the requirements established in Section 2.5.5.

3.3.2.3 Methods — The ambient lighting survey should be conducted under normal lighting and emergency lighting. The display illumination survey should be conducted under normal lighting. The analyst conducting the test should be aware that ambient

TABLE 3-1 NOISE SURVEY

NT: Nuclear Power — Unit 2	DATE: April 27, 1980	TIME: 3:30 p.m.
TEST CONDUCTED BY: B. Smith		
SOUND LEVEL METER MODEL: GenRad 1933 SERIAL NUMBER: 1546	MICROPHONE MODEL: GenRad 1865 SERIAL NUMBER: 1009	CALIBRATION DATE: Jan 2, 1980
OPERATOR POSITION: Vertical Board 3		

NOISE CONDITION/SOURCE/DIRECTION OF MEASUREMENT		dB	dB(A)	dB(C)	REMARKS
1. Basal Level	Towards Panel	65	60	62	
	Towards Benchboard	64	60	61	
2. Annunciator Alarm	Towards Annunciator Alarm	80	77	79	
	Towards Panel	76	72	74	
	Towards Benchboard	72	68	70	
3. Alarm Printers and Phones Ringing	Towards Printers	75	71	73	
	Towards Panel	74	68	69	
	Towards Benchboard	71	65	67	
4. Annunciators, CR2 Alarms, All Other Noise Sources	Towards Annunciators	83	80	78	
	Towards Panel	78	76	73	
	Towards Benchboard	76	73	70	

lighting, besides being too dim, can also be too bright. Dim light makes reading difficult. Lighting which is too bright can cause eye fatigue, reflected glare and poor display luminance contrast.

a. Test Conduct - Ambient Illumination — Measurement of ambient illumination should be taken at all operator positions. These positions should include, at a minimum, the following:

- Reactor Operator's work desk
- Senior Reactor Operator's work desk
- Each panel
- Each point where reading of printed material might be required
- Any area that is perceived as a potential problem.

These measurements should be taken for all positions selected under both lighting conditions. The light meter should be held about eye height and pointed first at the panel/desk and then a second reading should be taken with the meter pointed at the ceiling. If the position requires reading a specific type of printed material, this should be in place when the measurement is taken. The data should be recorded on a form similar to Appendix IV-b. A completed form is illustrated by Table 3-2.

3.3.2.4 Test Conduct - Display Illumination — The evaluator should assess which displays appear to be dim enough to warrant a measurement. The following are display types that may require measurement:

- Indicator and legend lights
- CRT (video) characters
- Projection display and light emitting diode (LED) characters
- Mimic lines that are illuminated.

The spot brightness meter should be placed so that the light source fills the required area (reticle) in the viewfinder. A reading should be taken, and then the reticle should be positioned on the surface adjacent to the display. Another reading should then be taken. Several readings should be taken over the surface of a CRT, projection and LED characters and mimic lines to verify uniformity of illumination. In addition to specific areas that appear dim, measurements should be taken from a wide selection of displays on the boards to provide an adequate sampling of the brightness of the control room displays. The measurements should be recorded on a form similar to Appendix IV-c. Table 3-3 provides a sample of a completed display illumination survey.

TABLE 3-2 AMBIENT LIGHTING SURVEY

PLANT: Nuclear Power — Unit 2	DATE: April 26, 1980		TIME: 11:00 a.m.
TEST CONDUCTED BY: M. Jones			
PHOTOMETER MODEL: Photo Research Serial Number: SERIAL NUMBER: FC-200	CALIBRATION DATE: July 9, 1980		

OPERATOR/MEASUREMENT POSITION	LIGHTING CONDITIONS		REMARKS
	NORMAL	EMERGENCY	
1. CC1 - Towards Board - Ceiling	65 FC 69 FC	8 FC 10 FC	
2. Back of CC2 - Towards Board - Ceiling	63 FC 69 FC	7 FC 10 FC	Drawing on Board
3. VB3 - Towards Board - Ceiling	67 FC 69 FC	6 FC 10 FC	Midpoint of Board
4. VB1 - Towards Board - Towards Ceiling	51 FC 67 FC	5 FC 7 FC	Shadowed Vertical Meters (Meter Names)
5. CC2 - Small Writing Surface - Panel - Ceiling	 58 FC 62 FC	 11 FC 15 FC	

3.3.2.5 Data Reduction — The data from Section 3.3.2.3 should be compared to the appropriate guidelines from Volume II. The data from Section (b) of 3.3.2.4 should be substituted in the following formula to calculate luminance contrast:

$$LC = \frac{L_1 - L_2}{L_1} \quad \text{where } L_1 = \text{Bright area and } L_2 = \text{Dark area}$$

The values should be compared to the appropriate guidelines in Volume II. If there are any deviations from the guidelines, a Human Engineering Discrepancy Report should be completed.

3.3.3 Design Conventions

Design conventions are rules used to standardize the operation of functionally identical interface between the operator and the control panels. For instance:

- Valve open = red; valve closed = green
- To close valve turn counter clockwise; to open valve turn clockwise
- "PRZR" always means "Pressurizer."
- Panel background color pink is used for reactor control
- Star handle rotaries are used for steam generator controls
- Vertical Displays = "level" indication.

The advantage of a design convention, of course, is that the operator can learn a fairly simple rule rather than memorize all of the operation of each interface covered by the rule. Thus, design conventions reduce the operator memory load substantially.

3.3.3.1 Objective — This survey will yield a listing of design conventions used in the control room. This listing will be used later in checklists to identify any interfaces that violate these rules.

3.3.3.2 Instrumentation — None.

3.3.3.3 Method — Using the survey form in Appendix IV-d, locate examples of controls, displays, labels, etc., and record their designs. Where design conventions appear to be used (most or all interfaces surveyed follow the same operational rules) the convention should be noted for use with checklists.

For a particular interface design rule to qualify as a convention, it is not necessary for the rule to be applicable throughout the control room. Some rules may apply only to

TABLE 3-3 DISPLAY LIGHTING SURVEY

PLANT: Nuclear Power — Unit 2	DATE: April 11, 1980		TIME: 7:30 a.m.	
TEST CONDUCTED BY: P. Turner				
SPOT BRIGHTNESS METER MODEL: SPECTRA UB-1 SERIAL NUMBER: 2631			CALIBRATION DATE: Jan 5, 1980	
DISPLAY TYPES	LOCATION	BRIGHT AREA (L.) (FT. LAMBERTS)	DARK AREA (L.) (FT. LAMBERTS)	LUMINANCE CONTRAST
1. Simple Indicator (name of indicator)	SAF	8	3	0.63
2. Valve protection display	Computer Console			
- Top of Character (7)		7	5	0.29
- Midpoint		8	4	0.50
- Bottom		7	4	0.43
3. CRT Screen	Computer Console			
- Top Left		9	2	0.78
- Middle		8	2	0.75
- Bottom Right		9	3	0.67
4. Legend Light	SB-1			
- Bright is Right				
- Dim Phase		5	3	0.40
- Bright Phase		8	3	0.63
5. Annunciator Window	Above SB-2	11	5	0.55

one major panel (e.g., switch positions on radiation monitoring equipment), some to one or more systems (e.g., valve operations on NSSS) and others to a particular type of display (e.g., color coding of annunciators). While the universal convention is quite a powerful aid to the operator, the local convention is useful (to the extent that it embraces several interfaces, i.e., controls, displays, labels, etc.) even though the operator will be using different local rules when addressing other interfaces. Therefore, the panels, systems, etc., using a particular convention should be identified and noted.

3.3.3.4 Data Analysis — A matrix of design conventions x control panels should be prepared, and the conventions applicable to each panel (or subpanel, if necessary) checked off (Table 3-4).

TABLE 3-4

Design Convention Array

Convention	Panel 1	2	3	4	5	....	N
Vlv Open = Red	X	X		X			
Vlv Open CW	X	X		X			
Auto = White		X	X		X		

3.3.4 Emergency Garments

Most nuclear power plants provide some type of emergency garments for operator use, including perhaps protective clothing and breathing apparatus. Since operators must be able to don and use these garments during emergencies, it is necessary to review the time needed to don and any operational restrictions or problems associated with their use.

3.3.4.1 Objective — This task will yield information needed to complete the human engineering checklists. In general the results will indicate any problems in performing control room operations while using the protective clothing and/or breathing apparatus.

3.3.4.2 Instrumentation — Video tape recorder and camera to record garment donning and operation sequences.

3.3.4.3 Method — The detail survey procedures and data recording forms are given in Appendix IV-e. It would be best if this survey could be conducted in a simulator where the suited operators could perform selected procedures. If no simulator is available, standard measurements described in Appendix IV-e should be taken.

3.3.4.4 Data Analysis

a. Impact on Staffing — Based on Technical Specifications requirements, estimate the total number of man-minutes that will be dedicated to donning protective equipment before all operators are fully equipped. Subtract this number from the total number of man-minutes available during this period to arrive at the man-minutes dedicated to plant operations.

b. Speed of Operations — Based on simulations, estimate the percentage difference in time to complete operations with and without protective garments.

c. Human Error Factors — List and describe factors that might reduce operator reliability, for instance:

- Visibility of breathing apparatus face mask
- Tactile discrimination through gloves
- Speech impairment through face plate
- Hearing impairment (noise of breathing apparatus)
- Size of gloved hand (inadvertent actuation).

3.4 Checklist Procedures

The checklists described in Section 2.5.3 are the primary means for comparing panel design to established human engineering practices. The checklists contained in Appendix V incorporate the guidelines in Volume II appropriate to the subject (e.g., annunciators, rotary switches, process controllers, etc.).

3.4.1 Objective

The objective of completing the checklist is to compare the details of the control room design to the Human Factors Guidelines in Volume II. The detailed items contained in the checklists allow for a comprehensive evaluation from the system, panel and generic component level.

3.4.2 Instrumentation

Certain checklist items require that physical measurements be performed. Appropriate instrumentation should be selected from Table 2-1.

3.4.3 Methods

The completion of the checklists requires access to the control room, a basic familiarity with the control room and the systems being evaluated, and the assistance of a qualified operator. Certain checklists are more appropriate for the control room as a whole, others more appropriate on a panel or system level. The sample checklists from Appendix B that lend themselves to general control room evaluation are 1 through 6. Checklist 12 can be appropriate for both the general control room and specific panels or systems. The remainder of the checklist samples are appropriate for a panel system or component level evaluation.

Once the appropriate checklists have been selected, a packet of checklists should be made up for each panel or system to be evaluated. The checklists should then be completed in the following manner. The panel or system name, if appropriate, should be placed on each checklist. Then each checklist item should be considered. If the item does not apply, an "N/A" should be placed in the check column. If the item is complied with, a "yes" should be placed in the check column. If the item is not complied with, a "no" should be placed in the check column and the discrepancy should be described in detail in the notes column. The notes column should be used for any and all comments felt necessary or appropriate. Table 3-5 illustrates a completed checklist.

TABLE 3-5
SAMPLE CHECKLIST

HUMAN ENGINEERING CHECKLIST
— TYPICAL COMPONENT —

Vertical Indicators

Panel ____________________ Date ____________________

System ____________________ Reviewer ____________________

EVALUATION GUIDELINE	CHECK	REF.*	NOTES
1. Pointer extends to, but does not obscure, index marks			
2. Pointer mounted close to display surface			
3. Display readable without stooping, stretching			
4. Parallax avoided			
5. When off, pointer is off scale (not at zero)			
6. Displays labeled			
7. Displays readable from normal operating position			
8. Display covers do not produce excessive glare			
9. Scales indexed consistent with system requirements			
10. Are used to indicate levels			

* Guideline (Volume II) Page Number

The operator should be queried to elicit full information on the checklist items to determine whether there is compliance. For example, on item 9 above:

Human Factors Engineer: "Does the index on this scale provide you with information that is as accurate as you need?"

Operator: "Well, yes and no."

Human Factors Engineer: "What do you mean?"

Operator: "The nominal position for the pointer on this scale is 120 volts. This position actually means that the system is operating at 480 volts."

Human Factors Engineer: "This means that you must interpret the index?"

Operator: "That is correct."

If a checklist item is found to be inappropriate, this should be noted on the checklist and the checklist should be included in the completed data package. This will preclude later confusion. Every component, system, panel and operational grouping of components in the control room should be examined and compared to all relevant checklist items. This is an arduous process but it assures that most potential human factors engineering problems will be revealed.

3.4.4 Data Reduction

The checklists should be reviewed for discrepancies (items marked "no") and each of these should be compared to the relevant guidelines in Volume II. A Human Engineering Discrepancy Report should be completed for each item that does not comply with the guidelines.

3.5 Conduct Procedures Walk-Throughs

While all controls and displays in the control room are sufficiently important to be on the panels, some gain extra importance since they are used, perhaps frequently, in emergency operations. Operators are trained to know all of the displays and controls involved in performing procedures, but rarely do the written procedures contain a complete complement of all equipment used.

3.5.1 Objectives

Videotaped walk-throughs are to be conducted in order to document operator actions as they interface with the control room panel and layout during normal and emergency operations. The videotape will be used to identify and validate human engineering discrepancies in workspace and procedure design.

3.5.2 Instrumentation

For an authentic simulation of procedures, a plant-specific simulator presents the ideal situation. If a plant-specific simulator is not available, the walk-throughs should be performed in the control room.

As the walk-throughs are being performed they should be filmed or videotaped utilizing equipment which allows voice recording in sync with action. The camera used should be capable of close-up shots, enabling identification of specific controls and displays, and should be mobile enough to follow the operators' actions throughout the CR.

3.5.3 Method

The walk-throughs/simulation will be accomplished in three phases.

1. Prior to taping, have the control room operator describe the event to be simulated, indicating which systems will be involved and generally where action will take place on the panel. This will allow the camera operator and analysts to anticipate operator actions during the walk-throughs.

2. For the first taped walk-through, allow a full complement of operators to perform the procedural actions in as close to a real-time mode as possible. Be sure that one operator narrates the action, describing all controls/displays involved. Each control or display should be pointed out.

3. The second taped walk-through should be performed by one operator, step-by-step, describing all actions performed as part of the procedure. Each control or display should be pointed out, identified by label name and its use described (i.e., switch to the off position to the left; a rise in level indicated by an increase on the meter; valve closed, green indicator light on). Camera operator should interrupt to clarify which control/display is involved. Analysts should interrupt with questions on procedural actions, controls/displays, system response, etc.

To facilitate recordkeeping, on the outside of each tape, affix labels with identifying information (plant unit number, date of taping and sequential tape number). A form, such as the Procedures Walk-Through Log form in Appendix VII, may be used to log in procedure name and number, first or second taped walk-through, tape number and footage.

In taping, be sure to have the control room operator announce on tape which procedure is being performed prior to taping. Allow several feet of leader tape between walk-throughs.

3.5.4 Data Reduction

Videotapes will be reviewed against the results of the task analyses and any operator actions not identified in a procedures task analysis should be recorded, insuring completeness of the task analysis.

Human engineering discrepancies should be validated against the walk-throughs. For any component identified as discrepant, a count should be made for the number of times it is used in emergency operations, during immediate actions, supplementary actions and during normal operations procedures. Those used frequently and during immediate actions under emergency conditions will be more critical in evaluating human reliability.

A third review of procedures walk-through videotapes will yield identification of procedural and operational factors which may lead to human error. The following lists such factors:

- Vital communications — sent or received
- Accessibility of controls/displays
- Traffic pattern/panel operability
- Fidelity of procedure to CRO actions
- Steps performed at high speed
- Steps performed with timing requirements
- Comparison of two or more displays in rapid fashion
- Decisions based on multiple source inputs
- Displays monitored over prolonged periods
- Controls/displays being discriminated from among similar components
- Displays to be discriminated which change rapidly
- Actions taken with inadequate visual or verbal feedback specified
- Actions where error-resolution interrupts task performance.

Where such factors occur in the procedures, the controls/displays, and other equipment or components being operated are more likely to be involved in human error in operation. They should therefore receive further scrutiny via applicable surveys and checklists.

3.6 Conduct Task Analyses

The tasks that the Operators are required to perform when compared to their physical and cognitive capabilities, will define the displays and controls needed to maintain the plant in balance and to respond to emergency conditions. "Task analysts" can yield baseline requirements on:

- Staffing (number, type, team structure)
- Information display (type, rates)
- Control
- Task timing
- Training
- Procedures.

3.6.1 Objective

The purpose of developing a detailed task analysis for each emergency procedure and sample normal operations is to provide detailed documentation of all operator actions, information requirements, controls and displays used under these conditions. Through the task analysis, critical controls and displays, those used during emergency operations will be identified along with their sequence of operation and impact of potential operational error.

3.6.2 Instrumentation

The sample form illustrated in Section 2.5.6.2 and included in Appendix VI may be used to collect task analysis data. An alternative format may be used as long as it provides space for recording all the pertinent data.

3.6.3 Method

Data for the task analyses will be collected and recorded in the appropriate row or column.

a. Procedure — Procedure name and referencing/identifying number should be filled in completely.

b. CR and Unit — List plant name and unit number for complete recordkeeping.

c. Analyst — Analyst's name(s) should be noted.

d. Task — This column is used to identify the specific task to be accomplished. Entries in this column are to be ordered sequentially to enable the analyst to identify operational sequence.

e. Activity — Actual behavior/action performed by the operator is listed in this column. The analyst here describes what the operator must do to complete the task. The description should contain an action verb which adequately describes the operator's response (examples: monitors; actuates; verifies).

f. Est. Time (Min.) — Under this heading, the analyst records the estimated amount of time required for the operator to complete each activity. These data are useful in evaluating the ability of the system to operate within established time constraints.

g. f (Frequency) — In this column, the analyst records the number of times an activity is performed for each specific task.

h. Information/Communication Requirements — Under this heading, the analyst describes the information or communications needed to perform the task cueing the operator to take action. The stimulus may be annunciator alarms or other out-of-tolerance display indications, a signal from another operator, or any input indicating a need for control room operator response.

i. Control — In this column, the analyst enters the name or description of the control used for the activity. Precise labeling text should be used for clarity.

j. Indication/Display — Under this heading, the analyst describes the source of feedback available to the operator which indicates that the necessary system response has occurred. Again, precise labeling text should be used in listing displays.

k. Concurrent/Shared Tasks — Tasks that require more than one operator or are initiated by the control room operator but performed by field operators are described under this heading.

l. Potential Error — In this column, the analyst lists probable sources of error based on the type of response required of the operator and characteristics of the equipment used. Probable sources of error are referenced in the guidelines for each equipment type.

m. Error Impact — Under this heading, the analyst describes the effect of possible errors on the system or task performance.

Task analysis data collection will be conducted and validated in four phases, entering information on the form as described above.

1. For each emergency and sample normal operations procedure, record information in the appropriate column on the data form. From the procedures, list tasks and operator actions. As they are provided by procedures, list also controls, displays and other information requirements for each task.

2. Experienced control room operators, as systems and subject experts, will be needed to fill in much of the remaining data, such as estimated time to perform a task; frequency of each activity; tasks performed concurrently or shared; potential errors; and error impact. Potential errors, as suggested by operators, should be checked against those listed in the guidelines for each component type involved. Operators will also provide information concerning tasks not included in procedures documents but performed by operators in the execution of the procedures.

3. A review of the videotaped walk-throughs should be used to validate steps listed as well as controls, displays and information requirement involved. The real-time simulation should substantiate estimated time requirements; if not, further evaluation is required.

4. Where possible, observation of actual task performance is useful in validating information listed on the forms. This should be easily accomplished with normal operations such as startup or power reduction, but unlikely with operations generally contained in emergency procedures.

3.6.4 Data Reduction

Data generated by the task analysis will identify critical information and communication links (source and content) required by the operator. Control and display data will aid in the determination of the sufficiency of equipment provided the operator. The sequential ordering of the tasks and frequency of each activity will aid in determining the efficiency of workstation design and panel configuration. Those components utilized sequentially or simultaneously, frequently, or within constrained time periods, will be identified in the task analyses. If such components are not functionally grouped, the impact of potential error should be evaluated. If such error is likely and impact affects safety, a backfit to enhance human reliability is required. A Human Engineering Discrepancy Report should be completed for problematic control/display arrangements identified.

4.0 EVALUATION OF HUMAN ENGINEERING DISCREPANCIES

As each of the several human engineering reviews progresses, some of the operator-control room interfaces reviewed will not meet the guidelines quoted in Volume II. Each of these discrepancies should be documented and reviewed with respect to its importance in plant safety (and, perhaps, reliability), and then, if of sufficient importance, backfit alternatives should be investigated.

4.1 Prepare Human Engineering Discrepancy Reports

Personnel involved in the Data Collection task (3.0) should be instructed to complete a Human Engineering Discrepancy (HED) form for each and every incidence where the control room design does not comply with human engineering guidelines. No attempt should be made during actual data collection to determine whether or not a particular discrepancy is sufficiently important to report.

HEDs should be completed for all discrepancies including environmental, layout, instrumentation, job design, procedures, etc.

4.1.1 Objective

The objective of this task is to provide complete and accurate documentation of all human engineering discrepancies in the control room; to anticipate the specific human errors that might result from the discrepancy; and to record the likely response of the plant systems to this error.

4.1.2 Method

As the control room is reviewed, data collection personnel will uncover a number of operator-control room interfaces that do not meet the human engineering guidelines. These discrepancies should be recorded on a form similar to Appendix VIII, Human Engineering Discrepancy Report form, and should include:

a. A short title for the discrepancy

b. Hardware or procedures items, nomenclature (label) and panel locations

c. Human engineering guidelines which were violated

d. Operator error(s) that might result from the discrepancy

e. Procedures or operations that use the items listed in b.

f. Plant and system level consequences of these errors.

An HED report should be prepared for each and every discrepancy and a photograph or photocopy of the equipment or procedure, respectively, should be kept (where appropriate) to document specific discrepancies.

