DETAILED CONTROL ROOM DESIGN REVIEW

PROGRAM PLAN

FOR THE

VERMONT YANKEE NUCLEAR POWER PLANT

License No. 50/271 DPR 28

Expiration Date 2007

Approved ______________________ 6-14-84
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June 12, 1984

General Physics Corporation
Columbia, Maryland

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SECTION 1. INTRODUCTION

Following the incident which resulted in fuel damage at the Three Mile Island nuclear power plant, the NRC expressed concern that the man-machine interface in the control room may have been a contributing factor. Numerous recommendations and suggested ways to improve this interface in the form of NUREG and REG GUIDES were issued for review and comment. In addition, numerous papers addressing the problem were issued by industry groups. The regulatory requirements were eventually defined in Generic Letter 82-33 and NUREG-0737, Supplement 1, which states:

"Conduct a control room design review to identify human engineering discrepancies. The review shall consist of:

(i) The establishment of a qualified multidisciplinary review team and a review program incorporating accepted human engineering principles.

(ii) The use of function and task analysis (that had been used as the basis for developing emergency procedures Technical Guidelines and plant specific emergency operating procedures) to identify control room operator tasks and information and control requirements during emergency operations. This analysis has multiple purposes and should also serve as the basis for developing training and staffing needs and verifying SPDS parameters.

(iii) A comparison of the display and control requirements with a control room inventory to identify missing displays and controls.

(iv) A control room survey to identify deviations from accepted human factors principles. This survey will include, among other things, an assessment of the control room layout, the usefulness of audible and visual alarm systems, the information recording and recall capabability, and the control room environment."

In addition:

"c. Assess which human engineering discrepancies are significant and should be corrected. Select design improvements that will correct those discrepancies. Improvements that can be accomplished with an enhancement program (paint-tape-label) should be done promptly."

Documentation of these efforts is required as follows:

"a. All licensees shall submit a program plan within two months of the start of the control room review that describes how items 1, 2, and 3 above will be accomplished.

b. All licensees shall submit a summary report of the completed review outlining proposed control room changes, including their proposed schedules for implementation. The report will also provide a summary justification for human engineering discrepancies with safety significance to be left uncorrected or partially corrected."

NUREG-0737, Supplement 1, also addressed several other items of concern which are directly or indirectly related to the control room review. This program plan describes the method by which the Vermont Yankee Nuclear Power Corporation (VYNPC) proposes to conduct a Detailed Control Room Design Review (DCRDR) at the Vermont Yankee nuclear power plant.

The Vermont Yankee plant is a 540 megawatt electric General Electric boiling water reactor located in Vernon, Vermont. It went into operation in 1972 and is licensed to 2007. The operation of the Vermont Yankee plant is directed by the plant manager and his staff at the plant site. The corporate office is located in Brattleboro, Vermont. Engineering support services are provided by the Yankee Nuclear Services Division located in Framingham, Massachusetts.

1.1 Objective

The objective of this program is to review and improve, where necessary, the man-machine interface in the logical sequences of safe nuclear power plant operation in all operational modes. Throughout its years of operation, VYNPC has continued to assess the plant control room with the objective of creating and maintaining a control room environment conducive to safe and efficient operation. This process is accomplished by a continuing review of means to provide unambiguous information to the operator thereby minimizing any difficulties in determining the plant status. Prior to TMI, this process was conducted in an informal manner. Subsequent to the TMI incident, and as a result of later requirements imposed by the NRC, the process is being formalized.

Vermont Yankee's program for maintaining and improving the man-machine interface in the plant control room is long standing. Certain steps in the program have already been accomplished. The following paragraphs describe the events already completed at the time of the submittal of this program plan, as well as those planned for future implementation.

1. A preliminary evaluation of the control room was conducted by an engineering contractor using MIL-STD-1472B as a reference. Certain modifications were recommended but no significant safety hazards were discovered which required that immediate action should be taken.

2. A complete control room review was conducted by a team under the direction of the BWR Owners Group (BWROG). This consisted of a survey of all the control room panels, the control room environment, and operating reports as well as a series of operator interviews and a task analysis. The review was conducted in accordance with a prescribed procedure, used standard forms and was documented in a summary report. This team consisted of several engineering and operational personnel of other utilities who operate boiling water reactors, human factors engineers and representatives of the reactor

vendor, General Electric. Subsequent to this review, a supplemental review was suggested by the BWROG to address concerns of the NRC.

3. A review of all modifications to the control board and control room subsequent to the BWROG survey will be conducted. These modifications will be evaluated against the same checklists used in the original survey. This will result in a complete survey which is current and will include the Alternate Shutdown panels, recently installed in response to the requirements of Appendix R. These panels are located outside of the control room.

4. A supplemental survey of the control board will be done using checklists provided by the BWROG. This survey responds to a request by the NRC to the BWROG that the original survey method be augmented.

5. A Task Analysis using the newly developed Emergency Operating Procedures (EOPs) will be conducted.

6. Human Engineering Discrepancies (HEDs) resulting from all previous steps will be combined into a numbered list, classified and prioritized.

7. Conceptual modifications will be developed to address those HEDs from Step 6 and submitted for review by the management team.

8. Following management team approval of the recommended modifications, a summary report will be prepared which will:

    a. Explain in detail the steps taken in the discovery and resolution of the HEDs. Procedures and findings will be included.

    b. Provide the list of HEDs and a schedule for implementation of those HEDs deemed worthy of correction.

The general layout of the control room and its interior components are shown on Figure 1.

This Program Plan describes a method of completing the DCRDR to meet obligations of Generic Letter 82-33. It incorporates reviews previously completed. All reviews, whether done prior to the creation of this program plant or subseqeuntly, were done in accordance with written procedure and thoroughly documented.