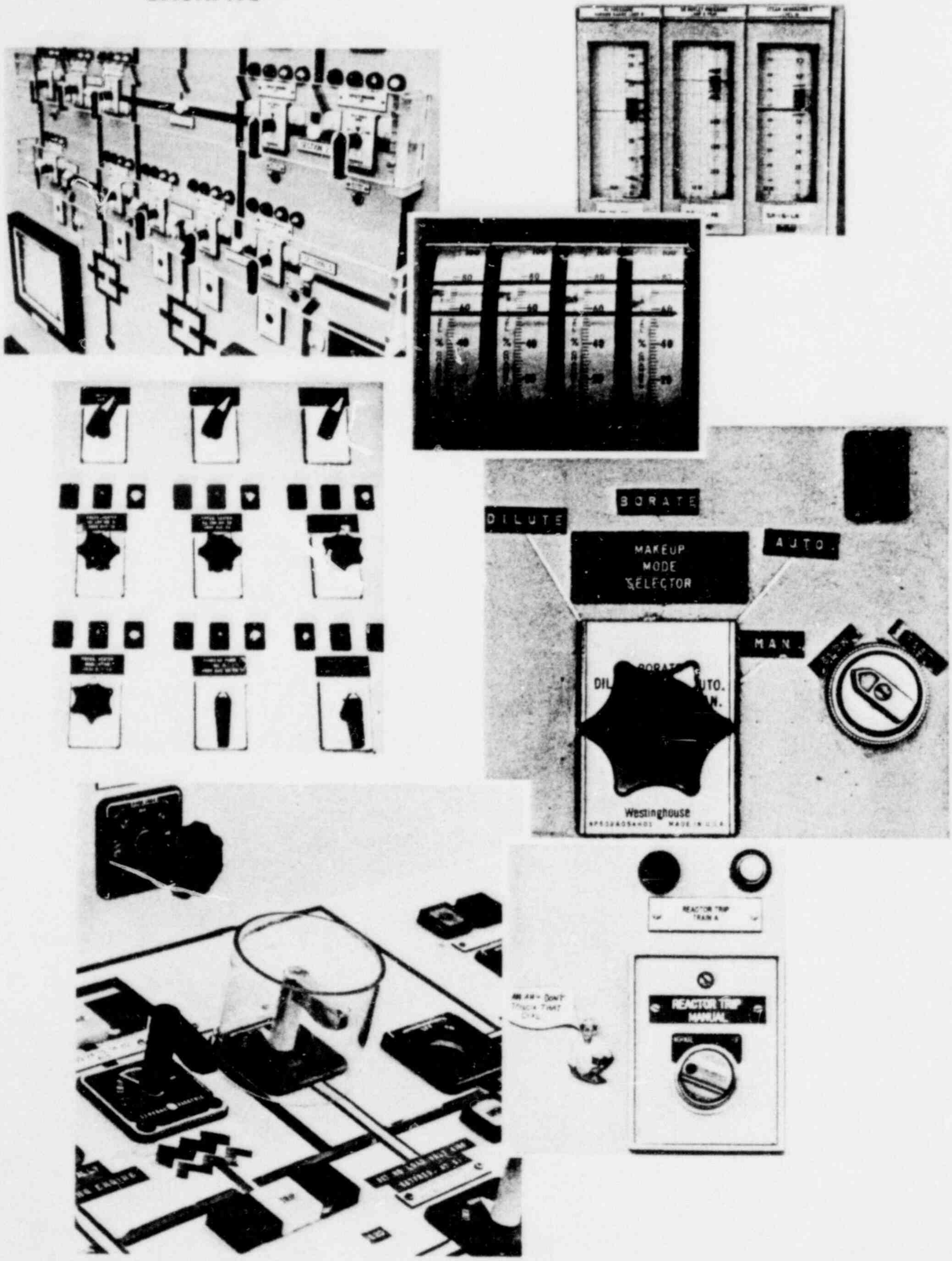
Where there are a number of interfaces with the same discrepancy, the same procedures involved, and the same cons ences of operator error, one "generic" HED might suffice. More likely there will be discrepancies where some of the information is identical from HED to HED. In this case photocopies can be used to reduce the paperwork.

The final step in HED preparation is the identification of suitable backfits (Part (g) of Appendix VIII). Most discrepancies can be corrected by any of several backfits with different potentials for reducing operator error likelihood and different costs. For instance:

- Change of instrumentation type or location
- Addition of repeating displays to improve control/display relationship
- Demarcation lines to improve operator localization of controls and/or displays
- Use of switch guards to reduce the likelihood of inadvertent or accidental operation
- Use of alarms or warnings to advise of a potential error
- Use of switch or display color coding to improve operator localization
- Use of display range markings (e.g., normal, emergency) to improve display discriminability at a distance
- Use of mimic lines to improve sequential control/display operations
- Use of warning labels to caution against specific actions
- Use of procedural cautions requesting a double-check of a difficult setting
- Use of shape coding on switch handles to tactually "separate" switches that are frequently interchanged in operation
- Attention given during training to difficult or error-prone control/display operations
- Use of indications with set points and out-of-tolerance alarm lights to improve discriminability at a distance.

Of course there are a number of backfits which might be possible with the addition of a graphic display; however, these backfits will not be considered here.

BACKFITS


DILUTE
BORATE
AUTO.
MAKEUP
MODE
SELECTOR
MAN.
Westinghouse
MADE IN U.S.A.
REACTOR TRIP
TRAIN A
REACTOR TRIP
MANUAL

As HEDs are completed they should be prioritized, reviewed and logged into the appropriate Human Engineering Evaluation Report (Appendix I-b).

4.2 Prioritize Human Engineering Discrepancies

The method for prioritizing HEDs presented below is intended to capture all HEDs that impact plant safety. Since estimates of operator reliability and frequency-of-occurrence of tasks are sometimes undependable, these two factors are secondary to the safety impact if the operator commits the error(s) resulting from the discrepancy.

Errors that would significantly reduce plant reliability might be important to the utility; therefore, these errors are identified but assigned a lower priority than errors impacting safety.

4.2.1 Objective

Determine the priority for backfit of each and every Human Engineering Discrepancy. To the extent that dependable information is present, determine the priority and, perhaps, the likelihood that the discrepancy-induced error will occur.

4.2.2 Method

The procedure for assigning backfit priorities to HED is described in detail in Appendix IX. This procedure is based on four fundamental determinations made initially by the Data Collection Specialists during control room review (see Figure 2-1).

1. Does the discrepancy-induced operator error degrade or jeopardize plant safety?
2. Does the operator error degrade or jeopardize plant reliability?
3. What features of the task or equipment would increase or reduce the chance of operator error?
4. How often does the operator/system interface occur in procedures?

These four basic questions are used to divide HEDs into five major categories.

- Category 1 — Safety Related, Minimum Opportunity to Correct Error
- Category 2 — Safety Related, Some Opportunity to Correct Error
- Category 3 — Reliability Related, Minimum Opportunity to Correct Error

- Category 4 — Reliability Related, Some Opportunity to Correct Error
- Category 5 — No Impact on Safety or Reliability

Each category *may* be subdivided into six steps according to the features of the task that could reduce operator reliability (e.g., performing two tasks simultaneously). While these steps could be applied to all five categories, use with categories 1 and, perhaps, 2 might be unnecessary since prudence would suggest a backfit for every HED in these categories.

Within categories 3, 4 and 5, prioritizing of HEDs beyond the six steps can be obtained by determining the frequency of the operator-control room interface producing the error.

In terms of backfit:

Category 1 — To enhance safe operation, the control room interfaces should be backfitted to:

- Remove or mitigate discrepancy
- Provide error feedback to the operator
- Increase time to respond to error.

Category 2 — To enhance safe operation, the control room interface should be backfitted to remove or mitigate discrepancy.

Category 3 — To enhance reliable operation, the control room interface might be backfitted to:

- Remove or mitigate discrepancy
- Provide error feedback to the operator
- Increase time to respond to error.

Category 4 — To enhance reliable operation, the control room interface might be backfitted to remove or mitigate discrepancy.

Category 5 — Backfits may improve operations.

As a second phase of prioritizing, an independent panel of plant experts should examine the data used to assign priorities to HEDs to assure that all relevant facts have been considered. In Figure 2-1 the panel would be chaired by the HED Processing Manager.

4.3 Identification of Potential Backfits

As part of HED preparation, the reviewer and the Data Collection Manager suggest backfits that would reduce the likelihood of the discrepancy-induced operator error. For most HEDs there will be several potential backfits of varying degrees of effectiveness and cost (see Section 4.1.2). In this task the HED Review Committee selects, for each high-priority HED, the most cost-effective backfit for presentation to the Evaluation Director who, in turn, recommends its implementation or its further study.

4.3.1 Objective

To select a backfit for each high-priority HED that will reduce to an acceptable level the likelihood of the discrepancy-induced error.

4.3.2 Method

In most cases a simple cost-effectiveness matrix will be sufficient for selecting among backfit alternatives. This matrix should contain data on:

- Description of Backfit
- General Advantages (e.g., operator acceptance, no changes in procedures, etc.)
- General Disadvantages (e.g., retraining, requires outage to implement, etc.)
- Estimated Performance after backfit (a rank order across potential backfits would suffice)
- Estimated cost to implement.

At this point most of the less effective and more expensive alternatives will be apparent, leaving only a few from which to choose. If a more sophisticated trade-off is desired and warranted, the "Estimated Performance After Backfit" could be a quantitative estimate of error probability after backfit, which would be plotted against cost. The point of inflection gives the mini-min solution (Figure 4-1).

COST-EFFECTIVENESS
Example of Backfit Tradeoff

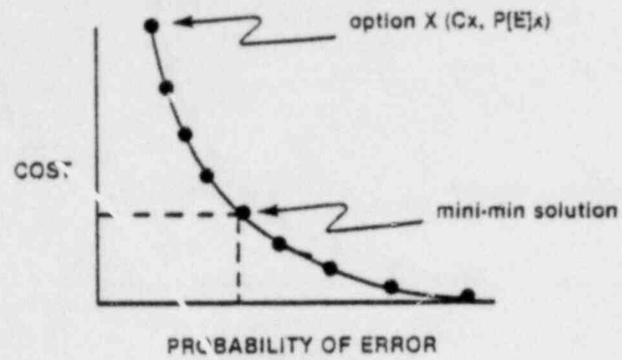


FIGURE 4-1

Of course it is unlikely that monotonic curves will be found, but the mini-min solution is usually apparent.

5.0 REPORTING

As noted in paragraph 2.4, the basic reporting requirements should be established in the Planning Phase to assure that Data Collection and HED Processing activities produce all of the information needed to prepare comprehensive evaluation reports.

5.1 Summary Report

An overview of all evaluation bases, activities, results, and findings should be prepared for NRC review.

5.1.1 Objective

The objective of this task is to prepare a report summarizing the control room evaluation in enough detail to demonstrate the thoroughness of the review, the validity of the evaluation and prioritization bases, and the action to be taken to correct significant deficiencies.

5.1.2 Method

A sample outline for a Control Room Evaluation Summary Report is shown in Figure 5-1 below.

FIGURE 5-1

AN OUTLINE FOR A "CONTROL ROOM EVALUATION SUMMARY"

1.0 INTRODUCTION

- 1.1 Evaluation Objectives
- 1.2 Evaluation Bases & Guidelines
- 1.3 Evaluation Activities
- 1.4 Management

2.0 APPROACH

- 2.1 Identification of Discrepancies
- 2.2 Prioritization of Discrepancies
- 2.3 Selection of Discrepancies for Backfit

3.0 RESULTS

- 3.1 High Priority Discrepancies and Backfits
- 3.2 Documentation Available for Review

4.0 REMEDIAL ACTIONS

- 4.1 Specifications for Changes
- 4.2 Schedule for Implementation

5.2 Summary of Discrepancies

The primary objective of this evaluation is to identify and remove the causes for operator error in nuclear power plant control room design and operations. A comprehensive list of discrepancies, priorities, and remedial actions documents that this objective will be met.

5.2.1 Objective

To prepare a listing and description of all Human Engineering Discrepancies found during the control room evaluation.

5.2.2 Method

An overall outline for the "Summary of Discrepancies" is suggested in Figure 5-2.

FIGURE 5-2

AN OUTLINE FOR THE "SUMMARY OF DISCREPANCIES"

1.0 INTRODUCTION

- 1.1 Evaluation Objectives
- 1.2 Evaluation Bases (Summary)
- 1.3 Evaluation Approach (Summary)

2.0 HUMAN ENGINEERING DISCREPANCIES

- 2.1 HED Descriptions
- 2.2 HED Priority by System
  (Sort HED numbers by priority and, within priority, by system)

The information to be presented in Section 2.1 (of Figure 5-2) on each discrepancy includes:

1. Human Engineering Discrepancy Number
2. Label (as it reads on panel) or procedure title/sector/paragraph
3. Components (or procedure steps) involved
4. Discrepancies found in components or procedures
5. Priority for backfit
6. Resolution of discrepancy
7. Estimated backfit completion date.

5.3 Supporting Information

During in-house and NRC reviews of the evaluation, it is likely that questions will arise that require details beyond the two summary reports. For instance, what specific guidelines were used to evaluate a given display? Or, perhaps, was control "X" examined?

Supporting information of this type was prepared as part of several planning and data collection activities; therefore, no new data need be collected unless the review described below locates oversights in the data set.

5.3.1 Objective

Review the component/group/system level data sheets (Appendix I-b), and identify and correct any oversights in data set.

5.3.2 Method

Each data sheet should be examined to assure that prescribed checklists, surveys, etc., have been performed; that all discrepancies have been prioritized; and that where, necessary, backfits have been developed. Also, at this point, it is prudent to review the data sheets against component titles to assure that all operator-control room interfaces have been examined.

6.0 IMPLEMENTATION

One of the most unfortunate misconceptions of human engineering evaluation is that there exists some relatively small number of backfits which, if implemented, will "cure" the human error problem. This view is patently incorrect. To substantially reduce the likelihood of human error jeopardizing safety, hundreds (rather than tens) of backfits may be implemented. This is caused by several facts:

a. Human reliability on current interfaces, while subject to improvement, is relatively high. Therefore it is unlikely that a few very poorly designed interfaces will be identified and backfitted with a resulting large improvement in system reliability.

b. There are a large number of operator-control room interfaces where operator performance would or could jeopardize safety. Therefore the opportunity for a safety-related human error is spread among large numbers of interfaces. In thinking of the number of interfaces, consider controls, displays, control-display functional groups, annunciators, and procedural steps, notes, cautions, addresses, etc. that the operator must use. Each is a potential source for error.

c. "Safety related interfaces" does not mean only interfaces in safety systems. For instance, some non-safety related actions may cause plant conditions which challenge safety systems. The layout of non-safety related systems could interfere with the performance of safety related tasks, or switch selection errors, caused by poor labeling or marking in non-safety related systems, could lead to inadvertent changes in the safety system. Thus, the number of interfaces that must be considered is so large as to embrace, perhaps, the entire control room.

All of this underscores the need for the control room evaluation to be comprehensive in the interfaces examined, in anticipating the possible human errors resulting from specific discrepancies, and in determining the consequences of errors on system safety and reliability.

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APPENDIX I-a

TYPICAL POSITION DESCRIPTIONS

TITLE	TYPICAL RESPONSIBILITIES	SUGGESTED QUALIFICATIONS
Control Room Evaluation Director	• Communicates between evaluation team and top management • Overall project scheduling • Approves HED review process • Final approval of HED priority and backfit selection • Provides authority to: - secure instrumentation - obtain technical and administrative support as necessary - purchasing - obtain all documentation needed • Determines project reporting and documentation requirements	• Holds upper-middle management position • Familiar with both operations and engineering departments and functions • Familiar with control room • Knows NRC regulations concerning control room design and operations • Recognizes the role of design in causing human error, and human error in causing safety and reliability problems
Engineering Coordinator (Staff to Director)	• Coordinates implementation of Engineering Backfits • Provides (secures) engineering documentation for project library • Communicates between evaluation team and engineering • Advises CR Evaluation Director on final disposition of Human Engineering Discrepancies (HEDs)	• Engineering management position (I&C engineer preferable) • Familiar with instrumentation and control of plant • Knowledgeable of NRC regulations on control rooms • Knowledgeable of all steps and costs in backfit process • Recognizes the role of design in causing human error, and human error in causing safety and reliability problems

TITLE	TYPICAL RESPONSIBILITIES	SUGGESTED QUALIFICATIONS
Operations Coordinator (Staff to Director)	• Coordinates implementation of operations backfits • Secures operations documentation for project library • Communicates between evaluation team and operations • Advises CR Evaluation Director on final disposition of Human Engineering Discrepancies	• Operation management position (operator or ex-operator preferable) • Familiar with operations in control room • Familiar with applicable NRC regulations • Recognizes role of design and procedures in causing human error, and human error in causing safety and reliability problems
Training Coordinator (Staff to Director)	• Coordinates implementation of training backfits • Secures training documentation for project library • Communicates between evaluation team and training • Advises CR Evaluation Director on final disposition of Human Engineering Discrepancies	• Training management position (manager of operator training preferable) • Familiar with applicable NRC regulations • Familiar with all aspects of operator selection and training • Recognizes role of design and procedures in causig human error, and human error in causing safety and reliability problems • Recognizes impact of design and procedural changes on Training.

TITLE	TYPICAL RESPONSIBILITIES	SUGGESTED QUALIFICATIONS
Documentation Specialist (Staff to Director)	• Prepares specifications defining the contents, formats, etc., for each team report • Coordinates report preparation by Data Collection manager and HED Processing Manager, with publications personnel • Advises CR evaluation director or publication schedules and constraints	• Publications manager • Familiar with preparing materials for NRC review • Authority to direct or coordinate all aspects of document preparation, reproduction and distribution for review
Data Collection Manager (Reports to Director)	• Data collection scheduling and planning • Develops data collection instruments • Specifies data collection instrumentation • Manages all data collection activities • Serves as human engineer on HED review committee • Approves all backfit suggestions for release to director • Provides advice to director on final disposition of HEDs • Approves HED and its priority for examination by the HED review committee	• Human factors engineer by training (senior level is preferable) • Experience in CR design or evaluation or in design or evaluation of comparable systems • Management (planning, administration, supervision) experience in interdisciplinary or systems engineering activities • Familiar with the human engineering guidelines applicable to CR design and procedures • Familiar with the validity and reliability of hardware instrumentation and data collection instruments suitable for CR evaluation • Understands role of operator in plant systems safety and reliability

TITLE	TYPICAL RESPONSIBILITIES	SUGGESTED QUALIFICATIONS
Data Collection Staff		
• Operator	• Provides advice and information to Data Collection Manager	• Senior reactor operator level • Fully knowledgeable of plant and CR design/operations • Advocate of improved CR design • Candidate for management might be preferable
• I&C Engineer	• Provides advice and information to Data Collection Manager	• Senior I&C engineer • Fully knowledgeable of I&C • Interest in human engineering of control rooms • Candidate for management might be preferable
• Data Collection Specialists	• Perform CR surveys • Perform CR checklists • Conduct task analyses • Conduct procedures walk-throughs • Fill out Human Engineering Discrepancy (HED) reports • Recommend HED priority • Identify potential backfits	• Junior and intermediate level human engineers are preferable; or operators/engineers trained to conduct the data collection activities • Specific understanding of evaluation procedures, instruments and instrumentation

TITLE	TYPICAL RESPONSIBILITIES	SUGGESTED QUALIFICATIONS
HED Processing Manager	• Conducts reviews to establish HED priority • Prepares HED review process for director's approval • Chairs all meetings of HED review committee • Identifies and requests advice from technical specialists as necessary • Advises Director on final disposition	• Systems engineer or engineer thoroughly familiar with I&C and CR operations • Knowledgeable of plant management and senior-level technical staff • Experience in decision making groups • Familiar with NRC regulations concerning CR design and operations
HED Review Committee		
• Senior Reactor Operator (not advising the Data Collection Manager)	• Reviews HEDs and participates in the validation of priorities and feasibility of backfits • Votes on the disposition of HEDs	• Thoroughly familiar with plant systems and CR operations • Experience in decision making groups
• Senior I&C Engineer (not advising the Data Collection Manager)	• Reviews HEDs and participates in the validation of priorities and feasibility of backfits • Votes on disposition of HEDs	• Thoroughly familiar with the design of plant I&C systems and the I&C requirements attached to each system • Familiar with NRC regulations concerning I&C • Experience in decision making groups

TITLE	TYPICAL RESPONSIBILITIES	SUGGESTED QUALIFICATIONS
(HED Review Committee, Cont)		
• Senior Human Engineer	• Describes each HED under review, provides justification for its priority and proposes a backfit where needed • Votes on disposition of HEDs	• Data Collection Manager

APPENDIX I-b
HUMAN ENGINEERING EVALUATION REPORT

(a) INTERFACE NOMENCLATURE OR DESCRIPTION: ______________________

(b) • PANEL ________
• SUB-PANEL ________
• PROCD/STEP ________
• GENERAL ________

(c) EVALUATION REQUIREMENTS:

SURVEYS	√	CHECKLISTS	√	WALKTHROUGHS	√	OTHER	√

(d) DISCREPANCIES:

HED NO.	TITLE	PRIORITY	BACKFIT

APPENDIX I-c

DESIGN FEATURES INFLUENCING HUMAN ERRORS

1.0 <u>Control Errors</u>

1.1 <u>Inadvertent Actuation (Accidental Activation of a Control)</u>

1.1.1 Control location/arrangement

1.1.1.1 Location with respect to the operator's body

1.1.1.2 Location with respect to the operator's hand while controlling other controls

1.1.1.3 Location with respect to other controls

1.1.2 Control design

1.1.2.1 No guards or barriers

1.1.2.2 Too little force required to activate the control

1.1.2.3 Type of motion required to activate makes accidental activation likely — e.g., toggle switch — up/down

1.1.3 Control visibility

1.1.3.1 Control is not easy to see and avoid

1.1.3.2 View of control is obscured by other controls or operator's hand

1.2 <u>Substitution Errors (Selection of the Wrong Control)</u>

1.2.1 Control location/arrangement

1.2.1.1 Control located in a string of other controls of the same shape

1.2.1.2 No consideration given to the sequence of control use

1.2.1.3 No functional arrangement of controls

1.2.2 Control design

1.2.2.1 Control shape not differentiated from adjacent controls

1.2.2.2 Control size not differentiated from adjacent controls

1.2.2.3 Control color not differentiated from adjacent controls

1.2.2.4 Control labelling/marking not readily distinguishable

1.2.2.5 Control location not differentiated from other controls

1.2.2.6 Difficult to distinguish pushbutton from legend light

1.2.3 Control visilibity

1.2.3.1 Control not readily visible

1.2.3.2 Line of sight to control is obscured

1.2.3.3 Control label not readily readable

1.2.3.4 Control label obscured by the control itself or by operator's hand

1.3 <u>Activation Errors (Selecting Wrong Position on Right Control)</u>

1.3.1 Location/arrangement

1.3.1.1 Control is located such that operator reach can result in mis-settings

1.3.1.2 Control is located or oriented such that selection of some positions is difficult

1.3.2 Control design

1.3.2.1 Direction of motion does not follow accepted stereotypes or conventions

1.3.2.2 Direction of motion is not consistent for similar type controls

1.3.2.3 Direction of motion is not labelled

1.3.2.4 No feedback of control activation

1.3.2.5 Control position arrangement is not consistent across different controls

1.3.2.6 Control positions are not readily distinguishable

1.3.2.7 The associated display is not located with the control

1.3.2.8 The associated display motion does not follow convention

1.3.2.9 The control permits selection of positions which are not used

1.3.2.10 Labelling of control positions is difficult to read

1.3.2.11 There is not sufficient spatial separation of different switch positions

1.3.3 Control visibility

1.3.3.1 Control position indications are obscured by the control itself or by the operator's hand

1.3.3.2 The feedback cue to control activation is obscured

1.4 Temporal Errors (Taking Too Much Time to Locate, Acquire and Activate a Control)

1.4.1 Location/arrangement of controls

1.4.1.1 Controls located out of reach of the operator

1.4.1.2 Access to the control requires excessive travel on the part of the operator

1.4.1.3 Access to the control requires special effort on the part of the operator

1.4.1.4 The control is located in an array of identical controls

1.4.2 Control design

1.4.2.1 Force required to activate the control is excessive

1.4.2.2 Required direction of control motion is unexpected or confusing

2.0 Display Errors

2.1 Reading Errors

2.1.1 Location/arrangement

2.1.1.1 Display orientation to operator's line of sight is less than 45°

2.1.1.2 Viewing distance makes reading difficult

2.1.1.3 Display located above the eye height of a 5th percentile operator

2.1.1.4 Display located such that operator's view is obscured

2.1.2 Display design

2.1.2.1 Displays difficult to read due to poor brightness contrast

2.1.2.2 Display readability impaired by glare

2.1.2.3 Scale increment size makes reading difficult

2.1.2.4 Scale graduations not standard nor consistent

2.1.2.5 Pointer parallax increased likelihood of reading errors

2.1.2.6 Strip chart pens leak

2.1.2.7 Strip charts use too porous paper

2.1.2.8 Strip chart pens do not always contact paper

2.1.2.9 Strip chart parameters require ranges different from those indicated

2.1.2.10 Pullout strip charts obscure view of other displays

2.1.2.11 Impact recorders difficult to read or to identify trends

2.1.2.12 Conspicuity of pointers too low

2.2 Interpretation Errors

2.2.1 Display design

2.2.1.1 Displays do not indicate in-tolerance and out-of-tolerance areas

2.2.1.2 Difficult to interpret trends

2.2.1.3 Process controllers display demand only — not actual valve

2.2.1.4 Required values not displayed on trend displays

2.2.1.5 Patterns of lights are confusing

2.3 Display Substitution Errors

2.3.1 Location/arrangement

2.3.1.1 Display located in a string of identical displays

2.3.1.2 Display located too close to adjacent displays

2.3.1.3 Display not located in a string by sequence

2.3.1.4 Displays not functionally grouped

2.3.1.5 Display arrangement is illogical or inconsistent

2.3.1.6 Display not located adjacent to its associated display

2.3.2 Display design

2.3.2.1 Display shape not differentiated from adjacent displays

2.3.2.2 Display size not differentiated from adjacent displ 's

2.3.2.3 Display color not differentiated from adjacent displays

2.3.2.4 Display labelling not readily readable

2.3.3 Display visibility

2.3.3.1 Display not adequately illuminated

2.3.3.2 Line of sight to the display is obstructed

2.4 Display Activation Errors

2.4.1 Display design

2.4.1.1 No light test capability

2.4.1.2 No indicator lights are provided

2.4.1.3 Direction of display motion not conventional or stereotypical

2.4.1.4 It is possible to transpose legend light faces

2.4.1.5 Trend re'order speed not controllable

2.4.1.6 A failure to achieve required status is indicated by an extinguished light

2.4.1.7 There is no standard procedure for checking failed lights

2.4.1.8 A meter can fail leaving the pointer at mid-range

2.4.1.9 Failure of a meter is not readily detectable

2.4.1.10 Valve travel is indicated by extinguishment of open and closed lights

2.5 Display Temporal Errors

2.5.1 Location/arrangement

2.5.1.1 Display not located within visual access from viewing position

2.5.1.2 Display is located in an array of identical displays

2.5.1.3 Display located where field of view is obstructed

2.5.2 Display design

2.5.2.1 Displays not functionally grouped

2.5.2.2 Displays not grouped by sequence of use

2.5.2.3 Displays not clearly labelled

2.5.2.4 Displays not clearly coded

3.0 Annunciator Errors

3.1 Reading Errors

3.1.1 Location/arrangement

3.1.1.1 Annunciator legend cannot be read at viewing distance

3.1.1.2 Annunciator legend cannot be read at viewing angle

3.1.2 Annunciator design

3.1.2.1 Luminance level of red annunciator too low

3.1.2.2 Annunciators have dyna-tape backfits which cannot be read when illuminated

3.1.2.3 Annunciators have different type fonts

3.1.2.4 Annunciator legends are too complex

3.2 Annunciator Activation Errors

3.2.1 Annunciator design

3.2.1.1 Annunciators not prioritized

3.2.1.2 Annunciators not functionally grouped

3.2.1.3 Annunciators not coded — as first out

3.2.1.4 High annunciator nuisance rate reduces operator readiness

3.2.1.5 Annunciator silence control is operated in a defeated mode

3.2.1.6 Different flash rates or duty cycles indicate different annunciator status — and the indications are not readily distinguishable

3.2.1.7 Auditory alarms are not coded by location

3.2.1.8 No annunciator silence with visual display retention

3.2.1.9 Until an alarm is cleared, a second alarm is inhibited

3.2.1.10 Alarms are less than 20 dB above ambient noise levels

3.2.1.11 Acknowledge control difficult to access

3.2.1.12 No clear notification of alarm cleared

4.0 Label Reading Errors

4.1 Readability

4.1.1 Location/arrangement

4.1.1.1 Labels not located consistently

4.1.1.2 No labels provided

4.1.1.3 No panel designators provided

4.1.1.4 View of labels obscured

4.1.2 Design

4.1.2.1 Label font makes labels difficult to read

4.1.2.2 Functions mislabelled

4.1.2.3 Safety tags cover labels

4.1.2.4 Labels have poor brightness contrast

4.1.2.5 Labels are cluttered

4.1.2.6 Labels have low contrast to the panel

4.1.2.7 Labels are illegible

4.1.2.8 Color not used consistently

4.1.2.9 Inconsistent use of abbreviations

4.1.2.10 Labels have small fonts

4.1.3 Use of labels

4.1.3.1 Too many operator added backfits used

4.1.3.2 Backfits not consistent

4.1.3.3 No demarcations grouping panel elements

5.0 Procedure Errors

5.1 Access Errors

5.1.1 Procedures location and arrangement

5.1.1.1 Procedures are not located to be easily accessed

5.1.1.2 Procedures are not arranged to be easily accessed

5.1.1.3 Only are set of procedures provided in the CR

5.1.2 Procedures indexing

5.1.2.1 Procedures are not indexed for ease of access

5.1.2.2 Procedures are not tabbed for easy access

5.1.3 Procedures design

5.1.3.1 Procedure titles are not sufficiently discriminable

5.1.3.2 No guidelines are provided to enable operators to establish which procedures are applicable

5.1.3.3 No cross referencing of different procedures

5.1.3.4 Cross referencing sends the operator to some ancillary document

5.2 Reading Errors

5.2.1 Procedures design

5.2.1.1 Use of ambiguous language

5.2.1.2 Procedures text not clear and concise

5.2.1.3 Instruction too long

5.2.1.4 Use of overly precise control processor settings

5.2.1.5 Phrasing of instruction is ambiguous

5.2.1.6 Excessive length of instructional steps cause operators to skim rather than read these steps

5.2.1.7 Multiple steps are nested in one instructional statement

5.2.1.8 Caution and warning notes not sufficiently highlighted

5.3 Procedures Following Errors

5.3.1 Procedures design

5.3.1.1 Procedures are not complete — steps are missing

5.3.1.2 Procedural steps are out of order

5.3.1.3 Procedures do not inform the operator when to stop using the document

5.3.1.4 Emergency procedures do not indicate the feedback for the system which should cue the operator on what to do next, or even that he is on the right procedure

5.3.1.5 Procedure nomenclature different from labels and component designations

5.3.1.6 Information on component location and function left to operator's memory

5.3.1.7 Procedural steps in emergency procedures not structured to support diagnosis of problems

5.3.1.8 Charts, graphs and schematics and diagrams are not incorporated in the text

5.3.1.9 No indications are provided on system response to operator action

5.3.1.10 Procedures are not anumerable to a checklist format allowing operator checkoff of each step as completed

5.3.1.11 Too many steps of emergency procedures must be committed to memory

5.3.1.12 Arrangement of notes is confusing — not clear to which step the note applies

5.3.1.13 Inconsistent use of acronyms and action verbs

APPENDIX II

GENERIC HUMAN ENGINEERING DESIGN ISSUES

Annunciator Design and Operation

- Organization of windows — not above systems they monitor
- Low contrast between alarming and steady-on windows
- No prioritization of alarms to aid in diagnosis
- Font size not consistent with reading distance requirements
- Difficulty in localization (low flash rates, no auditory alarm directionality correlates)
- Lack of positive indication of alarm condition cleared
- Multi-channel annunciators which have no reflash capability and lock out subsequent alarms.

Operator/Computer Interface

- No graphic trending capability on displays
- Computer operation requires lengthy searches for data point addresses (operators often substitute memory)
- Alarm computers that are limited in the number of near-simultaneous alarms that can be managed
- No alphanumeric displays whatsoever
- Display and hardcopy alphanumeric outputs which are poorly spaced, organized, etc.
- Printers obscured by cabinet.

Violations of Conventions and Stereotypes

- Switch position conventions (within plant) established and then violated on panel
- Switch and display organization by channel, bus, etc., varies within and between systems
- Stereotypic left-to-right and top-to-bottom organization of alphabetic- or numeric-ordered controls/displays is violated
- On-off, increase-decrease movement stereotypes are not followed
- Color meaning conventions are established and then violated in indicators.

Control/Display Strings

- Vertical meters, process controllers or switches are arranged in vertical or horizontal strings of 5 or more making location of mid-string components difficult
- Positioned in string without regard to operational sequence
- Coding methods are not employed to enhance discriminability
- Confusion in locating specific control/display is induced by layout or clustering
- Discriminability is reduced by C/D similarity.

Lamp Testing

- Application does not extend past annunciators/status lights
- Alternate operational methods to test lamps include valve closures/ openings and lamp replacement
- Information omission increases operator/personnel workload
- Failure states can remain unknown.

Labeling

- Readability is reduced by small font size
- Low contrast of lettering to label decreases readability
- Nomenclature is inconsistent or misleading
- Labels are not conspicuous
- Labels are not present
- Little use of summary labeling of functionally grouped components
- Contractions, abbreviations are not uniform
- Control and display label associations are obscure
- Obscured by switch handles, or other equipment.

Operator Protective Equipment

- Masks obscure visibility
- Breathing apparatus interferes with voice communication
- Operators are not practiced enough to don equipment within an acceptable period of time
- Accessibility is poor
    - supply insufficient equipment for the number of operators required to be in CR
    - store emergency equipment in locked cabinets or in obscure locations.

Intra-CR Communications

- Ambient noise levels are very high (60-70dB)
  - interferes with communications from back panels or across the CR
- Communications impossible when wearing protective breathing apparatus
- Emergency procedures are read by one operator while another takes required actions (high fidelity voice communications are required throughout the CR).

Procedures Content and Format

- Procedures are difficult to access due to storage and indexing
- Procedures lack completeness
  - steps missing
  - steps out of order from actual sequence of performance
- Actions not included in procedures are assumed to be learned in training
- Ambiguous language is used in instructional steps
- Synonyms are frequently used
- Information on system feedback is lacking
  - no instruction on operator requirements or recourse if system fails to respond
- Offer lack diagnostic aids
- Cross-referencing to other procedures or documents occurs within immediate and subsequent operator actions
- Procedures lack clarity and conciseness of text
  - instructional steps are wordy or discussional in nature
- Instructional steps are nested in notes or cautionary statements or in other steps
- Format does not agree with modern job performance aid technology
  - font size, style (10 or 12 pitch, non-ceriphed type)
  - column width (optimum width for eye scan, 3 inches)
  - sentence structure and length (10 words or less, simple sentence structure)
  - constrained vocabulary (use words of high familiarity; eliminate synonyms)
  - supplementary information (use of diagrams or pictures)
- Information on component location and function is left to operator memory
- Long lists of immediate actions tax operator long-term memory
- Field operations (not performed by control room operator) are not clearly identified as such.

Workspace Layout

- Primary panel space is cluttered with unused/inoperative controls and displays
- Accessibility of panel is obstructed by desks, computer consoles
- Critical displays are placed below the operator's line-of-sight
- Displays are located without regard for parallax or glare.

Control/Display Relationships

- Functionally related controls and displays are not colocated
- Control/display relationships are unclear
- Mimic panels, when used, are composed of overlapping, multi-colored lines which do not clearly associate controls/displays.

Positive Indication of System or Component Status

- Indicator lights indicate switch position rather than actual valve or breaker position
- Pre-trip status indication of engineered safeguards is lacking in a concise form.

Process Controllers

- Indication is given of signal sent rather than a positive indication of valve status
- Stereotype is violated in that counterclockwise control movement and increased display value (i.e., 100%) can signify a closed valve
- Control/display relationship is inverted (e.g., increase in control value produces decrease in display value).

Trend Recorders

- Trends are smeared and unreadable
- Pen position is parallaxed, unreadable or obscured
- Scaling increments do not agree with increments on paper
- Wrong color ink in pens.

General Maintenance in Control Rooms

- Bulbs burned out in indicator lights
- Labels missing or becoming unglued
- Ladders, cables and other equipment obstructing passage between panels
- Refilling of ink in trend recorders results in spillage; wrong color ink is used.

APPENDIX III

HUMAN ENGINEERING OPERATOR QUESTIONNAIRE

Date: ________________ HFE Analyst — Briefing: ________________

Unit: ________________ Interview: ________________

Licensed Operator _____ How Long? __________

or

Trainee _____ How Long? __________

A. Staffing and Workload

1. Please describe Tech. Spec. requirements for CR staffing.

a) If actual staffing differs from Tech. Specs., please describe actual staffing.

2. In your opinion, under worst-case conditions, what is the maximum number of operators actually needed to effectively operate the control room during each of the following:

a) Normal operations ________

b) Startup/shutdown ________

c) Transients/emergency operations ________

3. How many units do you presently operate? ____________

a) If you operate two or more, are they: (check one)

____ identical

____ nearly identical

____ mirror images of each other

____ dissimilar

b) If you operate two or more units, have you ever experienced any difficulties in shifting from one CR to another? ____ yes ____ no

____

____

____

4. Please describe your administrative or record keeping tasks (log entries, reading of parameters, etc.).

____

____

____

____

____

____

____

____

____

____

____

____

____

a) Have these responsibilities ever interfere with your operational duties, especially during off-normal conditions? ____ yes ____ no

____

____

____

5. Have you observed any problems associated with shift turnover? ____ yes ____ no

____

____

____

6. Please describe any recommendation you may have to improve shift turnover.

____

____

____

B. Workspace Design

1. Can the status of your plant be monitored from one central position? ____ yes ____ no

____

____

____

2. Are specific stations assigned to operators and watch foreman? ____ yes ____ no

____

____

____

3. During normal or off-normal operations, do the actions or tasks of another operator ever interfere with performance of your tasks?
____ yes ____ no

____

____

____

4. Have you ever experienced any difficulty in reaching a required control or seeing/reading a required display? ____ yes ____ no

____

____

____

5. Have you ever experienced any problems locating the correct control or display (for example, operating the wrong switch or inaccurately operating the correct switch)? ____ yes ____ no

____

____

____

6. Are panels arranged within your CR in a manner which is logical for normal and emergency operations? ____ yes ____ no

____

____

____

7. Are controls and displays pertaining to systems or subsystems grouped logically and distinctively within each panel? ____ yes ____ no

____

____

____

8. Does your panel lack important information, controls or displays, which would help you perform your job more effectively or safely? ____ yes ____ no

____

____

____

9. Are important data, controls or displays, inaccessible, or difficult to access, because of placement (for example, located in back panels out of operator's view)? ____ yes ____ no

____

____

____

10. Does your CR contain controls, displays or other equipment which is inoperative, not used or unnecessary for you to do an effective job? ____ yes ____ no

____

____

____

11. Do you find mimics or graphic/pictorial panel arrangements, if used, helpful in performing your job? ____ yes ____ no ____ N/A

____

____

____

a) If "no," please describe why you feel they are not helpful and any recommendations you may have to make them more so.

____

____

____

12. Have you ever inadvertently disturbed control settings (for example, accidentally bumping a switch)? ____ yes ____ no

---

13. Have groups of controls or displays which look identical or very similar been marked or coded to permit easy discrimination between them? ____ yes ____ no

---

a) If "no," please describe areas where you feel marking or coding would enhance your ability to discriminate between components.

---

14. Please describe the administrative procedure for adding operator-recommended modifications to labeling, demarcation lines, mimics, or for adding guarding for certain controls, or otherwise modifying the panel.

---

15. Do you find operator-added modifications helpful? ____ yes ____ no

---

a) If "no," please describe those modifications which you find to be a hindrance.

____

____

____

16. Are major panels, sub-panels and panel segments clearly and consistently labeled? ____ yes ____ no

____

____

____

17. Is the Control Room (CR) arranged to be effectively operated by the minimum shift required?

During normal operations ____ yes ____ no

During transients/emergency operations ____ yes ____ no

____

____

____

C. Workspace Environment

1. Do CR features of an environmental nature, such as listed below, ever interfere with effective performance of your job? If "yes," please describe the nature and source of each problem and their effects on job performance.

a) Ventilation ____ yes ____ no

____

____

b) Temperature/humidity ____ yes ____ no

____

____

c) Illumination ____ yes ____ no

d) Noise levels ____ yes ____ no

e) Excessive traffic through the CR ____ yes ____ no

f) Other environmental factors ____ yes ____ no

2. Are there problems with time and distance involved in leaving CR to prepare food or use facilities? ____ yes ____ no

D. Communications

1. Are there problems with communications procedures or equipment which interfere with receiving or transmitting required information in any of the following instances? If "yes," please describe.

a) CR to field/auxiliary operators ____ yes ____ no

b) Field to CR ____ yes ____ no

c) CR to supervisor ____ yes ____ no

d) Between units ____ N/A ____ yes ____ no

e) CR to NRC ____ yes ____ no

f) CR to others (please specify) ____ yes ____ no

2. Are you aware of any instances in which intra-control room (operator-to-operator) communications have been lost or misheard due to distance or noise levels? ____ yes ____ no

3. Does the operation of communications equipment, or requirements for communications interfere with operations: (Please describe if "yes.")

a) During normal operations ____ yes ____ no

b) During off-normal operations ____ yes ____ no

c) During transients/emergencies ____ yes ____ no

4. Have you experienced any problems with using communications equipment in any of the following areas? (If "yes," please describe the problems.)

a) Location of the equipment ____ yes ____ no

b) Operation of the equipment ____ yes ____ no

c) Ability to receive or transmit messages (speech intelligibility) ____ yes ____ no

d) Number of transmitters/receivers ____ yes ____ no

e) Failed or broken equipment ____ yes ____ no

E. Annunciator/Warning System

1. Please describe your alarm annunciator system and its operation from incoming alarm to acknowledge to condition cleared.

2. Does the annunciator system in your CR provide you with specific information about the nature of an abnormal event? ____ yes ____ no

____

____

____

3. Do alarm annunciators provide you with information about the necessary action to be taken in response? ____ yes ____ no

4. Alarm annunciators located above the instrumentation of systems which they monitor? ____ always ____ frequently ____infrequently

____

____

____

5. Are alarm annunciators prioritized in any way? ____ yes ____ no

____

____

____

6. Please describe any use of color coding used in the annunciator system.

____

____

____

7. Do you have any problems reading annunciator messages from any point in the CR from which these messages must be read? ____ yes ____ no

____

____

____

8. Are the auditory warning signals differentiated to provide meanings, such as priority alarms or locality of system components? ____ yes ____ no

____

____

____

9. Do "nuisance" or "false" alarms ever interfere with your performing your job effectively?

Under normal conditions ____ yes ____ no

Under emergency conditions ____ yes ____ no

a) If "yes," please identify frequent nuisance alarms and the problems they present.

____

____

____

10. Are alarm acknowledge/silence/reset controls available to the operator?

Are there sufficient number ____ yes ____ no

Are they easily accessible from all panels ____ yes ____ no

____

____

____

11. Are alarm annunciators provided with a test capability?

For visual/lamps ____ yes ____ no

For audible ____ yes ____ no

12. Do you have any recommendations which would enhance the operator usability of your annunciator system?

____

____

____

F. Operator Protective Equipment

1. Please describe the operator protective equipment available in your CR.

____

____

____

2. Please describe the quantity and location of the equipment.

____

____

____

3. Does the face mask interfere with visibility? ____ yes ____ no

4. Does your protective breathing apparatus interfere with the following:

   a) Operator-to-operator communications ____ yes ____ no

   b) Use of communications equipment ____ yes ____ no

5. Have you ever encountered difficulty in performing required tasks as a result of wearing protective equipment? ____ yes ____ no

____

____

____

6. Do you feel sufficiently practiced in donning protective equipment so that, if the need arises, you feel you could don it easily and quickly? ____ yes ____ no

7. Do you have any other comments or suggestions concerning the suitability of the available protective equipment or its use?

____

____

____

G. Computers

1. Please describe the functions performed by the computer to assist you in operating the system.

____

____

____

2. Do you find the computer useful and reliable? ____ yes ____ no

____

____

____

3. Do you feel that operators are adequately trained to use the computer? ____ yes ____ no

____

____

____

4. What changes or additions in computer usage would you recommend?

____

____

____

H. Procedures/Documentation

1. Do you find that your procedures documents are difficult to access because of labeling, indexing or storage? ____ yes ____ no

____

____

____

2. Are your procedures sufficiently detailed to permit effective operation of your CR during normal and emergency operations? ____ yes ____ no

____

____

____

3. Are there procedures which you find difficult to execute? ____ yes ____ no

____

____

____

4. Please list the procedures which address operation of the most difficult or critical systems.

____

____

____

I. Operations

1. Do you feel that too many functions are performed automatically by the system in controlling abnormal event? ____ yes ____ no

____

____

____

2. Can you provide examples where direct control by the operator would be preferable to automatic control? ____ yes ____ no

____

____

____

3. Can you suggest examples where automatic control would be preferable, where not currently provided? ____ yes ____ no

____

____

____

4. Please describe any additional operational problems you have experienced with the current panel design.

____

____

____

5. Please describe any recommendations you would make in design or procedure which would enhance the effectiveness of the operator's job.