1.2 Scope

The scope of the DCRDR consists of the following activities:

- A review of historical operational information.
- A representative series of operator interviews.
- A complete review of the control board.
- An evaluation of the control room environment.
- Documentation and evaluation of any enhancements or modifications suggested by the previous steps.
- A task analysis, using the EOPs.
- Documentation, evaluation and prioritization of HEDs revealed by these steps.
- Development of conceptual design modifications, where required.
- Evaluation of these modifications to determine if they resolve the HED and to assure that no new HEDs are created.

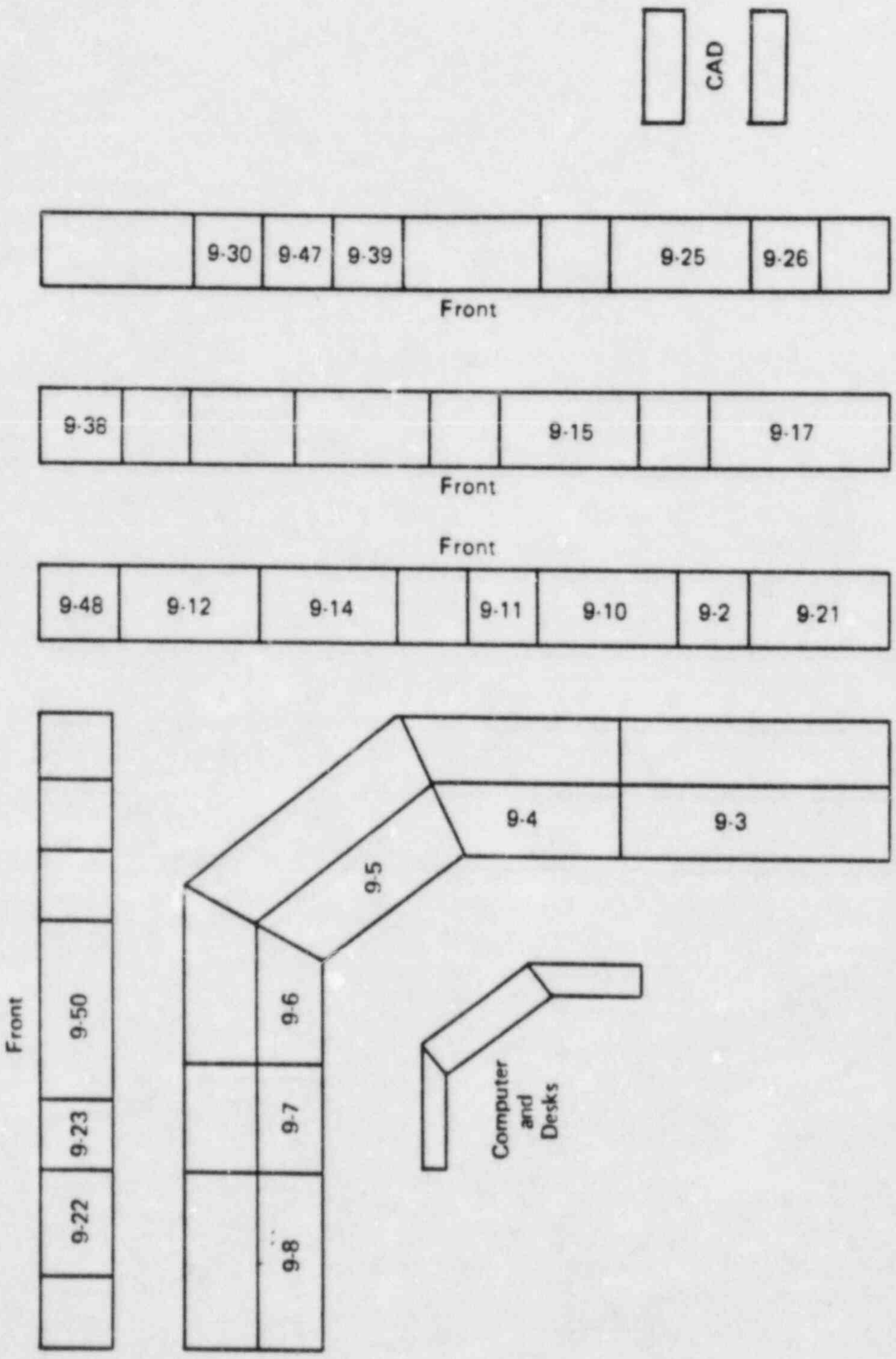

Figure 1. Vermont Yankee Control Room Arrangement

- A summary of the entire process, the findings, a description of any resulting modifications, and a schedule for implementation which will be provided to the NRC.

These items are described in greater detail in Sections 4 and 5.

1.3 Schedule

A schedule depicting the sequencing and duration of major tasks in the Vermont Yankee DCRDR process is shown in Figure 2.