____

____

____

J. <u>Operator Work Scheduling</u>

1. Would you prefer a different system of shift scheduling? ____ yes ____ no

a) Do you have any comments or suggestions for improving the effects of shift scheduling on the operator?

____

____

____

2. Have you ever experienced any negative effects in changing from one shift to another, in yourself or in other operators? ____ yes ____ no

a) If "yes," has this effected operating abilities? ____ yes ____ no

b) Any comments or recommendations?

____

____

____

3. How many overtime hours do you generally work in a month? ________

a) Do you feel that extended shifts or overtime degrades your ability to perform your job effectively? ____ yes ____ no

b) Have you ever experienced any problems in operating the plant as a result of working extensive overtime? ____ yes ____ no

c) Any comments or suggestions?

____

____

____

4. Are you aware of any operators who have experienced personal problems as a result of working shifts and/or overtime? ____ yes ____ no

a) Any comments?

____

____

____

APPENDIX IV-a NOISE SURVEY

PLANT:	DATE:	TIME:
TEST CONDUCTED BY:		
SOUND LEVEL METER MODEL: SERIAL NUMBER:	MICROPHONE MODEL: SERIAL NUMBER:	CALIBRATION DATE
OPERATOR POSITION:		

NOISE CONDITION/SOURCE/DIRECTION OF MEASUREMENT	dB	dB(A)	dB(C)	REMA

APPENDIX IV-b AMBIENT LIGHTING SURVEY

PLANT:	DATE:	TIME:

TEST CONDUCTED BY:

PHOTOMETER MODEL:

SERIAL NUMBER:

CALIBRATION DATE:

OPERATOR/MEASUREMENT POSITION	LIGHTING CONDITIONS		REMARKS
	NORMAL	EMERGENCY	

APPENDIX IV-c DISPLAY LIGHTING SURVEY

PLANT:	DATE:	TIME:

'EST CONDUCTED BY:

SPOT BRIGHTNESS METER MODEL: SERIAL NUMBER:	CALIBRATION DATE:

DISPLAY TYPES	LOCATION	BRIGHT AREA (L.) (FT. LAMBERTS)	DARK AREA (L.) (FT. LAMBERTS)	LUMINANC CONTRAST

APPENDIX IV-d DESIGN CONVENTION SURVEY

Operation: ______________________

Reviewer: ______________________
Plant/Unit: ______________________
Date: ______________________

INTERFACE DESIGN	PANEL NUMBER OR NAME														

APPENDIX IV-e

EMERGENCY GARMENTS & BREATHING APPARATUS

Have one or more trained operators don emergency garments and breathing systems (Video tape if possible)

- Where is emergency equipment stored (how far from main operating station)?
- How long does it take to obtain garments/apparatus?
- How many operators are needed to suit one operator?
- How long does it take to suit one operator?
- Can CR operators suit up simultaneously?
- How long will the air last before new tanks are needed?
- How long does it take to replace tanks?
- How many operators are needed for tank replacement?

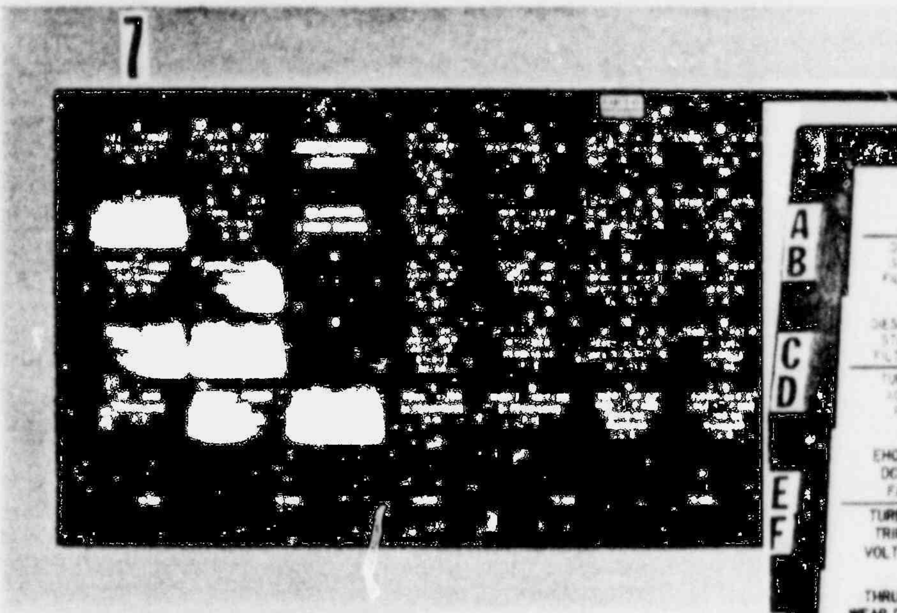
Have two operators don emergency garments and breathing systems and try to communicate at various distances. Have one operator read a 4-digit number and repeat it first in a normal voice and then shouting. Have the second operator attempt to repeat the number after normal loudness and shouting. Move the operators closer until the number can be heard shouting then record the distance between the operators. Move the operators closer until a different number can be heard with normal speech, then record the distance between the operators. Reverse the roles of the two operators. Record results below.

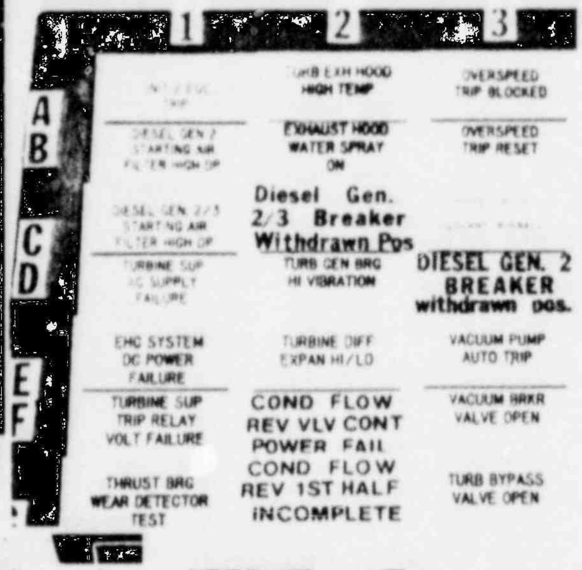
		Hearing Distance
Operator 1 Speaking		
	Normal	
	Shouting	
Operator 2 Speaking		
	Normal	
	Shouting	

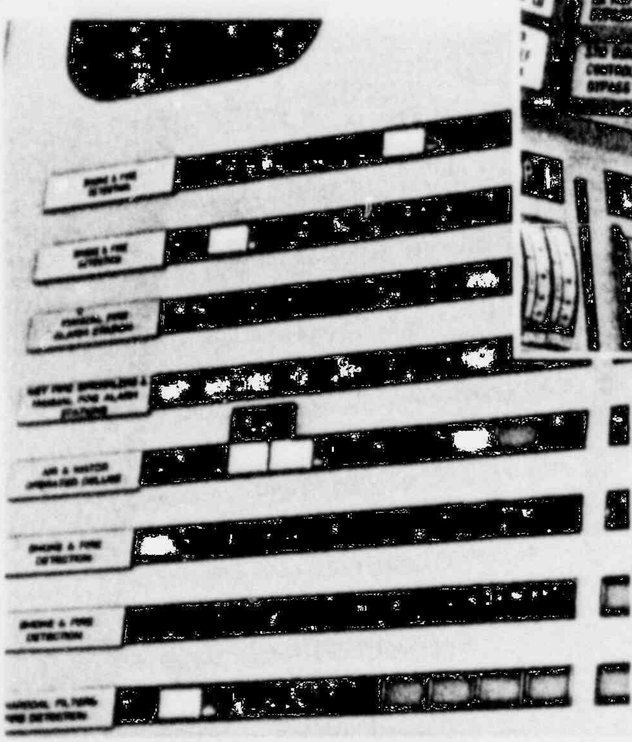
Check face mask for visual obstructions. Use the space below to describe the location and magnitude of any obstructions. Photograph mask.

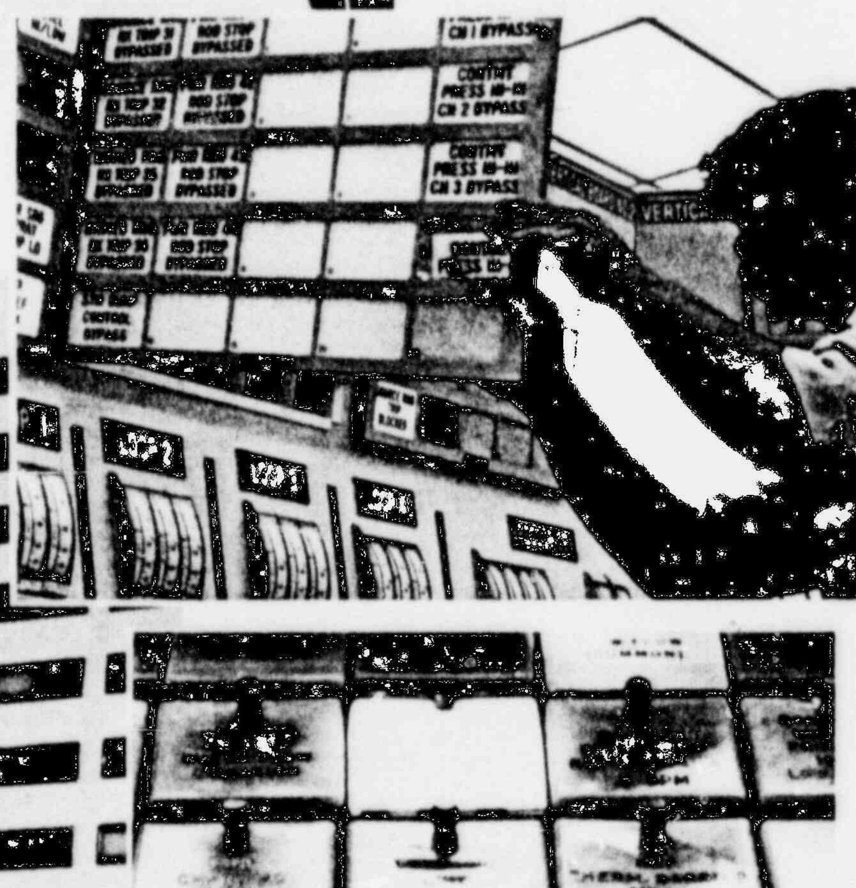
Measure extent of operator's reach envelopes with and without protective garments. Photograph positions (standard) at fixed distances.

ANNUNCIATORS





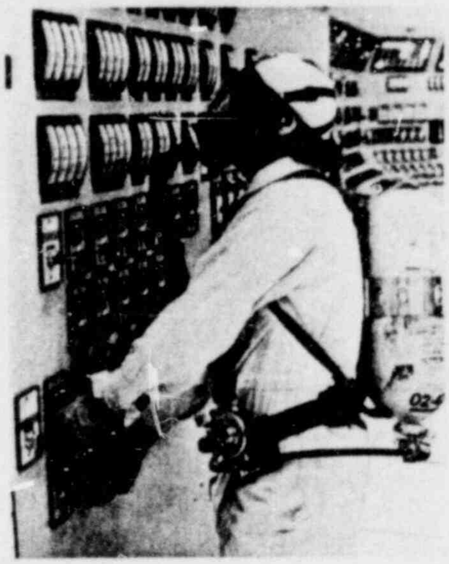


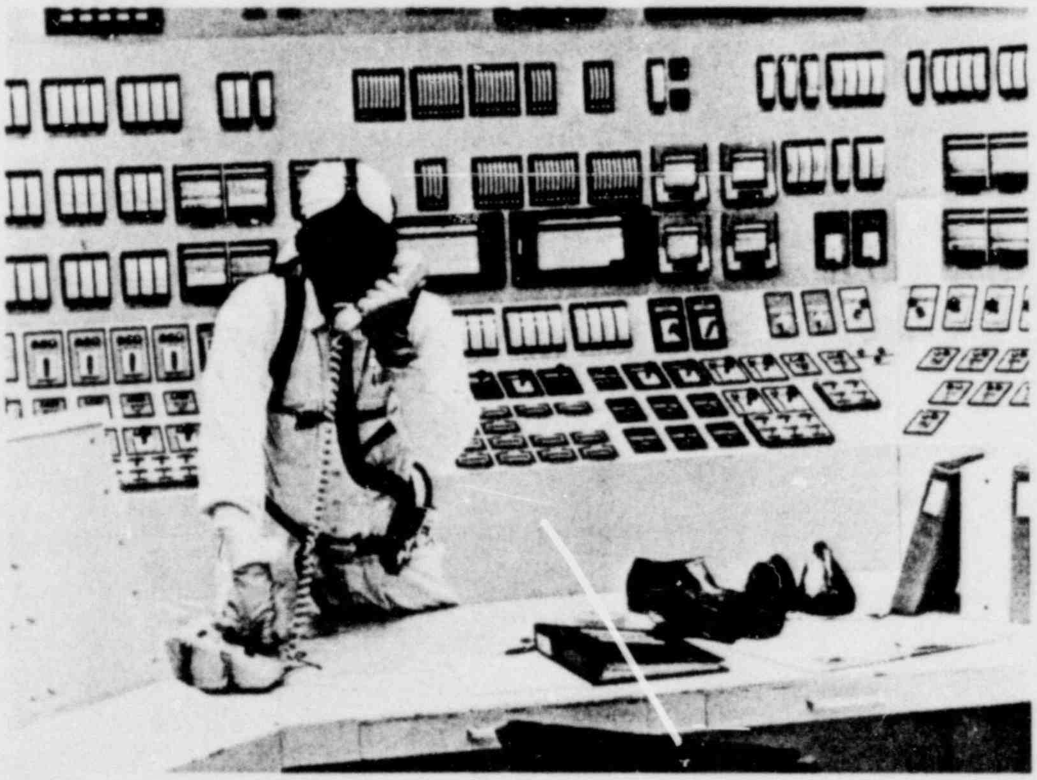


Photograph hand of operator (fingers spread and extended) with and without gloves. Have the operator close his eyes and discriminate among a number of small relatively common objects with the gloves on.

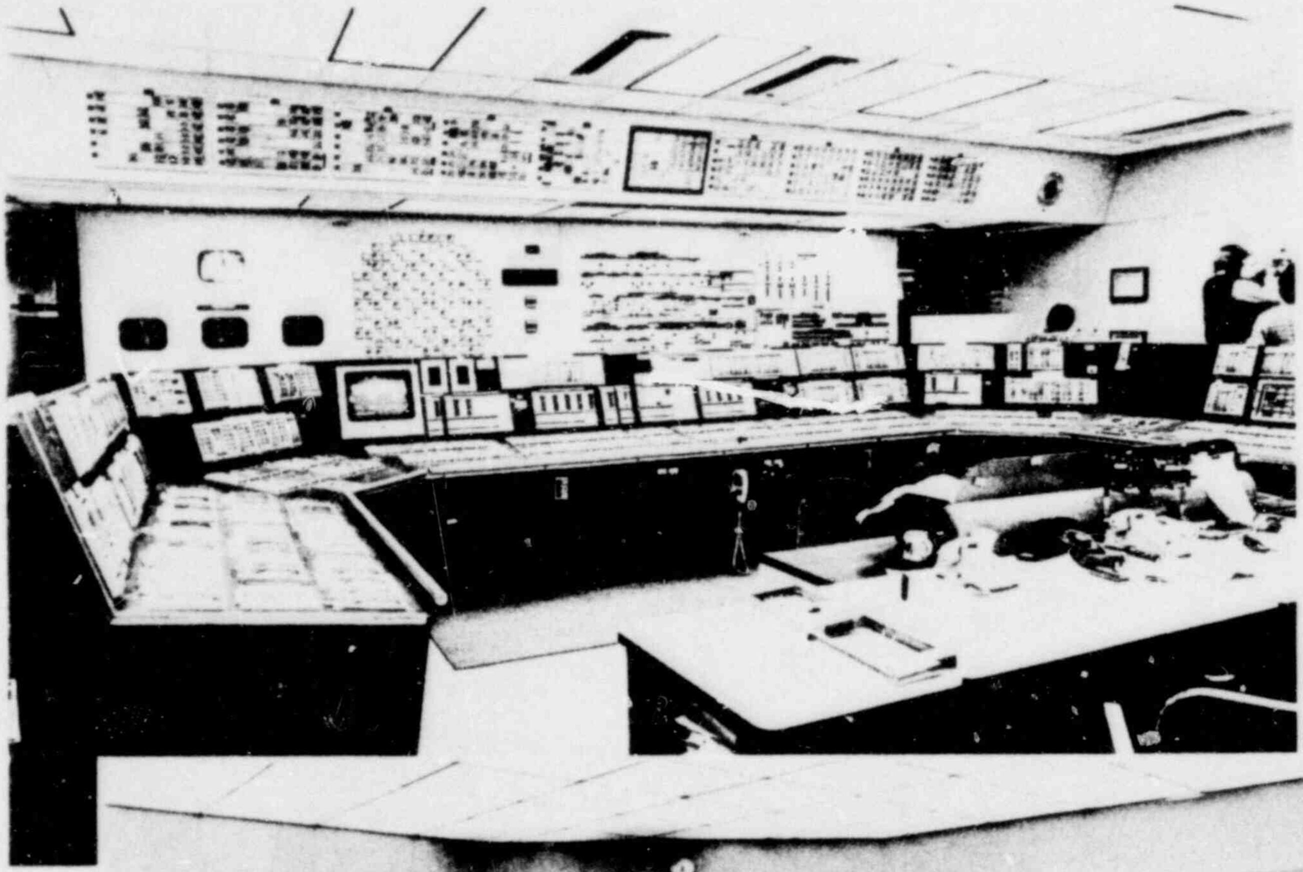
If possible, have the operators perform one emergency procedure with and without the garments/breathing apparatus on (video tape).

PROTECTIVE EQUIPMENT

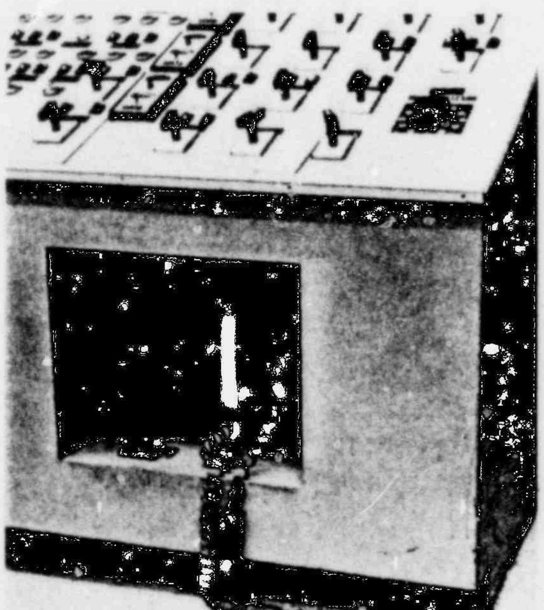


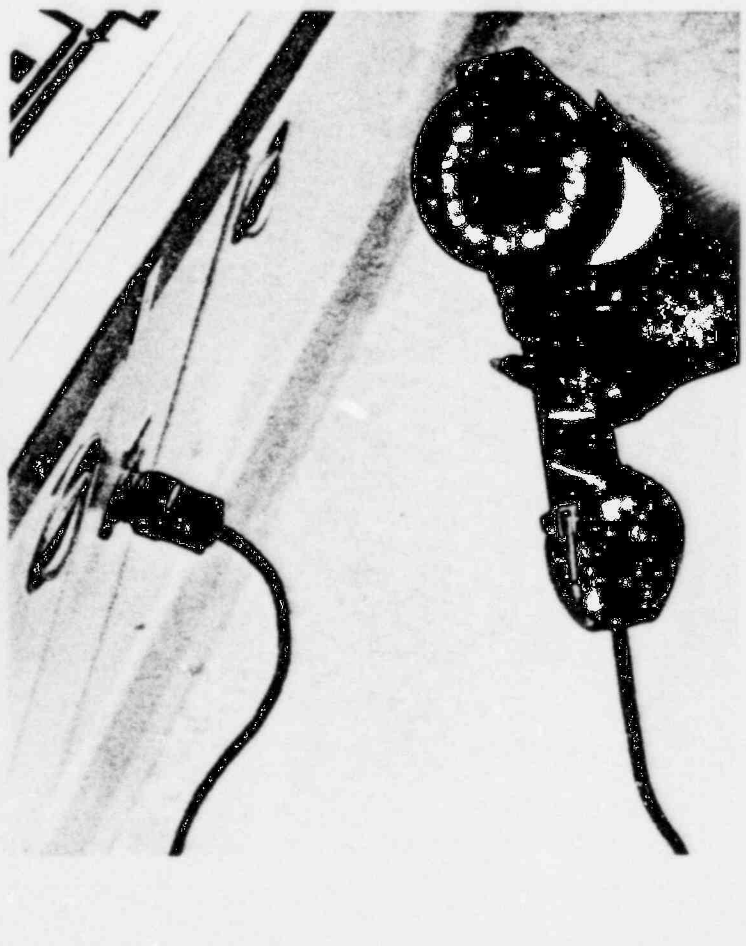


CONTROL ROOM

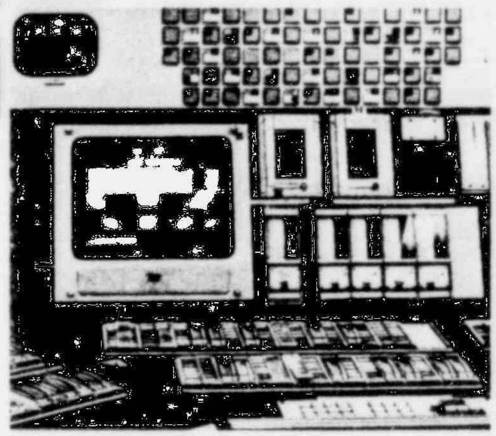


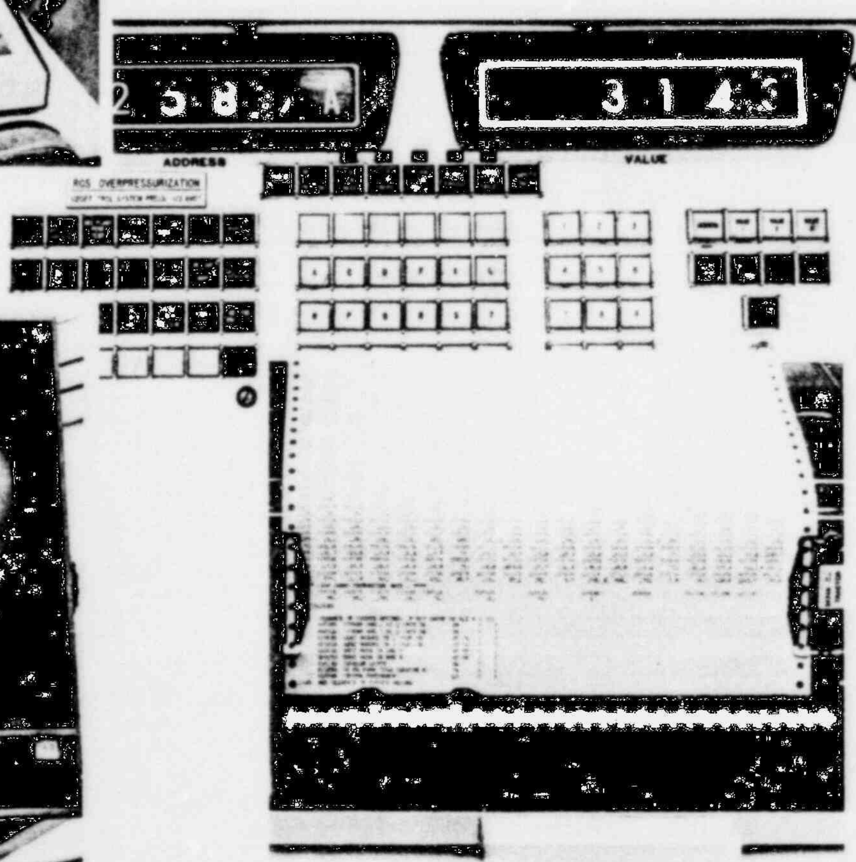
COMMUNICATIONS

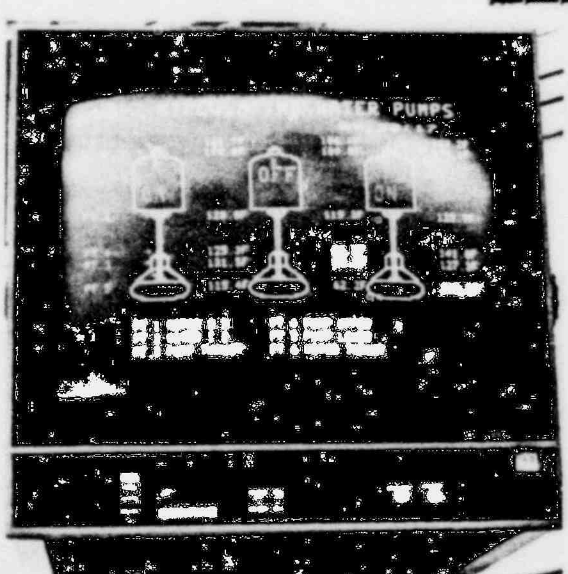




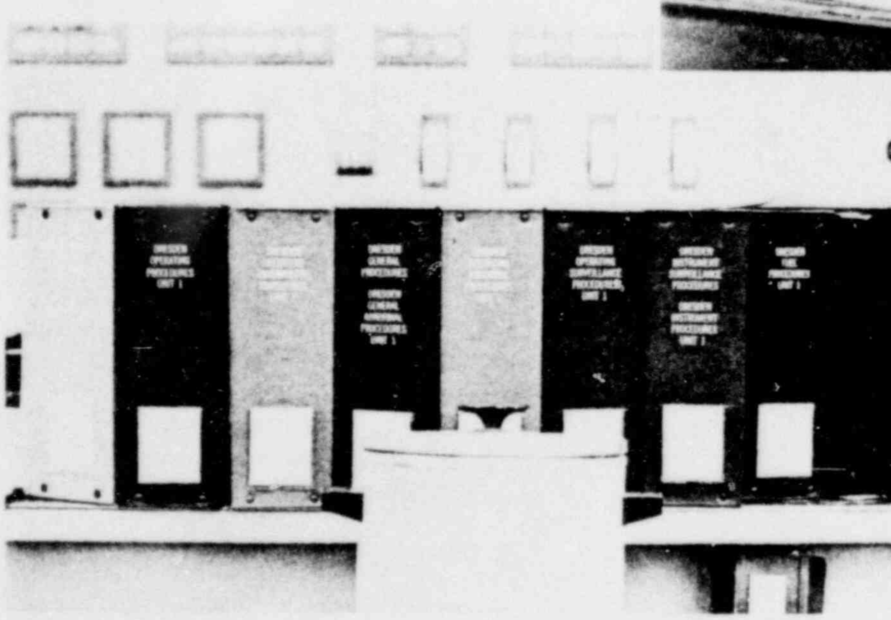
COMPUTERS



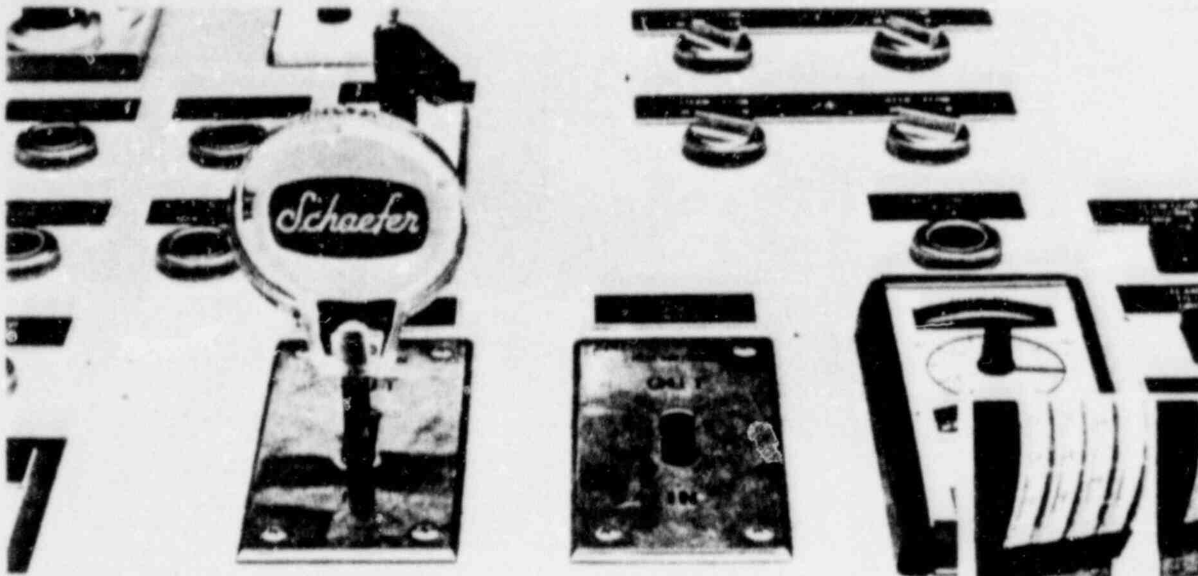


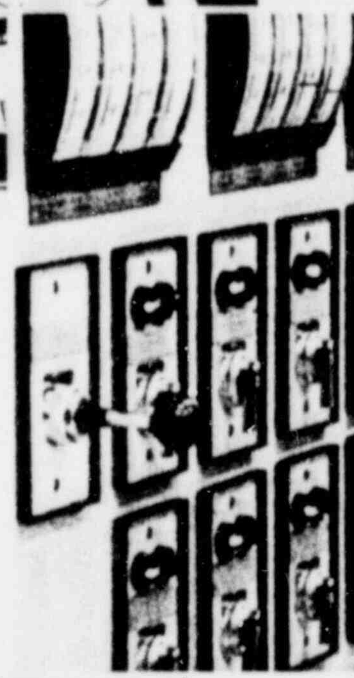


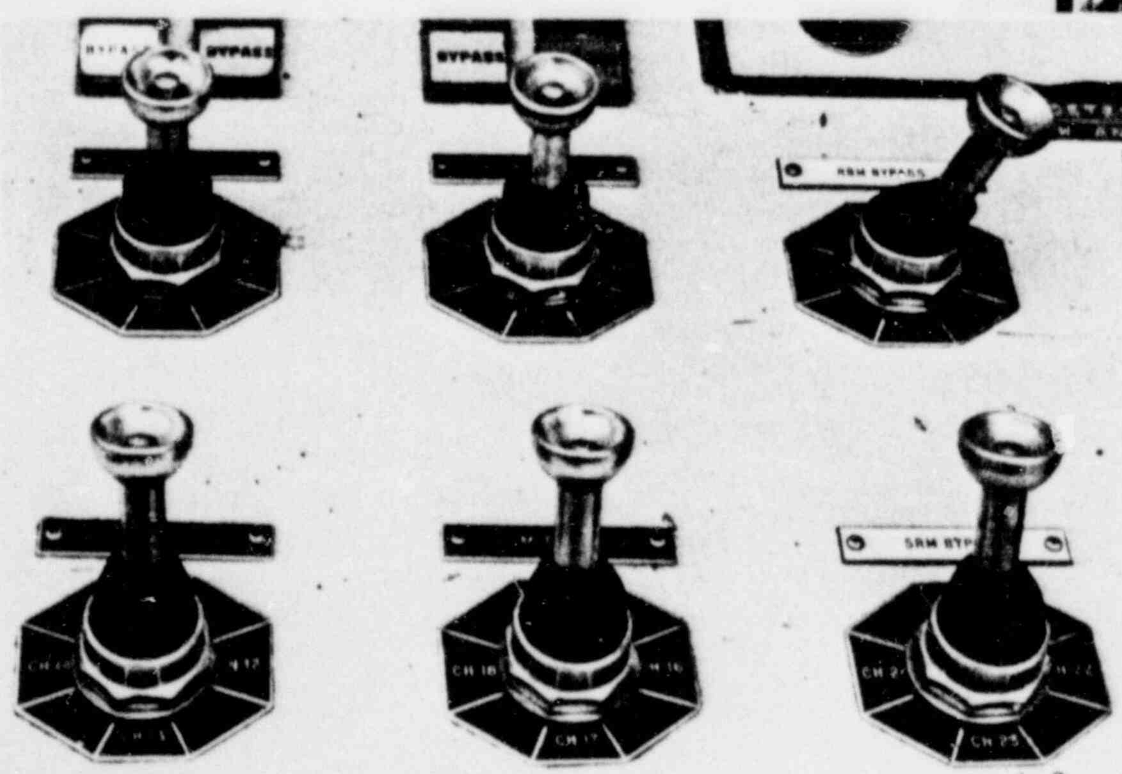
PROCEDURES DOCUMENTS



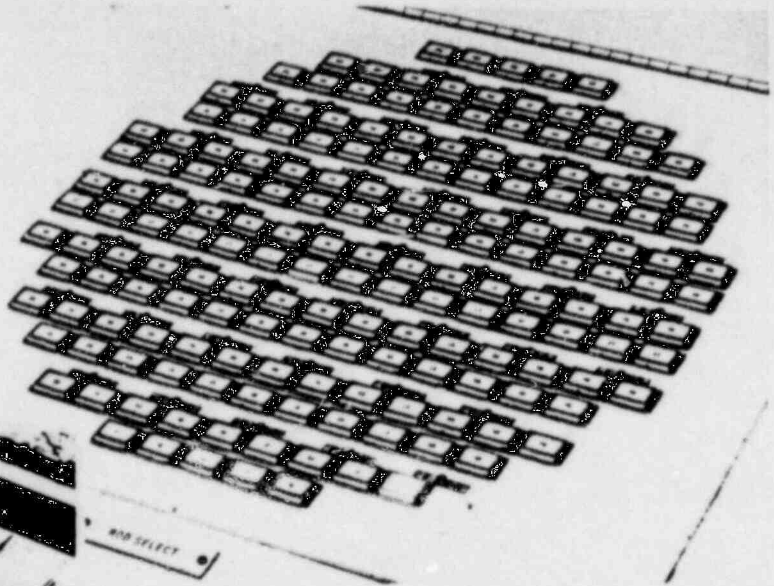
LEVERS

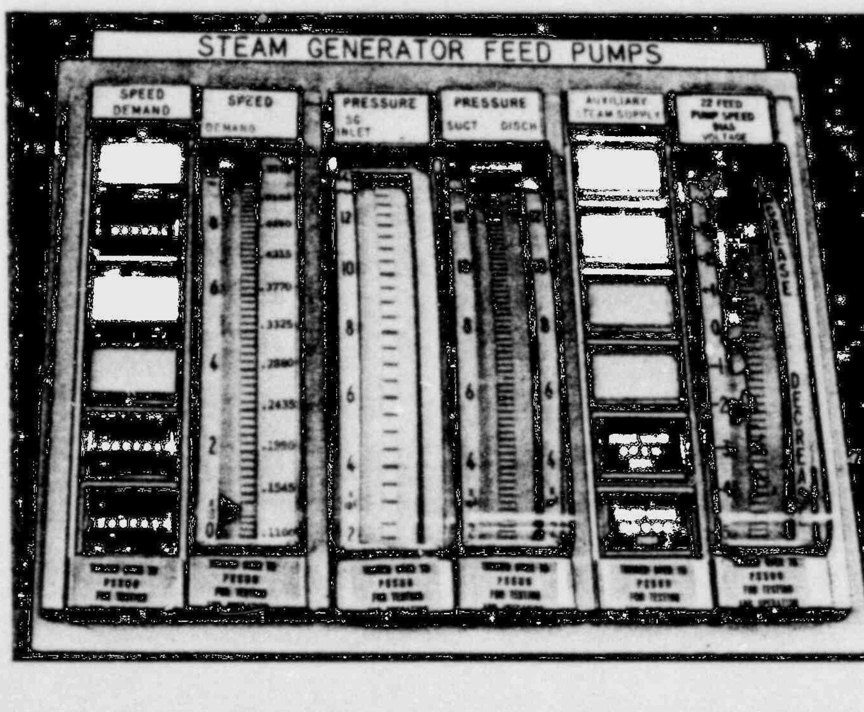




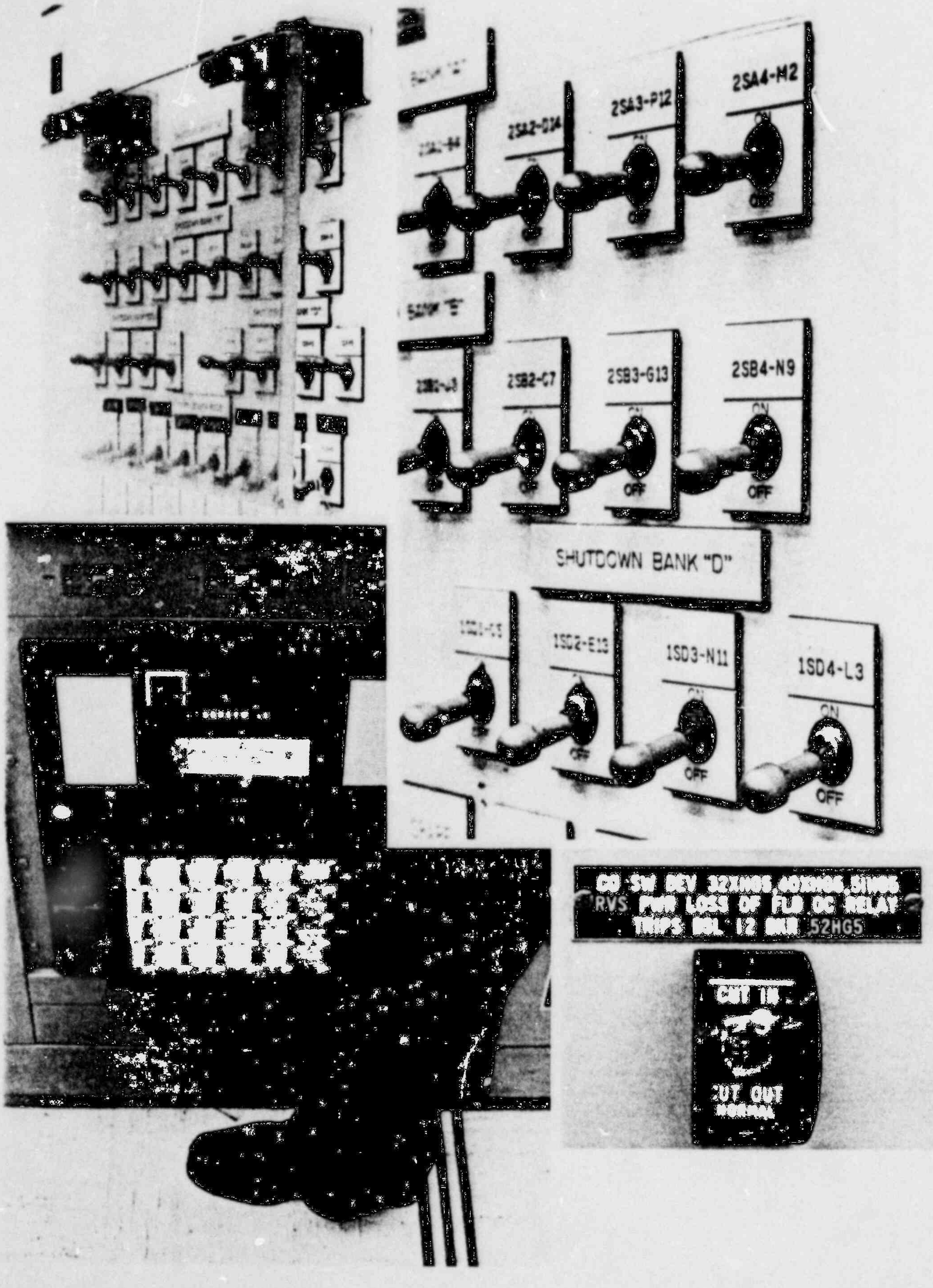


LEGEND PUSHBUTTONS

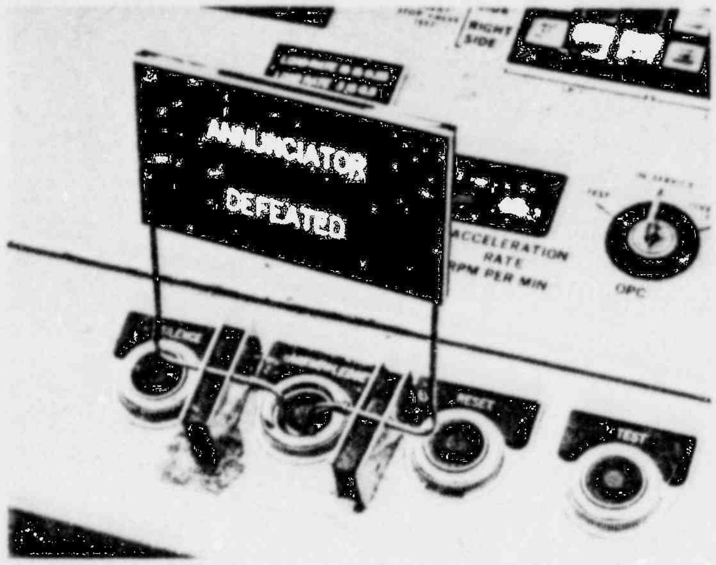


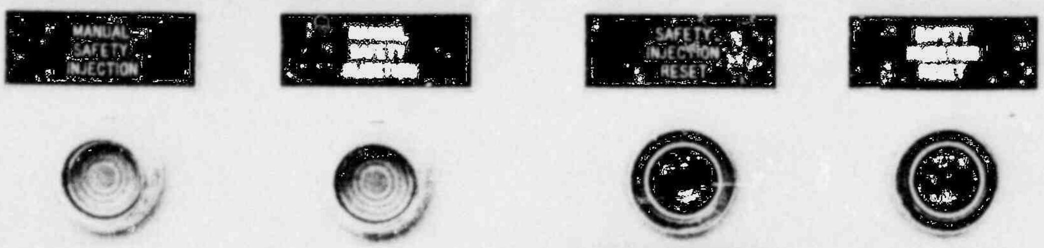


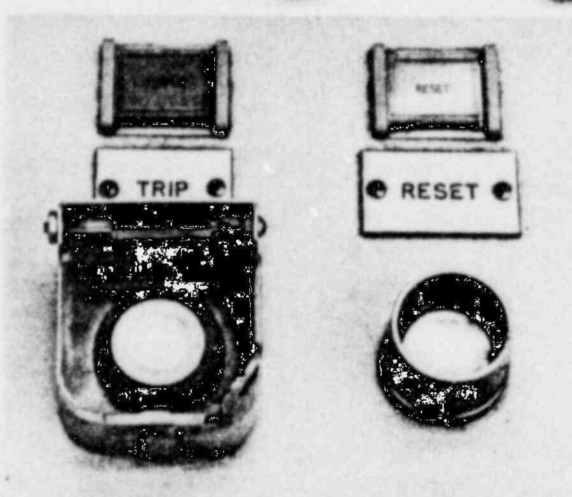
TOGGLE CONTROLS



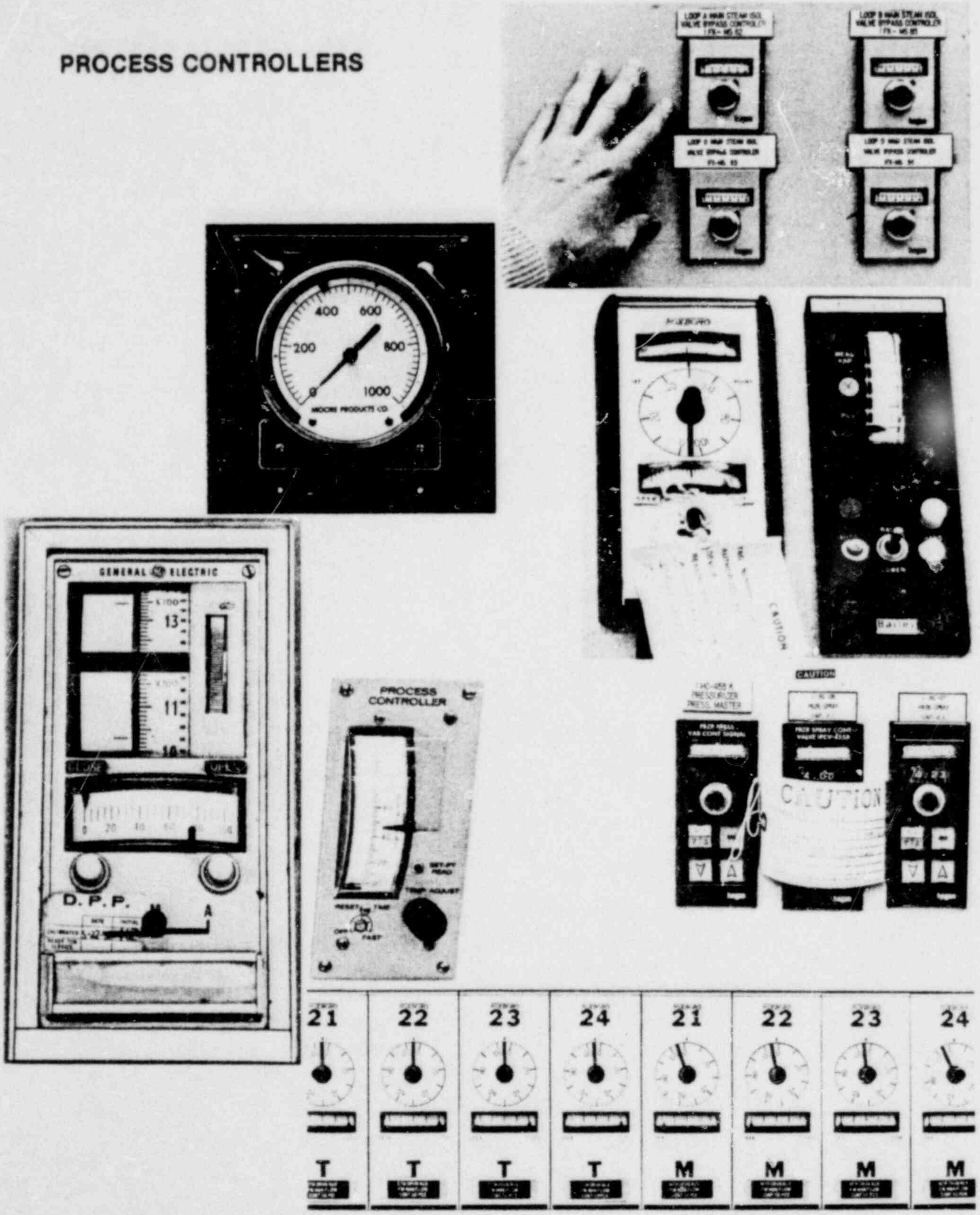
PUSHBUTTONS



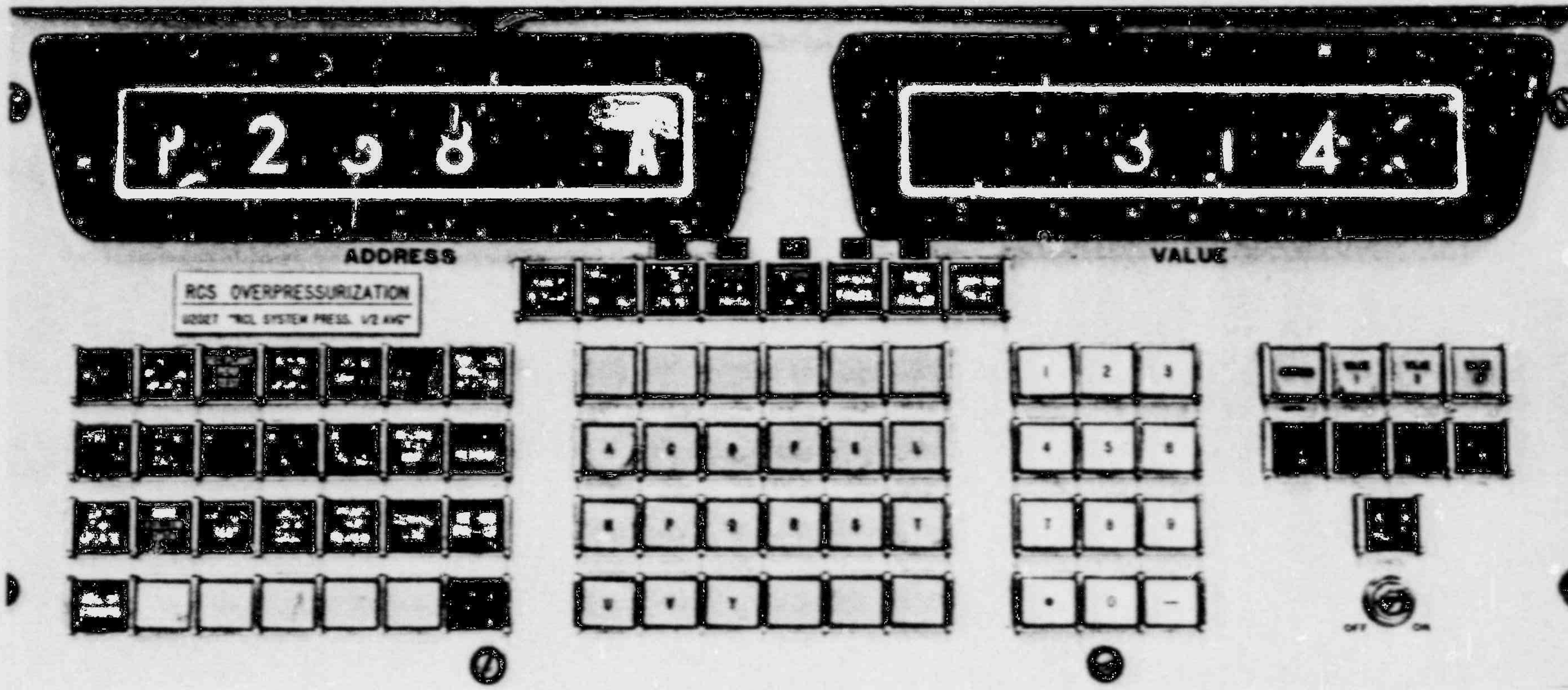




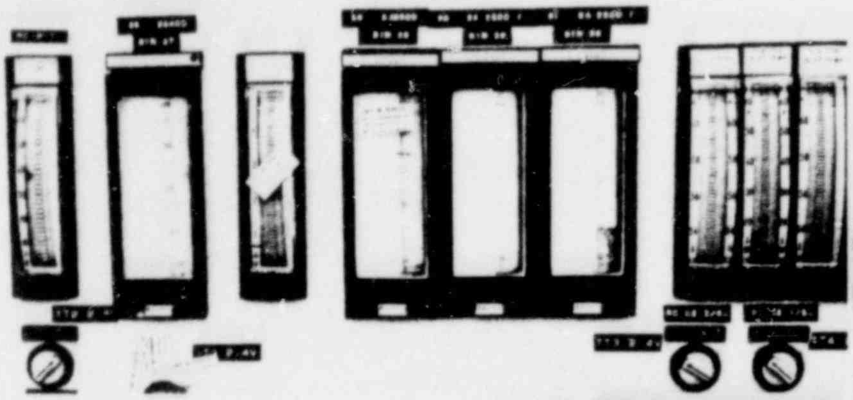
PROCESS CONTROLLERS

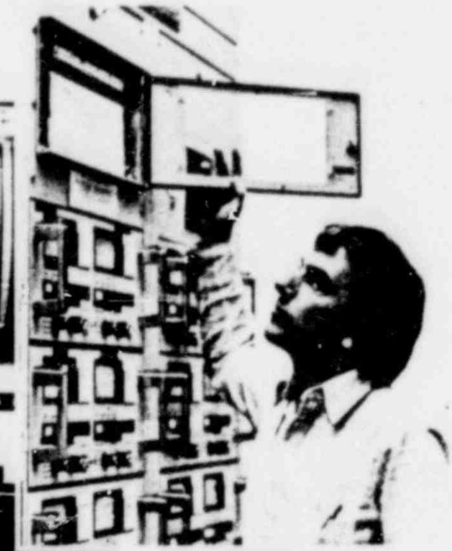


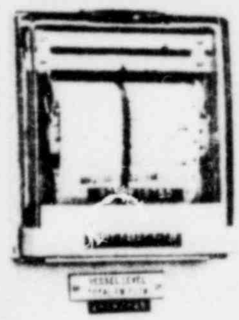
PROJECTION DISPLAYS

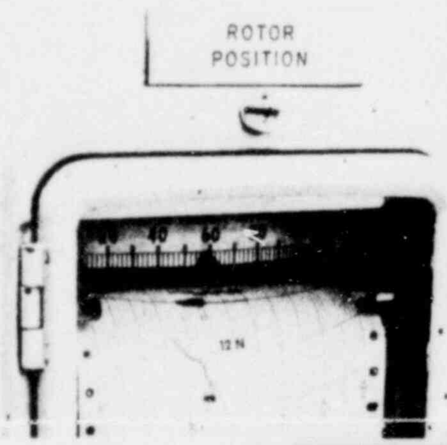


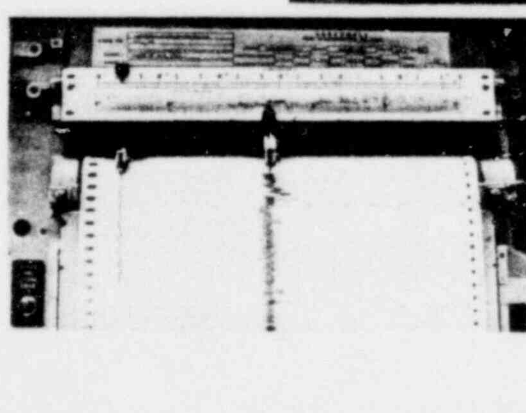
TREND RECORDERS