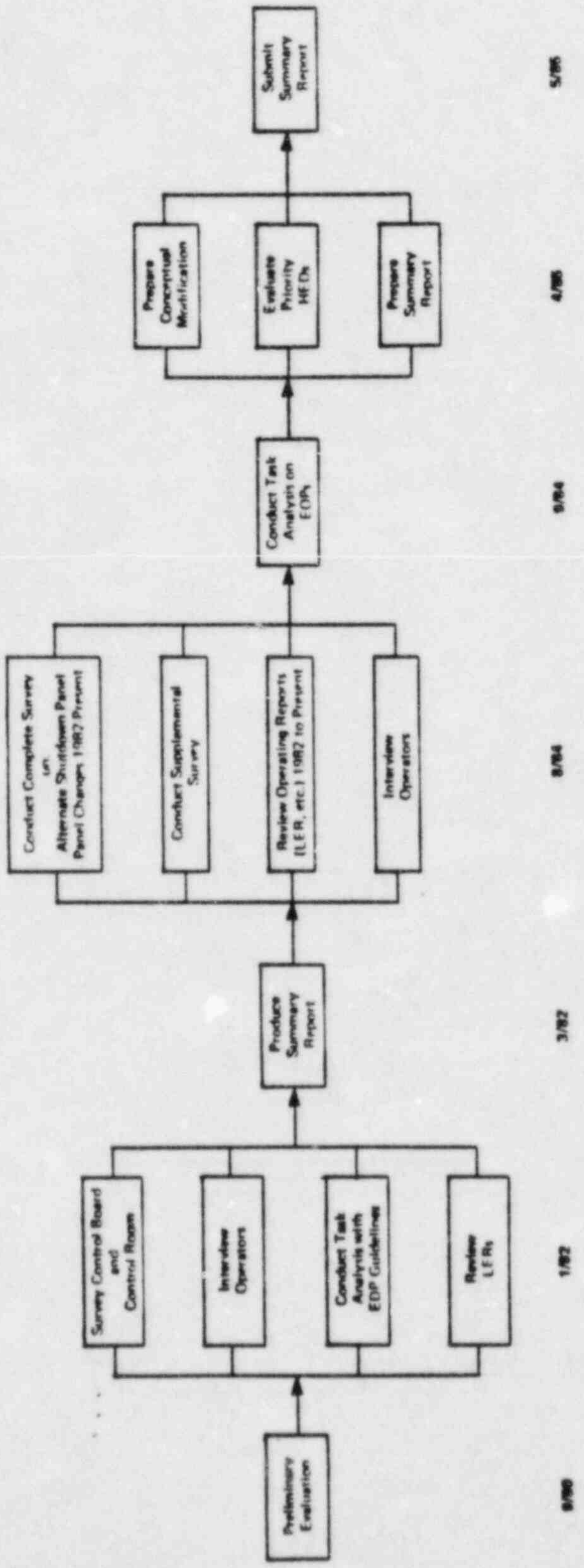

Figure 2. Schedule of DCRDR Activities

SECTION 2. MANAGEMENT AND STAFFING

Chapter 2 of the DCRDR Program Plan addresses the management and staffing aspects of the review. Section 2.1 describes the structure of the Review Team. Section 2.2 describes the qualifications of the Review Team. A discussion of how the DCRDR interfaces with and is integrated into the other human factors activities is contained in Section 2.3.

2.1 Structure of the Review Team

Two review teams have been formed as shown in Figure 3. A Management Review Team has overall responsibility for the program, its implementation, the resolution of its findings, and the authorization of its recommendations. To accomplish this, they direct the efforts of a Design Review Team which will evaluate all previous findings, conduct supplemental and additional reviews as needed, conduct the Task Analysis, evaluate all findings, propose suitable modifications, and prepare the summary report. The Design Review Team will be supplemented by additional personnel as needed.

The Design Review team will have a core group of specialists in the fields of human factors engineering, plant operations (e.g., licensed operators), and instrumentation and controls engineering; the core group will also include personnel who are cognizant of the related issues of NUREG-0737. This core group may be supplemented by personnel from other disciplines such as nuclear, mechanical, electrical, and civil engineering if required.

2.2 Qualifications of the Review Team

The qualifications of key review team members will be as follows:

- Human Factors Specialist: A degree, at the graduate level, in human factors engineering is recommended. Vermont Yankee will obtain the services of a human factors specialist and will use some of the following criteria during the selection process. Experience in the application of human factors principles to design and/or evaluation

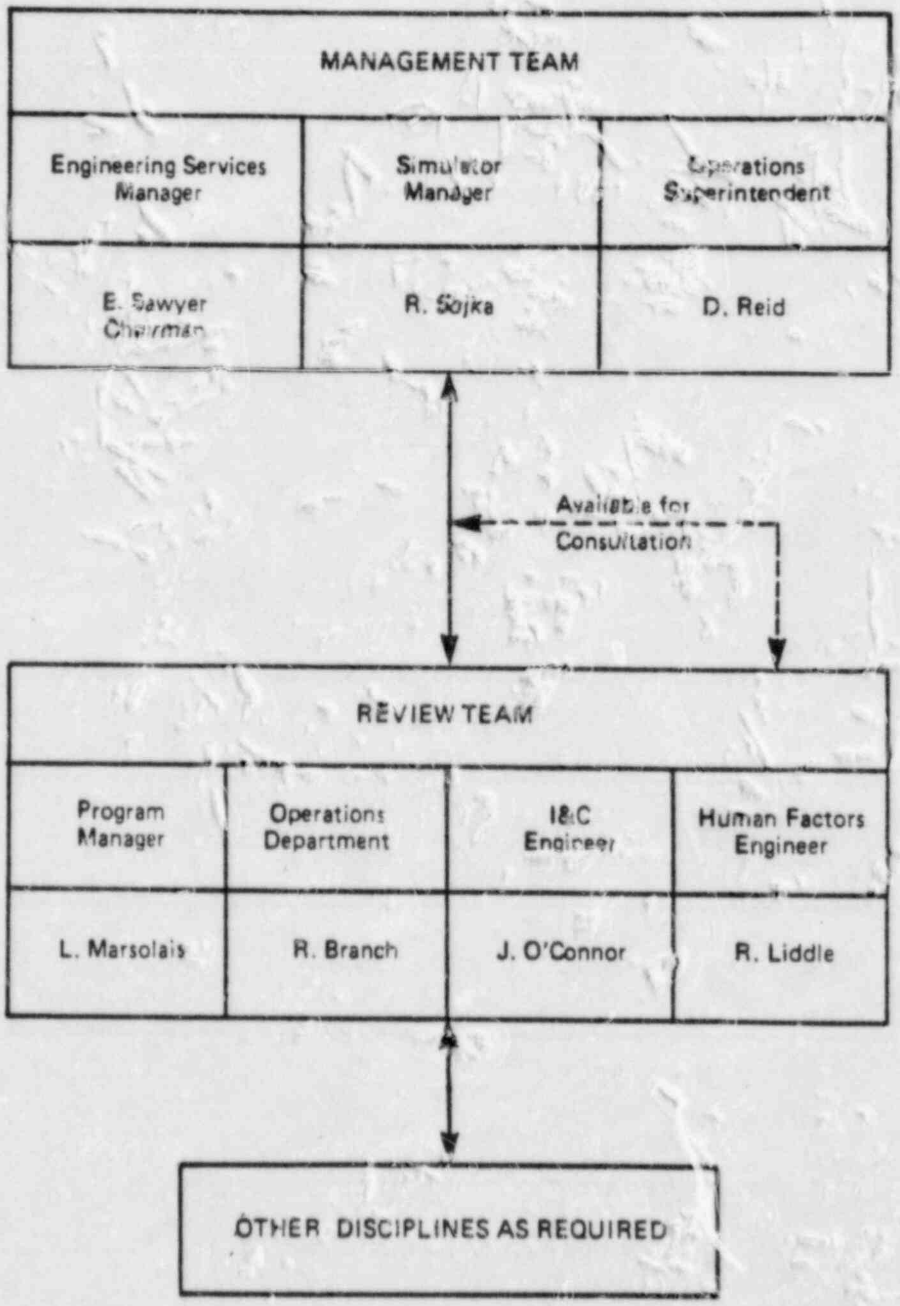

Figure 3. Review Team Structure

of systems and equipment in the power industry is preferred. Workspace layout, panel and instrumentation design (controls and displays) environmental conditions (e.g., lighting and acoustics), and procedures and training are areas of specific emphasis. Experience in systems analysis and task analysis must be within the capabilities of the human factors professionals on the team.

- Reactor Operator: A currently licensed senior reactor operator with a minimum of two years' experience in the Vermont Yankee control room being reviewed will be included on the Control Room Design Review team.

- Instrumentation and Control Engineer: A bachelors degree in electrical engineering and at least five (5) years experience in design of instrumentation and control systems with experience in the display of information will be included on the Control Room Design Review team.

- Program Manager: The Design Review Team will be directed by a Program Manager who shall have knowledge and experience in reactor plant operations, be knowledgeable in the engineering and regulatory requirements and have demonstrated administration and management skills.

- Other Disciplines: A bachelor's degree in the specific discipline will be provided as a minimum. A minimum of three years of applied design or operating technical experience is recommended. Professional licenses or certification and appropriate society memberships provide additional evidence of the experience level desired. Experience at nuclear plants or other process control applications is preferred. Alternatively, experience with other complex commercial, industrial, or military facilities and systems will be considered acceptable.

2.3 Integration of the Control Room Design Review With Other Human Factors Activities

The DCRDR Project will interface with and/or reference previous and ongoing human factors efforts at the Vermont Yankee Nuclear Power Plant. A description of some of the work is provided below.

2.3.1 Wyle Survey

A preliminary survey of the Vermont Yankee control room was performed by Wyle Laboratories in August 1980. Findings from the survey will be reviewed and included, as found applicable, in the final results.

2.3.2 BWROG Control Room Survey Program

In January 1982, the BWROG conducted a control room survey at Vermont Yankee. A team comprised of operations and engineering personnel from several utilities performed the checklist survey with the assistance of consultants from General Electric Company and the Massachusetts Institute of Technology. The survey consisted of four phases: (1) an analysis of plant LER's and scram reports to identify possible design-related operator errors, (2) interviews with approximately one-third of the plant operators, (3) panel evaluations using checklists developed from previous surveys and accepted human factors standards, and (4) task analyses and walkthroughs of selected emergency procedures. The result of the survey was a summary report and a completed checklist.

The intent of the BWROG Control Room Survey report for Vermont Yankee was to identify areas of control room design for which modifications should be considered. These were stated as general suggestions with the understanding that any corrective action should be considered on a control room wide basis.

Vermont Yankee is currently responding to the requirements set forth in Supplement 1 to NUREG-0737. This DCRDR Program Plan is the first step in responding to the DCRDR requirements (Section 5 of Generic Letter 82-33).

2.3.3 Supplement 1 to NUREG-0737 Activities

Given the integrative nature of Generic Letter No. 82-33, the DCRDR process will be coordinated with other post-TMI activities that are addressed in the letter. The results of the DCRDR project can be utilized in specific applications as discussed below:

- EOPs - A portion of the DCRDR (the Systems Function Description and Task Analysis) will use the Vermont Yankee-specific EOPs as its basis. It is assumed that the EOPs will be fully verified and approved before use in the DCRDR portion of the Task Analysis. Thus, examination of the EOPs will inherently integrate their upgrading with the DCRDR.

- SPDS - Vermont Yankee has no device specifically identified as an SPDS. Safety parameters are prominently displayed both on the control board and on the plant process computer. The findings of the DCRDR project may result in additional methods of display of these parameters on either the control board or the plant process computer.

- Reg Guide 1.97 - The Verification of the Task Performance Capabilities portion of the DCRDR systematically verifies the presence or absence of information required by the operator during emergency operations. The results of this process will give insight into the monitoring instrumentation that is available to the operator and, conversely, if any type of indication is required but missing. This information will be available for use in responding to the needs of Reg. Guide 1.97.

SECTION 3. DOCUMENTATION AND DOCUMENT CONTROL

A large number of documents will be referenced and produced during the DCRDR. Therefore, an efficient and systematic method for controlling these documents is necessary.

3.1 Documentation Requirements

The documentation methodology described in this section will be utilized to meet the following requirements:

- Provide a record of all documents used by the review team as references during the various phases of the DCRDR.
- Provide a record of all documents produced by the review team as project output.
- Provide a systematic method to document all identified HEDs and their resolution.
- Develop project files in a manner that allows future access to help determine the effects of control room changes proposed in the future.

Documentation collected during the DCRDR project will be maintained in the Vermont Yankee files at the Yankee Atomic Electric Co., Nuclear Services Division.

3.2 Input Documentation

The following documents have been identified as primary reference material which may be used during the review process. As the review progresses it is anticipated that additional material will be identified and referenced. Therefore the following list of documents, if available, is preliminary.