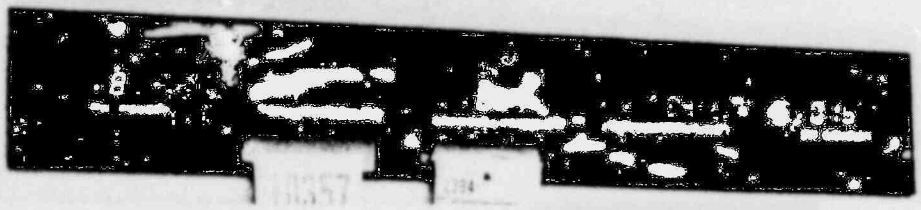


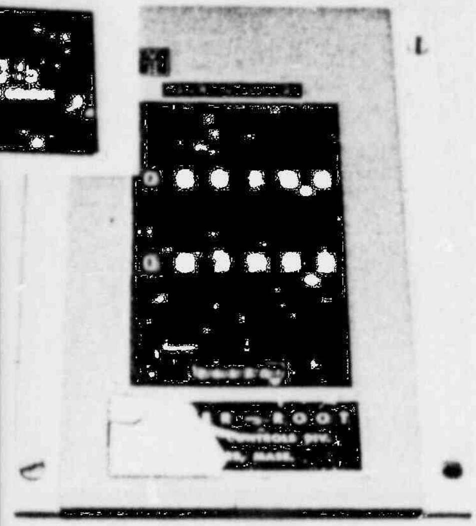


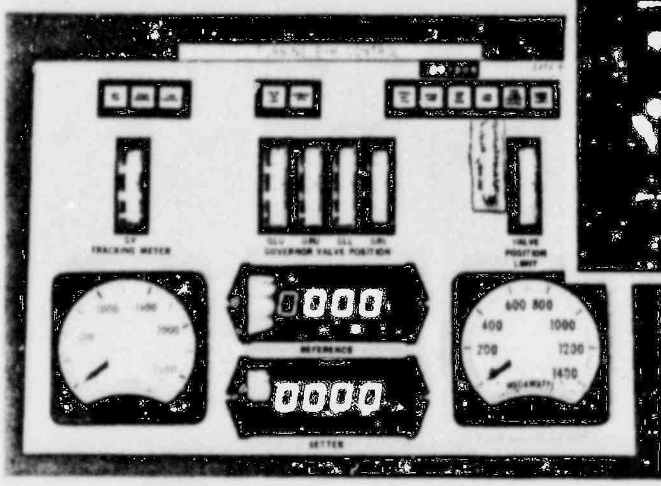




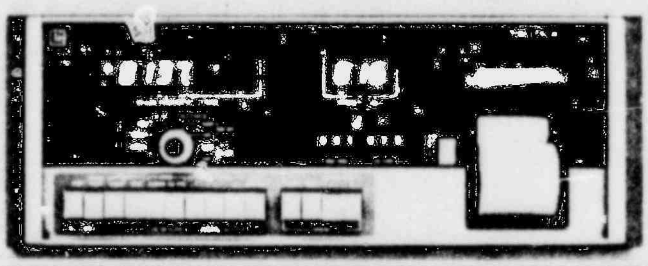
COUNTERS

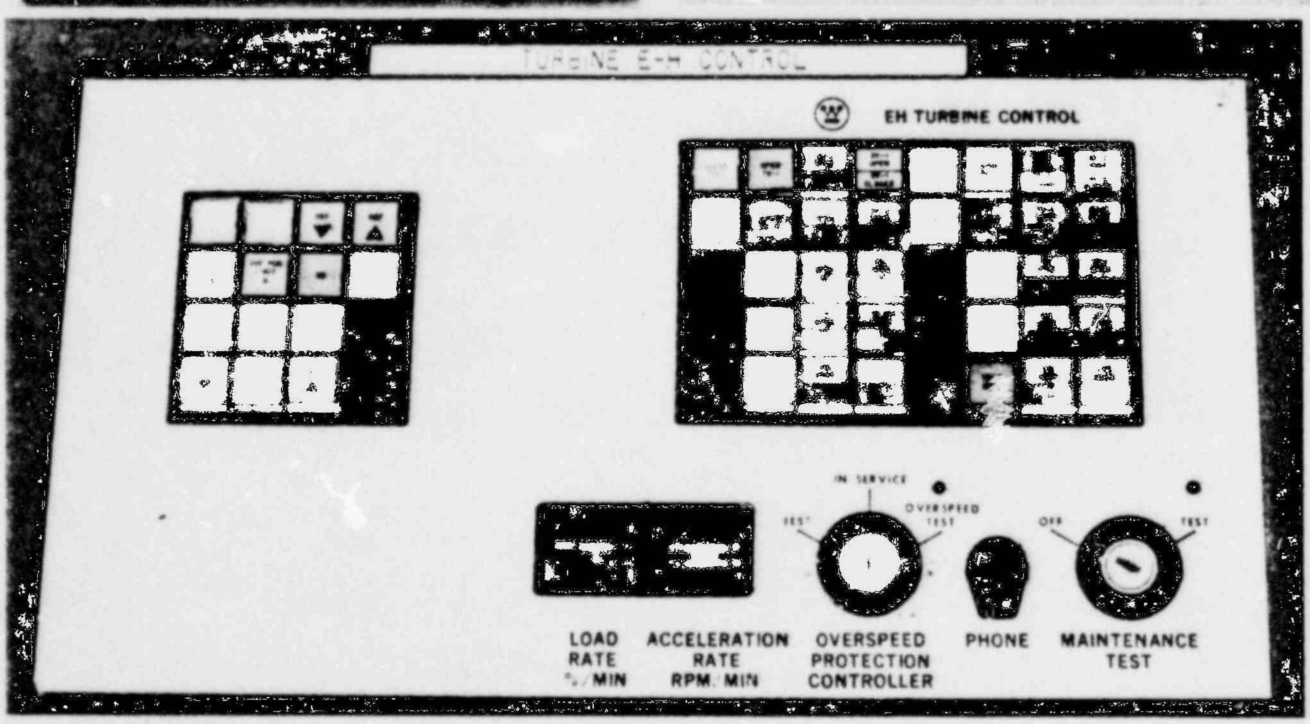




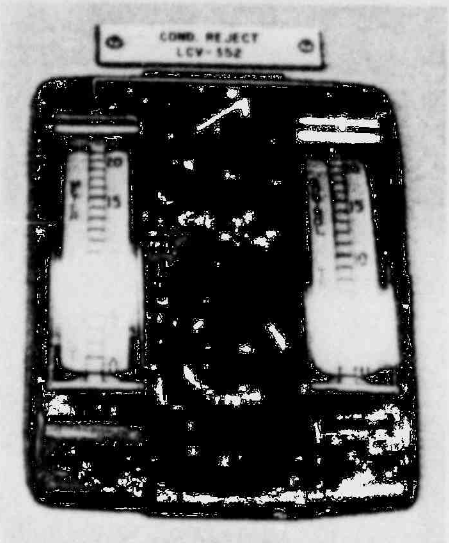


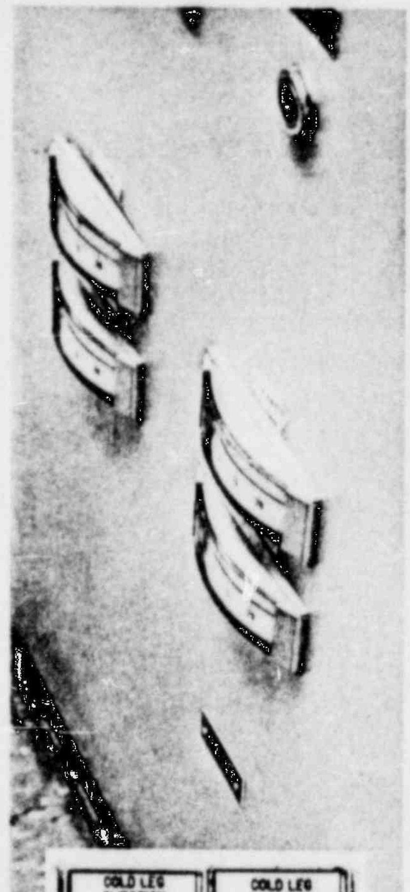

SATURATION

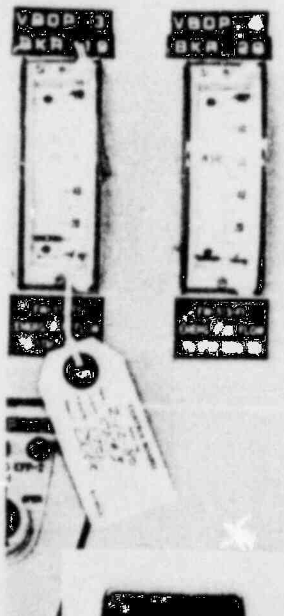


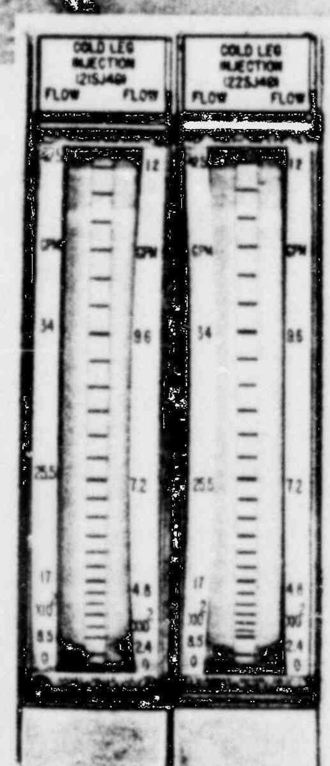

TURBINE E-H CONTROL
EH TURBINE CONTROL
IN SERVICE
OVERSPEED TEST
TEST
OFF
TEST
LOAD RATE %/MIN
ACCELERATION RATE RPM/MIN
OVERSPEED PROTECTION CONTROLLER
PHONE
MAINTENANCE TEST

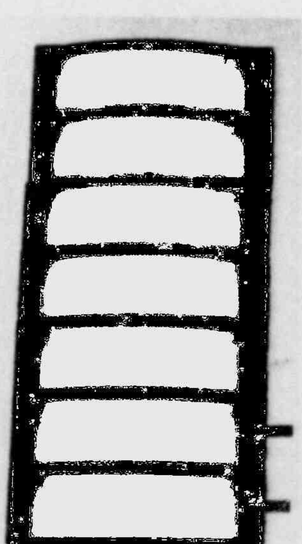
HORIZONTAL & VERTICAL INDICATORS

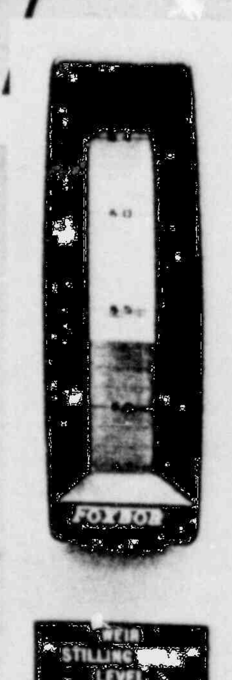


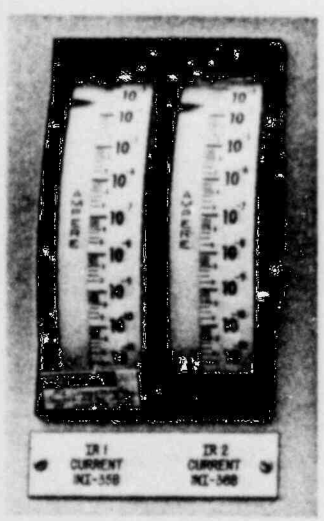






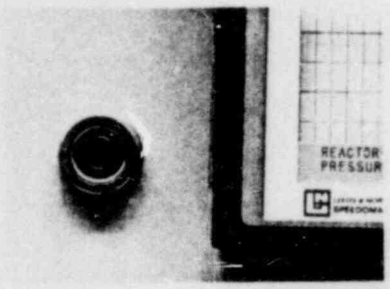


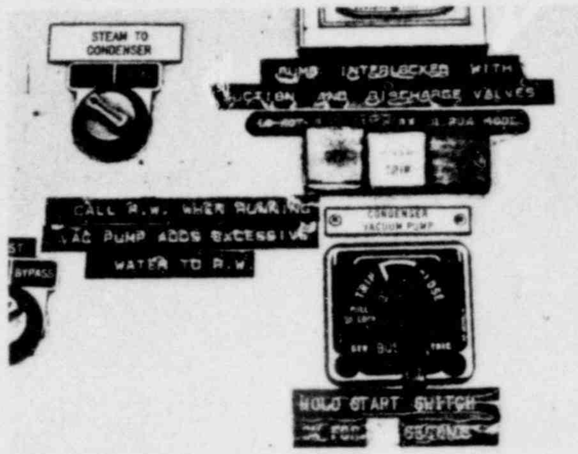


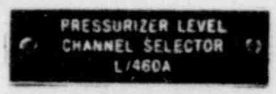


LABELS

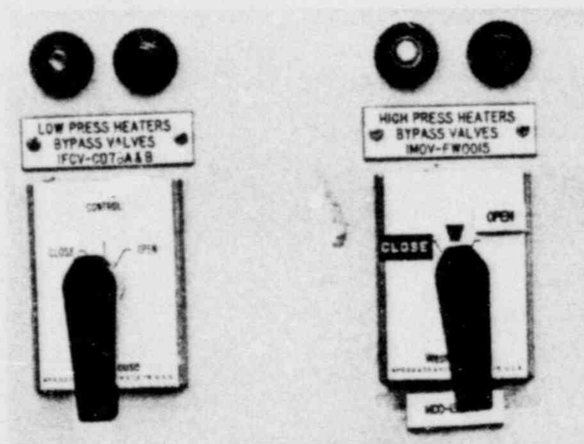

3-WAY VALVE TO

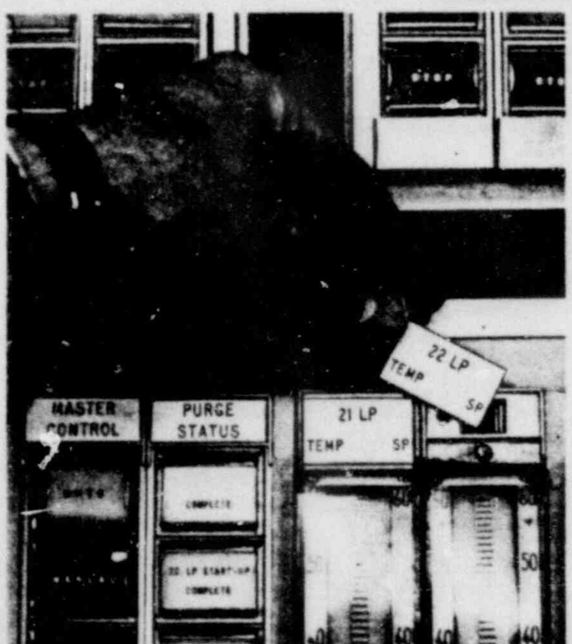

REACTOR
PRESSUR


STEAM TO
CONDENSER
CALL R.W. WHEN RUNNING
VAC PUMP ADDS EXCESSIVE
WATER TO R.W.
CONDENSER
VACUUM PUMP
BYPASS
HOLD START SWITCH