- Licensee Event Reports
- Scram Reports
- Plant Information Reports
- Final Safety Analysis Report (FSAR)
- Systems descriptions
- Piping and instrumentation drawings
- Control room floor plan
- Panel layout drawings
- Panel photographs
- BWROG Generic Emergency Procedure Guidelines (EPGs)
- Vermont Yankee Plant-Specific EOPs
- Applicable Design Change Descriptions

3.3 Output Documentation

Throughout the review process standard forms will be used to record data, and to document analyses and record findings wherever possible. All of the documentation produced during the course of the review will be controlled in accordance with the procedures described in Section 3.4. The following list represents a preliminary estimate of the types of documents that will result from the DCRDR project:

- Detailed Control Room Design Review Program Plan
- Project Schedule
- Operator Questionnaire
- Operating Experience Review Report
- Panel Checklists
- Task Analysis Worksheets
- List of HEDs assessed according to their safety implications
- Photographs of Control Board
- Summary DCRDR Report

3.4 Documentation Control Procedures

All documents used as primary input during the review or generated during the review will be maintained in a central file at the Yankee Atomic Electric Company Nuclear Services Divison offices. A complete listing of the documents contained therein will be continuously maintained and controlled by the Program Manager or his designee. This file will be available for inspection or audit upon reasonable notice.

3.5 Management of HED Records

When an HED has been identified, the engineer records his/her observations on an HED form (Figure 4 shows a typical form). This information allows the Review Team the opportunity to compare all of the discrepancies which apply to a given component. This section of the file will track the entire cycle of an HED from observation, through evaluation, to eventual recommendation and implementation. One possible resolution may read "This HED is being resolved by Engineering Design Change No. xx-xx".

* HUMAN ENGINEERING DISCREPANCY RECORD * PLANT:

REVIEWER: ST DATE: 02/17/82 NO.: 100

PANEL NUMBER | COMPONENT IDENTIFIER

1C 651 RFPT FLOW CONTROL DISPLAYS

DESCRIPTION OF DISCREPANCY

THESE DISPLAYS ARE NEITHER LOCATED DIRECTLY ABOVE ASSOCIATED CONTROLS NOR ARE THE DISPLAY CONTROL PAIRS ARRANGED IN ROWS

COMMENTS

SURVEY

RECOMMENDATION

PROVIDE GLOBAL LABELING AND/OR DEMARCATION TO ENHANCE CONTROL/DISPLAY RELATIONSHIP.

IMPLEMENTATION

THIS HED HAS BEEN RESOLVED. DEMARCATION HAS BEEN IMPLEMENTED

Figure 4. Typical HED Form

SECTION 4. REVIEW PROCEDURES

The Vermont Yankee DCRDR review procedures are primarily based on the Human Factors Engineering Control Room Survey, Revision 1, and the supplement produced by the BWR Owner's Group Control Room Improvements Committee. That BWROG survey program addresses the planning and review phases only of the DCRDR process. The assessment, implementation and reporting phases are described in this program plan specifically for the Vermont Yankee DCRDR.

The DCRDR addresses the following specific objectives:

- To determine whether the control room provides the system status information, control capabilities, feedback, and performance aids necessary for control room operators to accomplish their functions and tasks effectively.

- To identify characteristics of the existing control room instrumentation, controls, and other equipment, and physical arrangements that may detract from operator performance.

- To develop recommendations for measures to correct those deficiencies revealed by the two previous items, provide priorities for their implementation, and, if needed, provide conceptual design modifications which themselves have been evaluated for human factors considerations.

- To produce a summary report to the NRC describing the entire DCRDR process, its findings, and the resolution of those findings.

The first objective is concerned with the completeness of the control room given control room operator functions and task responsibilities. The second objective is concerned with the suitability of the design in light of human and equipment performance capabilities, individual task

responsibilities, and operational dynamics. The other objectives address those phases not included earlier in the BWROG program.

Six major processes are used to establish and apply benchmarks for identifying human engineering discrepancies of both completeness and human engineering suitability:

- Operating Experience Review
- Control Room Survey
- Control Room Inventory
- System Function Description and Task Analysis
- Verification of Task Performance Capabilities
- Validation of Control Room Functions

The procedures involved in each of the six processes are discussed in the following sections.

4.1 Operating Experience Review

4.1.1 Purpose

The purpose of the Operating Experience Review is to identify specific factors or conditions that could cause and/or have previously caused human performance problems and could be alleviated by improved human engineering. This review will provide information on potential problem areas by studying documented occurences of human engineering related problems that have occurred at Vermont Yankee.

Documents which report incidents at other plants, as well as informational reports from vendors and suppliers, or information notices from regulatory agencies, are reviewed under an in-plant program implemented in response to NUREG-0737, item I.C.5. That information is not reviewed again in this program.

4.1.2 Methodology

There are two major steps in the Operating Experience Review: a document Review and Operator Interviews. Both tasks were completed as part of the 1982 BWROG Control Room Survey Plan. The document review will be updated since approximately two years have elapsed since the completion of the BWROG work. The methodologies for both tasks are described below.

4.1.2.1 Document Review

Licensee Event Reports (LERs) for the Vermont Yankee plant were reviewed to identify plant specific design deficiencies known to have previously contributed to operator errors and to document the need for further evaluation during the other Control Room Review phases.

The 1982 BWROG survey program documented Vermont Yankee plant specific LERs and Scram reports from the preceding two years (1980-1981). To provide an updated review, LERs and Plant Incident Reports (PIRs) for the Vermont Yankee plant from 1982 to the present will be examined. Any occurrence for which operator error will be identified as a contributing factor was listed indicating the LER or PIR number and a description of the operator error.

The survey team will then analyze each event to identify possible deficiencies in the human engineering design of the control room by comparing corresponding items from the Control Room Review checklists. These items will be included in the detailed evaluation during the DCRDR assessment phase.

The results of the this update will be potential HEDs documenting operating experience problems related to the Vermont Yankee control room design.

4.1.2.2 Operator Interviews

The purpose of the Operator Interviews was to obtain direct operator input to aid in identifying potential or actual deficiencies in the control room layout or design or in operating procedures that result in confusion (mental activities), difficulty (manual activities) or distraction (the environment).

For the interview, a representative group of one-third or more of the operators was selected covering a range of experience, education, ability, and physical size. A total of ten operators were interviewed as part of the 1982 BWROG control room survey program.

Using the questionnaire in Appendix C, operators were asked to respond in writing based on their operational experience and knowledge of control rooms. Copies of the written responses were provided to the survey team for a preliminary review prior to actual interviews. Interviewees retained their copies and reviewed them with a survey team member during a later oral interview.

The interviews were conducted by utility personnel and survey team members with background or experience in operations and engineering or design under conditions conducive to a free flow of information. The oral interview took one to two hours for each operator with the entire interview process taking about one day.

Following the interviews, the survey team consolidated the information obtained and analyzed it to help identify specific areas of concern for detailed analysis during the DCRDR assessment phase.

Additional interviews of operators assigned to the control room since 1982 will be conducted. In this way, it is felt that a different perspective will be obtained from those operators who may have gotten accustomed to the existing control room instrumentation and configuration.

4.2 Control Room Survey

4.2.1 Purpose

The purpose of the Control Room Survey is to identify characteristics of instruments and controls, equipment, control room layout, and environmental conditions that do not conform to precepts of good human engineering practice, regardless of the particular system or specific task requirements. This is accomplished by conducting a systematic comparison of existing control room design features with human engineering guidelines. The ultimate objective is to identify potential modifications of the operator-control room interface which will reduce the potential for human error. This process was completed as a part of the 1982 survey and the more recent survey supplement.

4.2.2 1982 BWROG Survey Methodology

The methodology followed in conducting the control room survey is described in Appendix A of NEDC 30285 (BWROG Owner's Group Control Room Design Review Program Summary Report). The appendix is entitled "BWR Owner's Group Control Room Design Review Program" and is attached.

Each Control Room Survey was conducted by the survey team using the BWROG checklists which are titled, in order, (A) Panel Layout and Design, (B) Instrumentation and Hardware, (C) Annunciators, (D) Computers, (E) Procedures, (F) Control Room Environment, (G) Maintenance and Surveillance, and (H) Training and Manning. Checklist (A), (B), and (C) were completed for each panel in the control room, including back panels, auxiliary panels and peripheral equipment that contain controls and displays normally operated by the control room operator. The remaining checklists were completed only once since they were applicable to the entire control room.

In completing the checklists, particular attention was given to items identified as potential problem areas in the Operator Interview and in

the LER Analysis to ensure complete coverage. These items were compared to the checklist items where applicable.

Supplemental information was provided in the BWROG workshop to give additional guidance to review team members in completing the checklists.

Each checklist item was presented in the form of a question for consideration by a survey team member. Following that question was a series of numbers in which the specific item being reviewed was evaluated. The first set of numbers (4 3 2 1 0) indicated the degree of compliance wherein 4 indicated no complicance, 3 indicated somewhat compliance, 2 indicated mostly compliance, 1 indicated full compliance, and 0 indicated the specific question being considered was not applicable or could not be considered at this time. As each specific question was evaluated, the team member(s) actually doing the evaluation of that question indicated the relative degree of compliance by circling the applicable number.

Following the number indicating the degree of compliance for each item being evaluated was a predetermined number ranging from one to three which indicated the relative importance of that item with respect to the potential for causing or contributing to operator error. A 3 indicated high potential for operator error, 2 indicate moderate potential, and 1 indicated low potential. In the final evaluation of each item considered, it was the product of the degree of compliance multiplied by the potential for operator error that determined if the consideration of corrective action is justified.

Following each checklist item was space for the person performing the evaluation to enter comments. For each specific checklist item, these comments identified items or components of non-compliance, the scope of review, or any qualifying statement judged to be appropriate to the evaluation. If, for example, a large number of components are reviewed and only a few were non-compliance, these were specifically noted in the comment space and the general rating was "mostly compliance." To provide

additional documentation, still photographs were taken of major items or components of non-compliance such as mimic layouts, control/display groupings, labeling systems or equipment locations. These photographs were cross referenced to the specific checklist item by a notation in the comment space. Due to the importance of comments in the evaluation, additional Comment Forms were attached for more detail when necessary.

Each of these control room survey areas and general findings is described in the BWROG Human Factors Design Review of the Vermont Yankee Control Room Summary Report.

4.2.3 BWROG Supplemental Survey Methodology

The 1982 BWROG control room survey areas of the Vermont Yankee control room described above will be again reviewed using the BWROG Supplement checklist. This survey will be performed by the review team, supplemented by plant control room operators.

This Supplement is intended to augment Revision 1 of the BWROG Control Room Survey (CRS) Program dated 1/1/81 to further document proposed control room enhancements. The additional items listed in the supplement have been drawn from human engineering guidelines recommended in NUREG-0700 and verified through considerable experience of BWROG Survey teams.

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

SA. Panel Layout and Design

SB. Instrumentation and Hardware

SC. Annunciators

SD. Computers

5E. Procedures

5F. Control Room Environment

5G. Maintenance and Surveillance

This checklist supplement will be performed during the planned DCRDR activities. The results of BWROG 1982 checklist survey and the Supplement Survey will be compiled on HED forms described in Section 3, Documentation. These forms will be the input documentation for the DCRDR Assessment and Implementation phase.

4.2.4 BWROG Survey Update

To update the 1982 BWROG Survey, a review of all changes to the control room and control board will be conducted by the survey team by reviewing all design changes and plant alterations for changes on the control board. The modification to the control board discovered by this search will then be evaluated against the checklists of the original BWROG survey and any findings documented for further evaluation.

4.3 Control Room Inventory

The function of a control room inventory in the DCRDR is to determine whether the instrumentation and controls (I&C) needed to support operation under emergency conditions are present in the control room. This function will be accomplished as part of the task analysis effort and the related verification and validation efforts. The determination of I&C availability is described in Section 4.5, Verification of I&C requirements.