PRESSURIZER LEVEL
CHANNEL SELECTOR
L/460A

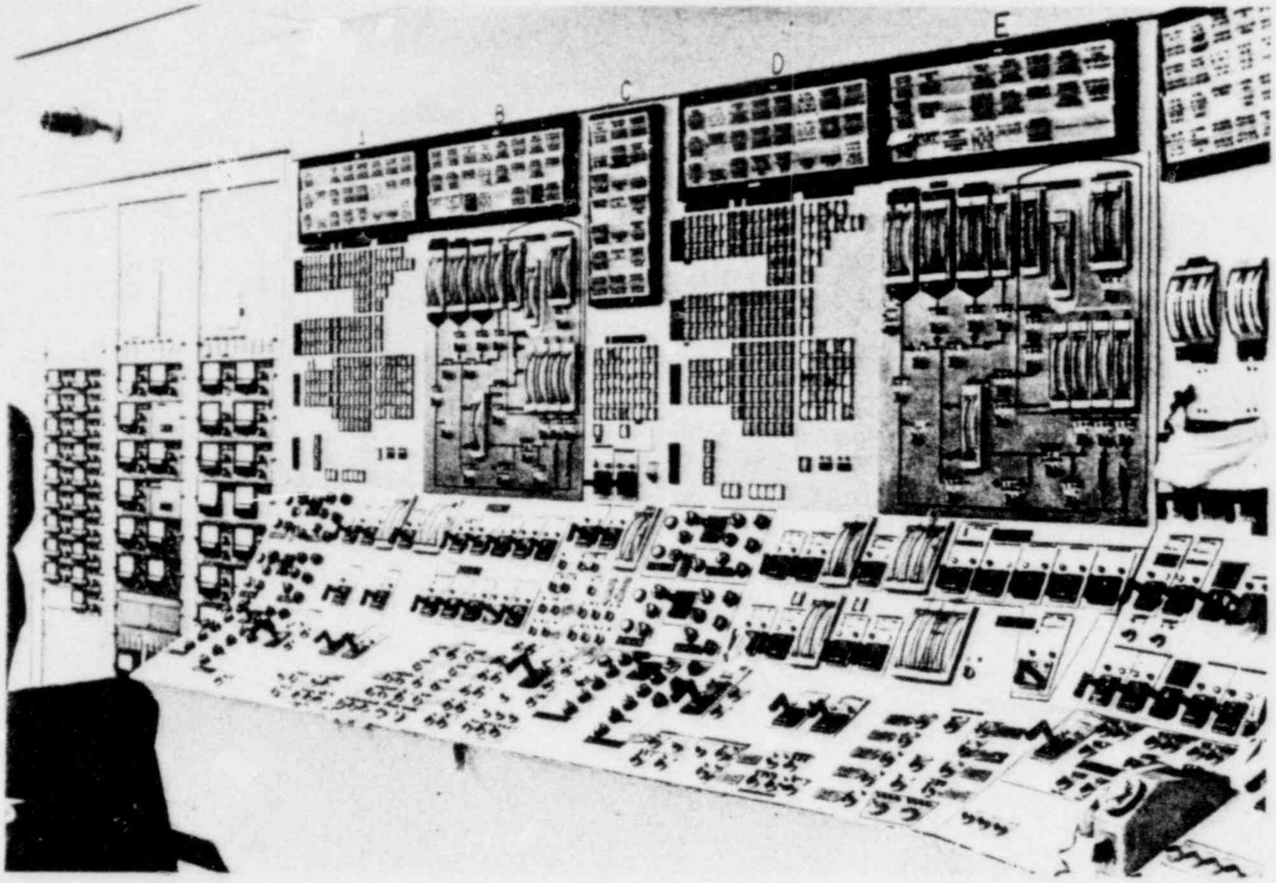

CONTROL
LEVEL/LETDOWN ISOL.
CH I / III
480/461
460

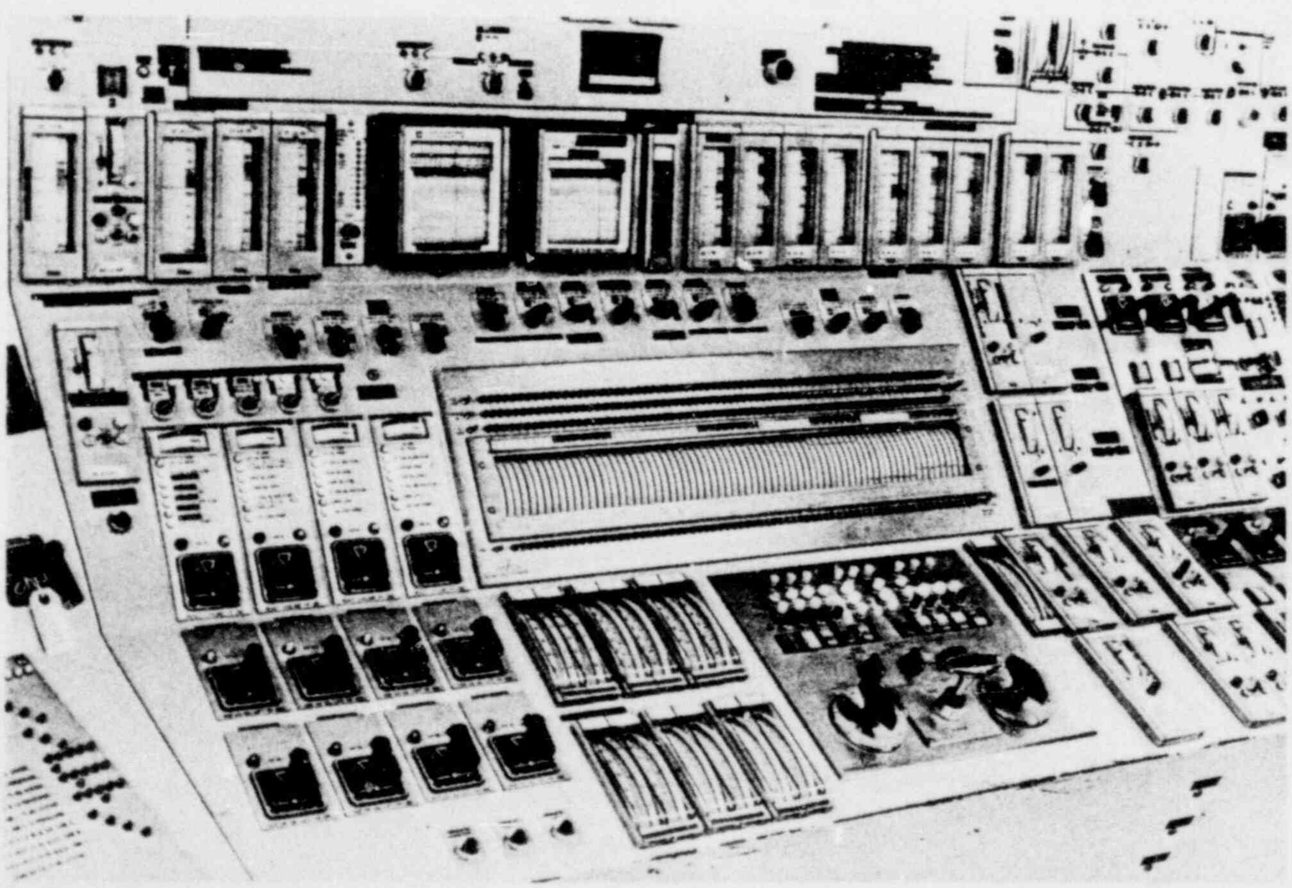

LOW PRESS HEATERS
BYPASS VALVES
HIGH PRESS HEATERS
BYPASS VALVES
IMOV-FW0015
CLOSE
OPEN


22 LP
TEMP
SP
MASTER
CONTROL
PURGE
STATUS
21 LP
TEMP
SP

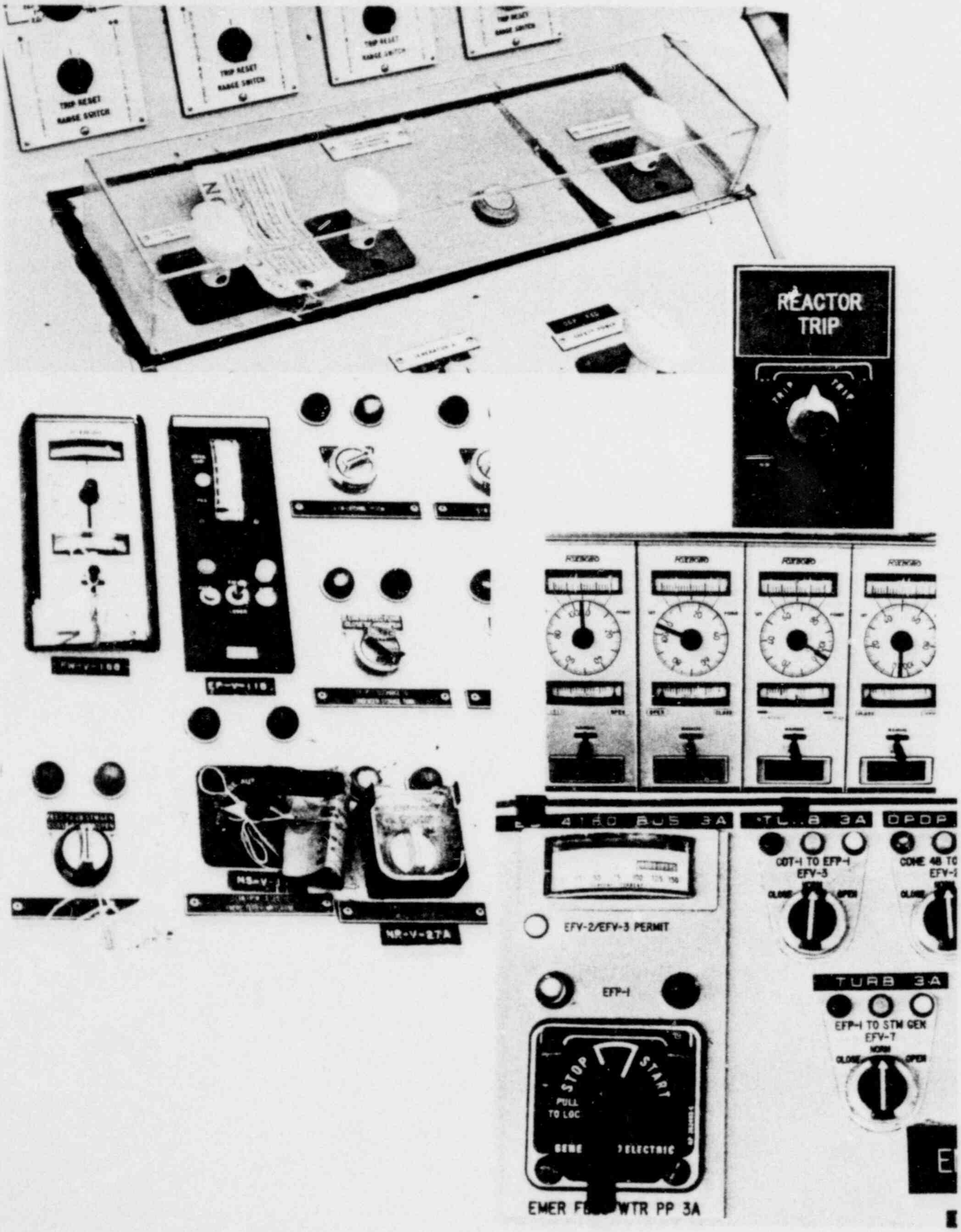

REACTOR TRIP
TRIP B

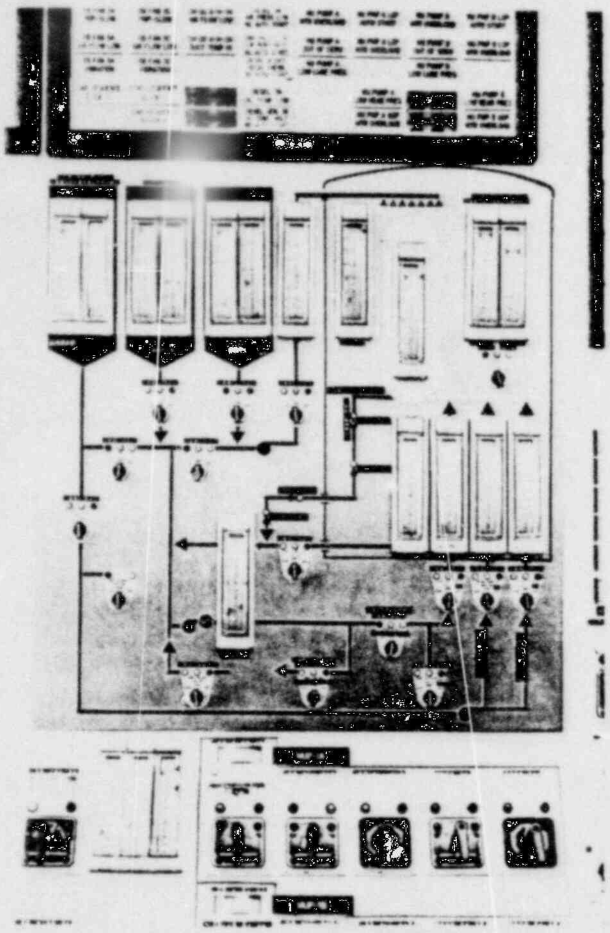
CONTROL AND DISPLAY PANEL



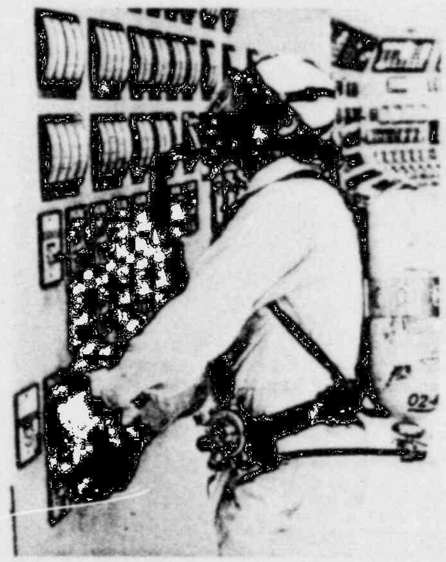


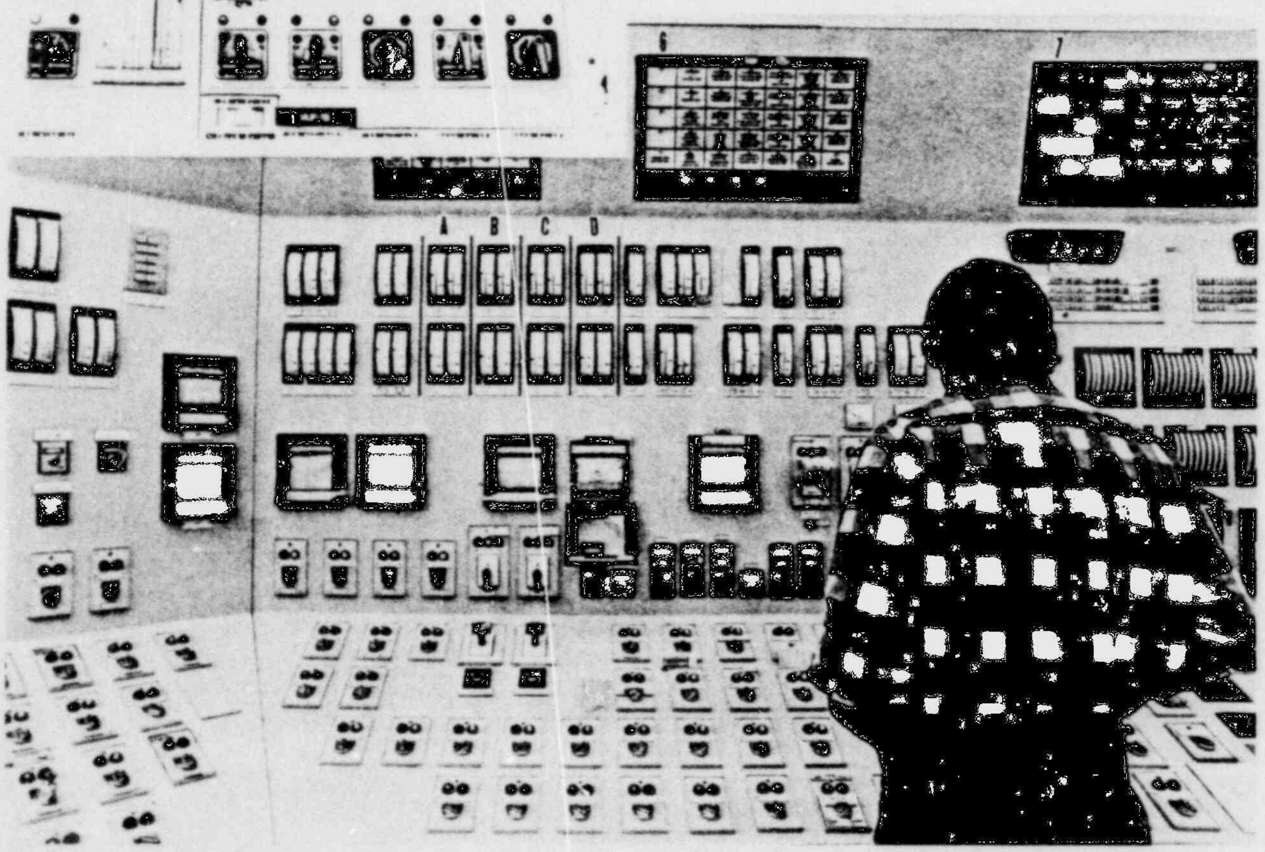
CONTROLS


TRIP RESET
RANGE SWITCH
REACTOR
TRIP
TRIP
TRIP
NR-V-27A
TURB 3A
EFV-2/EFV-3 PERMIT
EFP-1
STOP
START
TURB 3A
EFP-1 TO STM GEN
EFV-7
CLOSE
NORM
OPEN