4.4 System Function Description and Task Analysis

4.4.1 Purpose

The purpose of the Systems Function Description and Task Analysis portion of the DCRDR is to identify control room operator tasks and corresponding instrumentation and control requirements during emergency

operations. This will be accomplished by performing an analysis of events encompassed in the Vermont Yankee-specific EOPs.

4.4.2 Methodology

This portion of the DCRDR entails two major, sequentially-oriented tasks. Each of the two tasks is discussed separately below.

4.4.2.1 Systems Function Description

Plant systems and subsystems in the control room are described in the Vermont Yankee FSAR. This information will serve as a reference base for the subsequent Task Analysis and Assessment phases. In addition, the EOPs will be reviewed to select operating scenarios for each walk-through during the Task Analysis. Procedures will be used to exercise and evaluate all major areas of the control board.

4.4.2.2 Task Analysis

It is assumed that the procedures used for the DCRDR Task Analysis have already been evaluated and approved for use. Using these as a basis, the review team will identify and document the discrete tasks that the operators must perform during emergency operations. Correspondingly, the specific instrumentation, controls and equipment that are required to successfully perform the emergency operations will be identified and documented. In this task, the skills and knowledge of the human factors consultant, supplemented by operations personnel, will be utilized.

A Task Analysis Worksheet is shown in Figure 5. Operator tasks will be analyzed using the EOPs and documented in the following manner:

TASK ANALYSIS WORKSHEET

SCENARIO ____
PAGE ____ of ____

Procedure No.		Task/Subtask	Stan. Resp.	Crew Mem.	Loc.	Decision and/or Action Requirements	Information & Control Req.	Means	IBC Ident.		Verification		Comments/ Candidate HEDs
VY	EOP								Panel	No.	Avail.	Suit.	

Figure 5. Task Analysis Worksheet

1. The identification of discrete steps in the Vermont Yankee EOPs in order of performance. These steps will be recorded in the "Procedural No." column of the Task Analysis form and branching points noted depending on the plant transient being analyzed in the "Scenario Response" column. Note that there may be more tasks subsequently identified in Step 2 below than there are procedural steps or vice versa. In this case, a dash will be entered in the column when no explicit procedure step is present in the EOPs.

2. A brief description of the operators' tasks per procedural step will be recorded in the "Task/Subtask" column of the Task Analysis Worksheet. Note that there may be many more tasks described than are explicitly called out in the procedural step. All tasks, both explicit and implicit, will be documented by SRO subject matter experts and human factors specialists using EOPs, FSAR and System Descriptions.

3. The operator decisions and/or actions that are linked to task performance are then noted in the "Decision and/or Contingent Action Requirements" column. System functional response is described when appropriate in this column. This set of data also includes branching points in the EOPs that determine the outcome of the operating sequence.

4. Input and Output requirements for successful task performance are noted in the "Information and Control Requirements" column. These would typically be parameters, components or procedural information that is necessary for operators to adequately assess plant conditions or system status (e.g., reactor vessel water level, recirc. pump flow, reactor pressure, etc.). Specific values for parameter

readings or control selection will be noted based on EOPs and Technical Specifications.

5. Once the Tasks, Decision Requirements, and Information and Control requirements have been specified, the specific instrumentation and controls (I&C) that the operator requires per procedural step will be documented. All I&C needed to either (1) initiate, maintain or remove a system from service, (2) confirm that an appropriate system response has or has not occurred, i.e., feedback, or (3) make a decision regarding plant or system status will be listed. The "Means" column refers to how the information and control requirements should be presented on the control boards (e.g., switch, meter, etc.). The "I&C Identification" column provides the specific panel number and identification number of the actual control or instrument which meets the need expressed in the "Requirement" and "Means" columns. In this manner, a list of required I&C is developed and compared to the control board inventory.

The remaining columns of the Task Analysis Form will be utilized during the Verification of Task Performance Capabilities, which is described in Section 4.4. These columns are described below:

6. Verification column (used during V&V phase)
"Availability" of the necessary I&C for successful operator task performance is noted by a check in this column; "Suitability" of the I&C to meet the information and control requirements of operator task is noted by a check in this column.

7. Comments/Candidate HEDs
   Comments or candidate HEDs can be noted in this column during any step of the Task Analysis or V&V phases. Data for HEDs will be entered on an HED form and into the database.

The Task Analysis Worksheet thus serves as the complete record of operator tasks, decisions, information and control requirements; and I&C availability and suitability during the selected emergency operating sequences. This record is developed through the series of steps described above. All task data will be entered into the DCRDR database.

A preliminary on-site analysis of tasks will be performed prior to the walk-through to allow early identification of operational requirements and to refine the task analysis worksheets. Candidate human engineering discrepancies in control room design will be identified in this process. Using the appropriate Task Analysis Worksheets, human factors engineers of the review team will perform a walk-through of each scenario with Vermont Yankee control room operators. During this walk-through the tasks required will be analyzed in terms of the presence of necessary instruments and controls or other equipment or job aids (the Verification of Task Performance Capabilities specified in NUREG-0700) and the suitability of equipment, job aids and control room design for reliable execution of the required tasks (the Validation of Control Room Functions specified in NUREG-0700).

Real-time walk-throughs will then be conducted to fully document the tasks involved for all crew positions and the candidate human engineering discrepancies which may arise. A complete description of the walk-through method is described in the validation process in Section 4.6. The task data is subsequently examined in both the verification and validation process described in the sections that follow.

An important element for the successful and accurate completion of the task analysis is the involvement of all disciplines (engineering, operations and human factors) in each of the steps above.