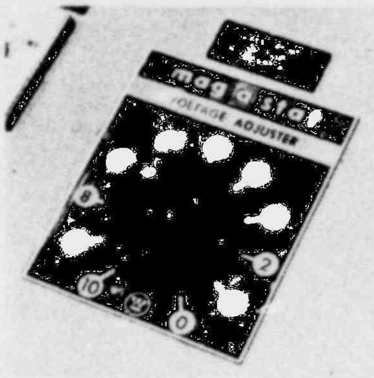


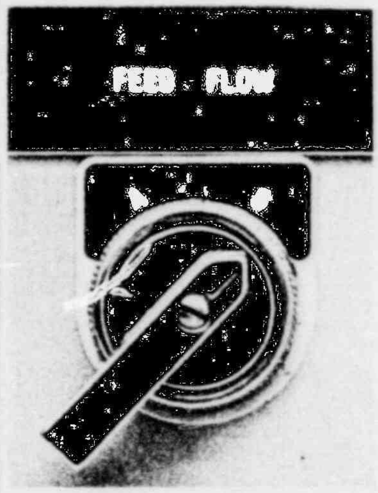
DISPLAYS

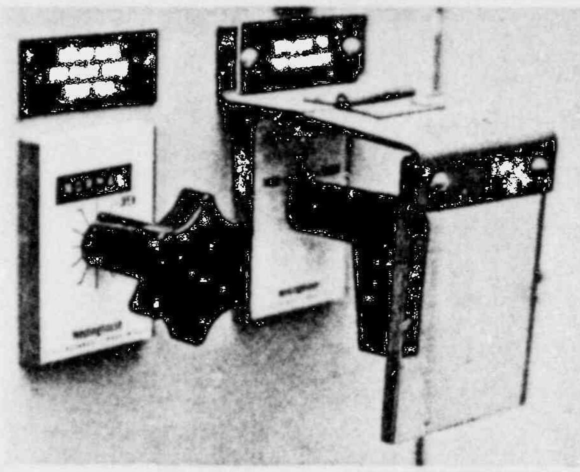


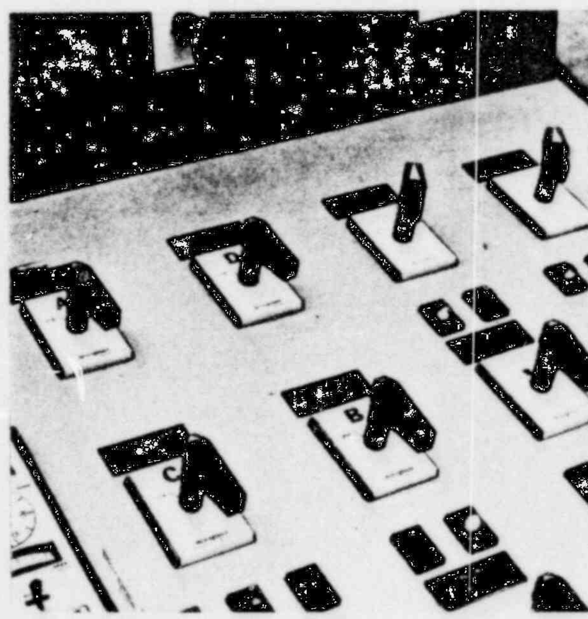


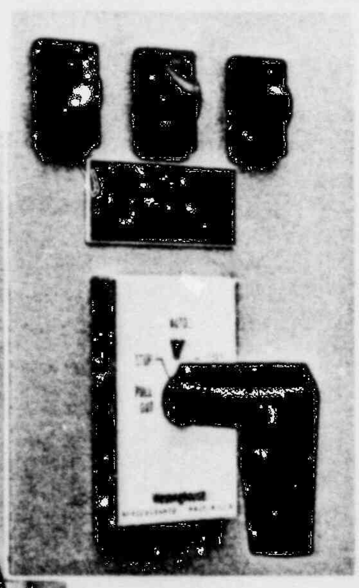
ROTARY SELECTOR SWITCHES

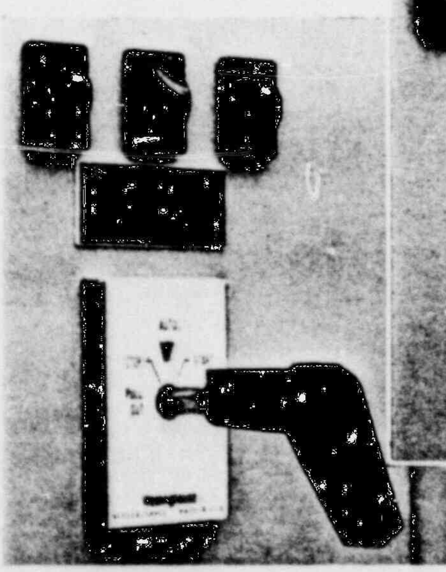


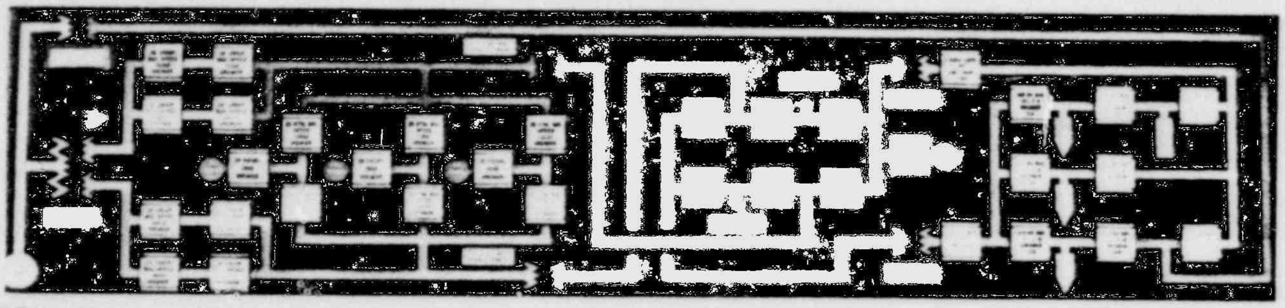




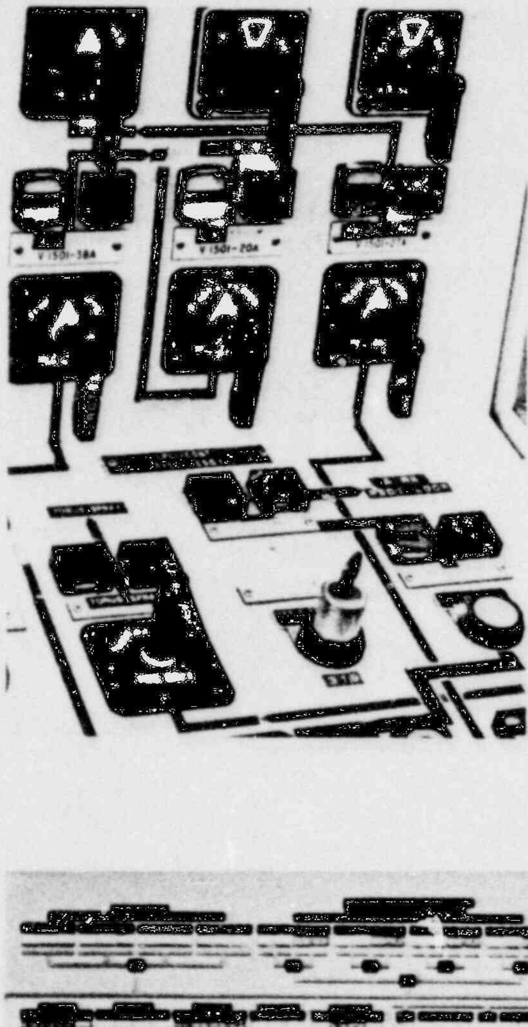


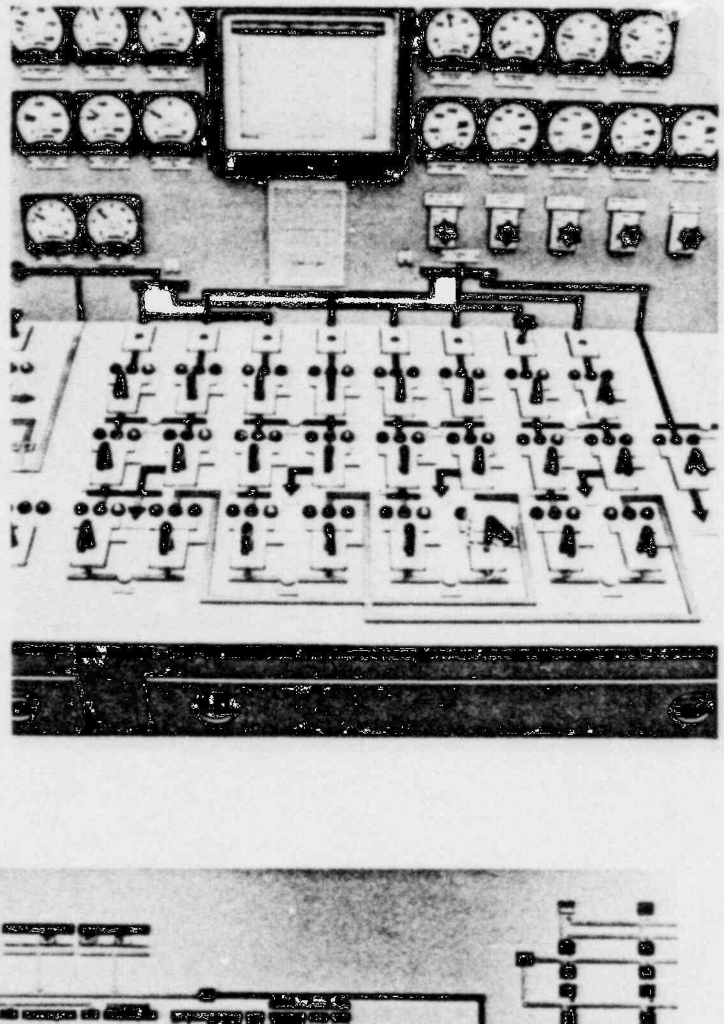


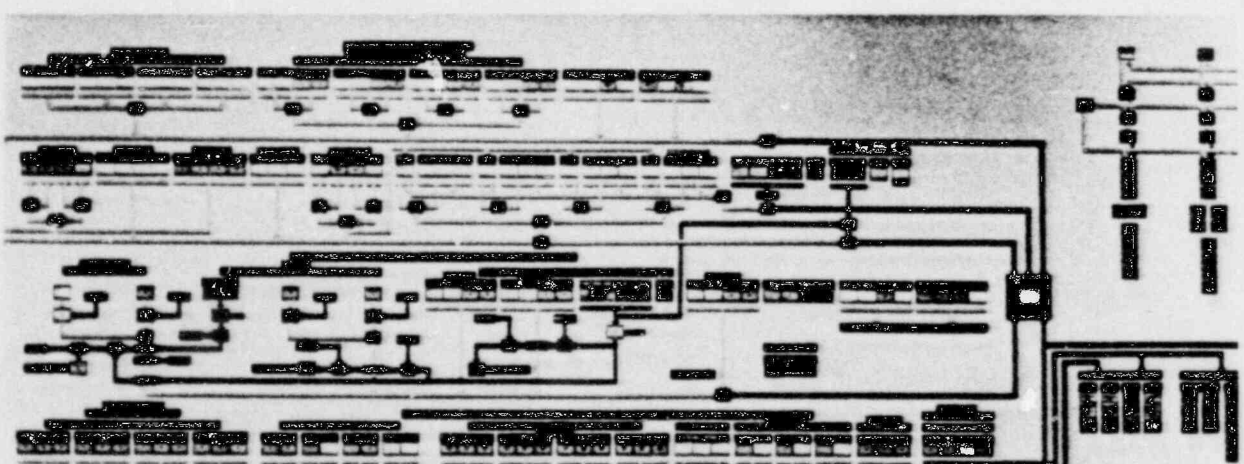




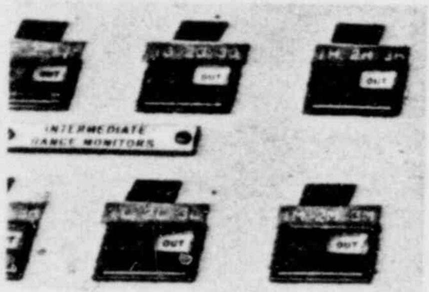
MIMICS

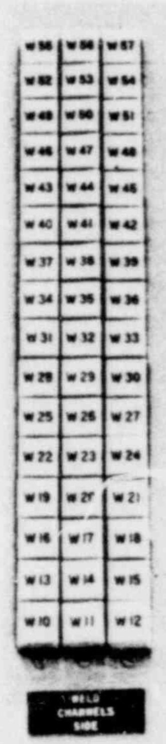


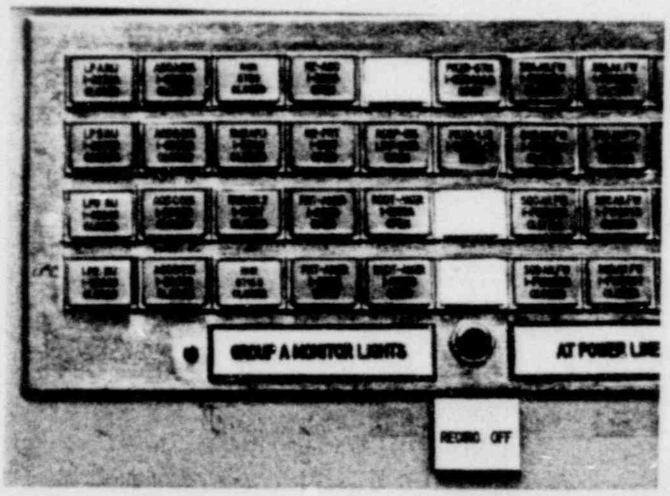


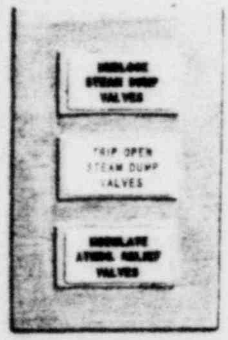


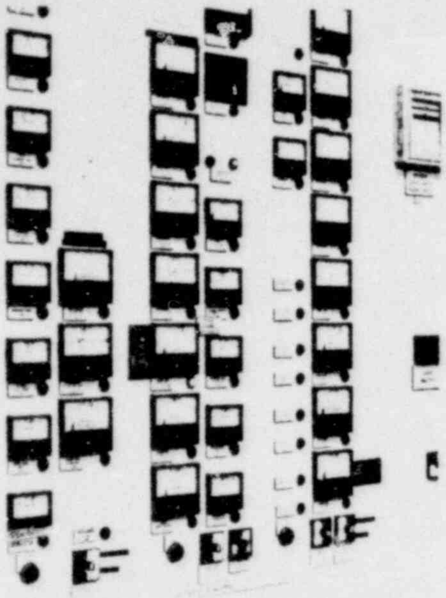
LEGEND LIGHTS



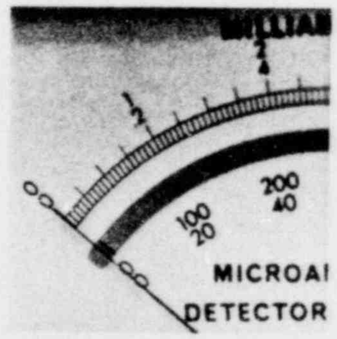


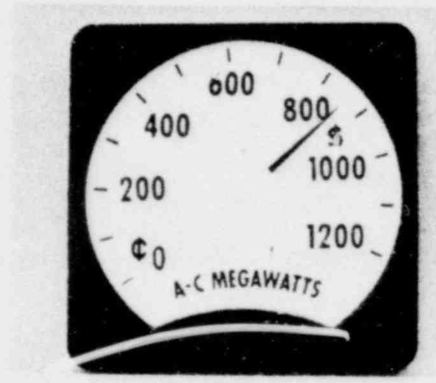


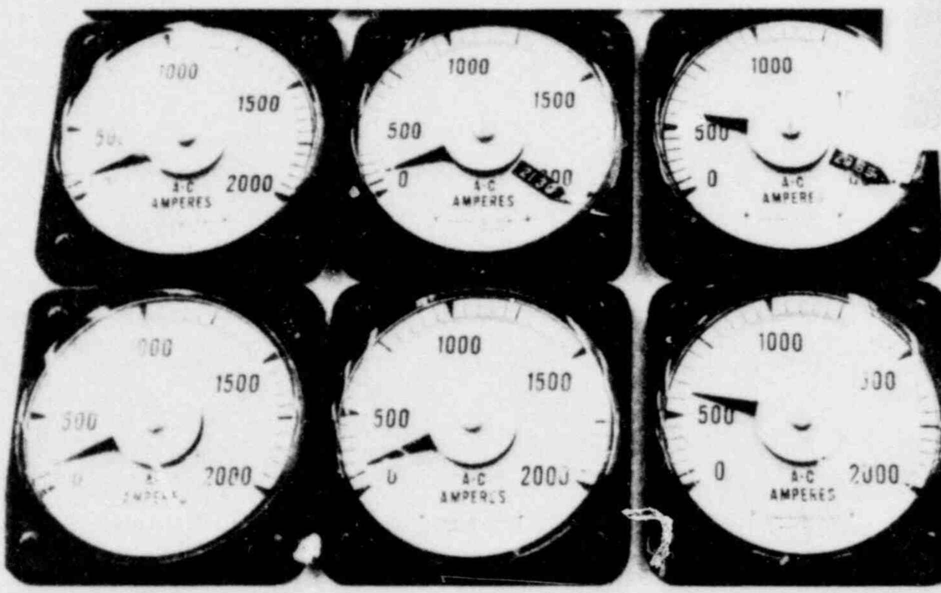


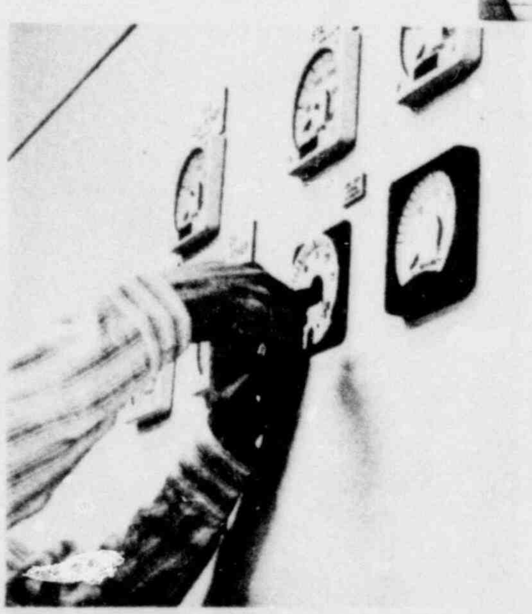


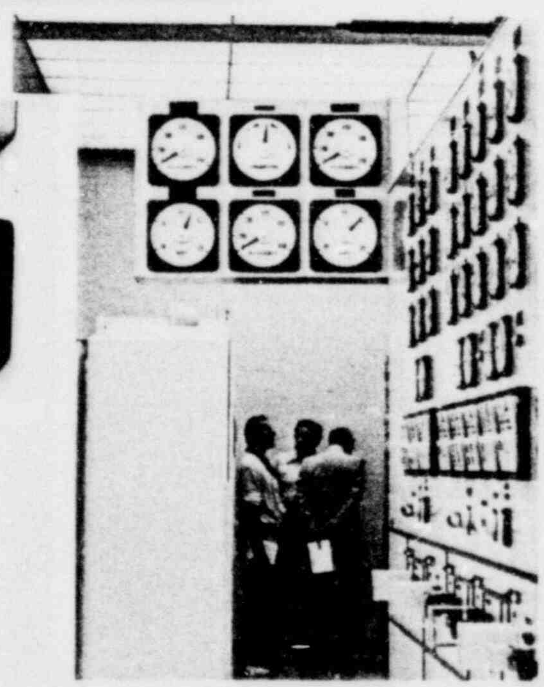
CIRCULAR METERS



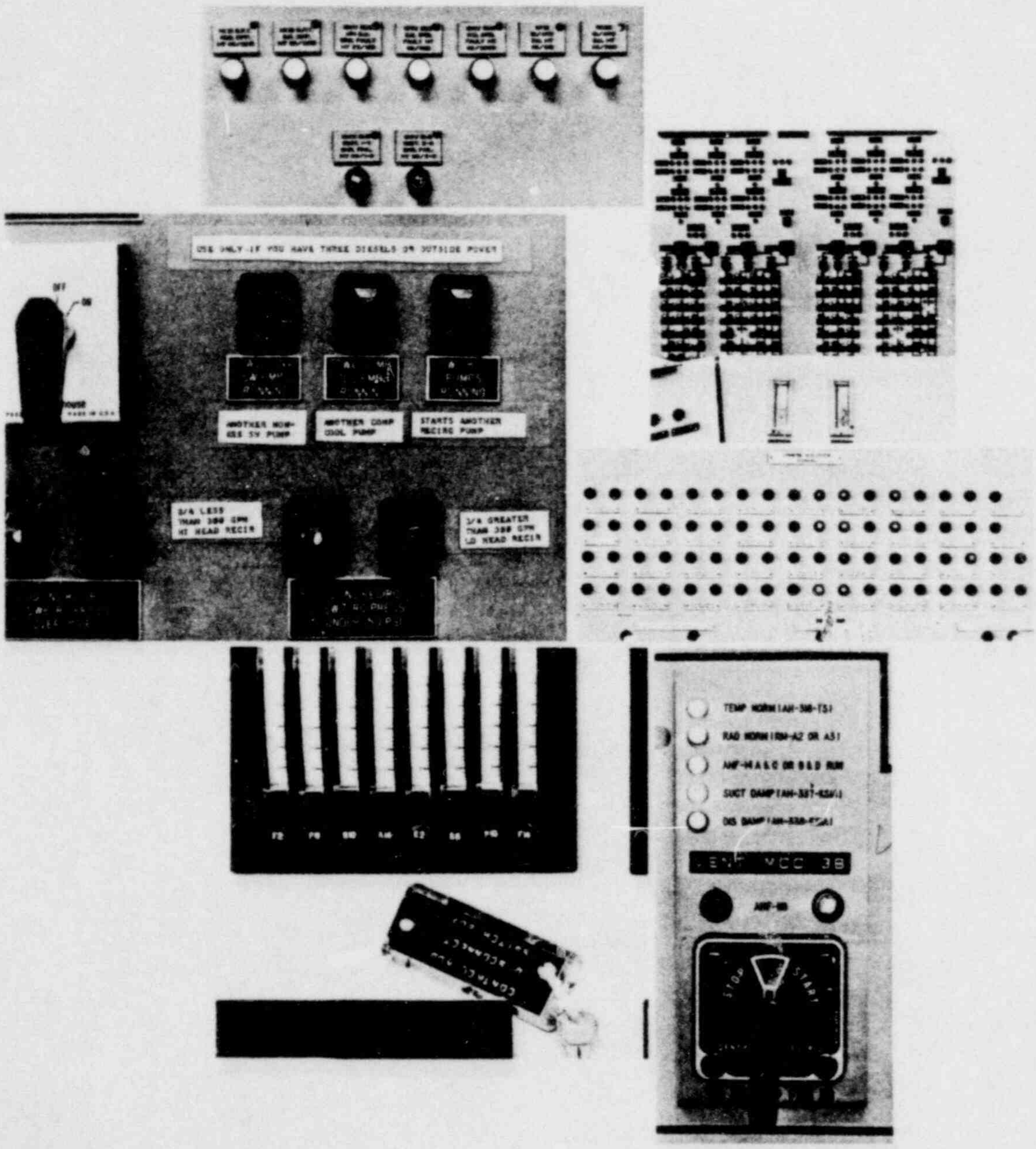








SIMPLE INDICATOR LIGHTS



APPENDIX VI CONTROL ROOM OPERATIONS TASK ANALYSIS

CR/UNIT: ____________________ ANALYSTS: ____________________

PROCEDURE: ____________________

TASK	ACTIVITY	EST. TIME (MIN.)	I	INFORMATION/ COMMUNICATION REQUIREMENTS	CONTROL	INDICATION/ DISPLAY	CONCURRENT/ SHARED TASKS	POTENTIAL ERROR	ERROR IMPACT

APPENDIX VII

PROCEDURES WALK-THROUGH LOG

Plant Name: ______________________________ Date: ______________________________

Camera Operator: ________________________ Analysts: ___________________________

Procedure Name & Number	Walk-Through Number	Tape Number	Footage

APPENDIX VIII
HUMAN ENGINEERING DISCREPANCY

NO: __________ PLANT-UNIT: ____________________ DATE: __________________

REVIEWER NAME: ________________________________

a) HED TITLE: ____

____

____

b) ITEMS INVOLVED:

ITEM TYPE	NOMENCLATURE	LOCATION	PHOTO NO.

c) PROBLEM DESCRIPTION (GUIDELINES VIOLATED):

d) SPECIFIC OPERATOR ERROR(S) THAT COULD RESULT FROM HED:

e) LIST THE PROCEDURES OR OPERATIONS THAT USE THE LISTED ITEMS IN A MANNER TO INDUCE THE OPERATOR ERROR:

f) LIST THE CONSEQUENCES OF OPERATOR ERROR DURING ALL MODES OF OPERATION:

g) SUGGESTIONS FOR POTENTIAL BACKFITS:

	NAME	DATE
REVIEWER		
DATA COLL. MGR.		
HED PROC. MGR.		
EVAL DIR.		

APPENDIX IX
HED PRIORITY DETERMINATION

DATE: ______________

HED NO.: ______________ INTERFACE DESCRIPTION: ______________

ERROR CONSEQUENCE EVALUATION TABLE
(see back for instructions)

PROC.	STEP	SPECIFIED ERROR	CONSEQUENCE OF ERROR	QUESTION							FREQ	P
				1	2	3	4	5	6	7		