4.5 Verification of Task Performance Capabilities

4.5.1 Purpose

The purpose of the Verification of Task Performance Capabilities is to systematically verify that the Instrumentation and Controls that were identified in the Task Analysis as being required by the operator are:

- Present in the Control Room
- Effectively designed to support correct procedure performance

4.5.2 Methodology

The Verification of Task Performance Capabilities will utilize a two-phase approach to achieve the purpose stated above. In the first phase, the presence or absence of the Instrumentation and Controls that were noted in the Task Analysis worksheets will be confirmed. This will be done by comparing the requirements in the "I&C Requirements" column of the Task Analysis Form to the actual control room, I&C listed in the "I&C Identification" and "Means" columns.

4.5.2.1 I&C Availability

The result of the verification of I&C availability will be a control room inventory in the task analysis worksheet column labeled "I&C Identification." A separate review of the I&C identified above will be done to ensure direct versus indirect indications of parameters.

The presence or absence of required Instrumentation and Controls will be noted by "yes" or "no", in the "Availability" column of the Task Analysis form. If it is discovered that required Instrumentation and Controls are not available to the operator, any such occurrence will be identified as an HED and documented

accordingly on an HED form. If the response is "Yes" it will signify that the available I&C satisfies the requirements.

4.5.2.2 I&C Suitability

The second phase will determine the human engineering suitability of the required Instrumentation and Controls. For example, if a meter utilized in a particular procedure step exists in the control room, that particular meter will be examined to determine whether or not it has the appropriate range and scaling to support the operator in the corresponding procedural step. If the range and scaling are appropriate, it will be noted by checking the "yes" area in the "I&C Suitability" column of the Task Analysis Worksheet. Conversely, if the meter range or scaling is not appropriate for the parameter of interest to the operator, the "no" area in the "I&C Suitability" column of the Task Analysis Form will be checked. This type of occurrence will be defined as an HED and documented accordingly on an HED form.

4.5.2.3 I&C Location

Special attention will be given to the location of indicators in relation to controls to determine if the parameter being controlled is indicated in a location readily viewed by the operator who is controlling or otherwise affecting that parameter. Annunciator alarms which require changing operators locations to determine or correct the problem will be evaluated.

The suitability review of I&C will be performed by the human factors specialist, an operations expert, and an I&C engineer.

4.6 Validation of Control Room Functions

4.6.1 Purpose

The purpose of the Validation of Control Room Functions step in the DCRDR process is to determine whether the functions allocated to the control room operating crew can be accomplished effectively within (1) the structure of the Vermont Yankee-specific EOPs and (2) the design of the control room as it exists.

Additionally, this step provides an opportunity to identify HEDs that may not have become evident in the static processes of the DCRDR, for example, in the control room survey.

4.6.2 Methodology

Utilizing the completed Task Analysis Worksheets, walk-throughs based on the Vermont Yankee EOPs will be performed in the control room. A normal complement of the control room operating crew will be performing the walk-throughs.

The purpose of the walk-through is to evaluate the operational aspects of control room design in terms of control/display relationships, display grouping, control feedback, visual and communication links, manning levels and traffic patterns.

The operating crew will be provided with copies of the EOPs to follow as they are walking through the events. DCRDR team members will use the Task Analysis Worksheets to record observations and potential HEDs.

One event at a time will be walked-through. Operators will be requested to perform the walk-through in slower than real time to provide a relatively slow-paced rehearsal of the event.

During the walk-throughs, the operators will be instructed to speak one at a time and describe their actions. Since this will force serial action, the operations will not be performed simultaneously. Specifically, the operators will verbalize:

- The component or parameter being controlled or monitored
- The purpose of the action
- The expected result of the action in terms of system response

As the operators walk-through the event, they will point to each control or display that they utilize, and indicate which annunciators are involved.

As the walk-throughs proceed, the operators will note any errors, such as improper step sequencing or branching, that may occur on the Task Analysis Worksheet. These errors will be traced back to the EOPs for investigation to ascertain whether the error occurred because of a procedural problem.

If a procedural problem is discovered, it will be documented. This documentation will be useful in responding to Item 7 of Supplement 1 to NUREG-0737, which involves the Upgrade of Emergency Operating Procedures. Procedure validation problems will be addressed as part of the task analysis and walk-throughs of the EOPs. This documentation will also be useful in any type of long-term training program which involves procedures upgrades.

The operators who performed the event will review the completed Task Analysis Worksheets along with human factors specialists. The operators will be asked to note any errors or problems that were encountered in the walk-throughs and to expound upon the source of the errors or problems. These errors or problems will be documented for investigation as possible HEDs.

For each procedural step, the following types of information will be recorded:

- An indication that the scenario response was accomplished will be noted in the "Scen. Resp." column.
- The identification of which member (RO, SRO or SS) of the operating crew is performing the task. This will be noted in the "Crew Member" column on the Task Analysis Worksheet.
- The location of the crew member when performing the task in the "Loc." column.
- A verification of the specific decision and contingent actions that are associated with each operator task. This will include communications between and among crew members.
- A verification of the Instrumentation and Controls requiring in the associated procedural step, for example, an indicating light on a controller energizing to red, or a pointer on a meter deflecting upward. This will be added to the "I&C Ident." column on the Task Analysis Worksheet.
- Comments related to verification or validation and potential HEDs.

Once the events have been analyzed to extract the information noted above, Link Analyses, which trace the movement patterns of the operating crew in the control room, may be prepared to assess whether the control room layout hinders operator movement while performing the events.

If the review team decides that the walk-through requires additional objectivity, the analysis will be reviewed by an operator who did not participate in the task.

Any dynamic performance problems that were uncovered during this phase of the DCRDR process will be documented for review in the HED Assessment phase of the DCRDR.

SECTION 5. HED ASSESSMENT AND RESOLUTION

5.1 HED Assessment

All HEDs that are identified as a result of the DCRDR process will be assessed and categorized. Additionally, recommendations for the correction or resolution of HEDs will be generated, and a recommended schedule for their implementation will be developed.

5.1.1 Purpose

The purpose of the HED Assessment phase of the DCRDR project is to examine the HEDs that have been identified and place them into categories in terms of their potential to increase operator error during operations. This is accomplished by analyzing and evaluating the problems that could arise from the identified HEDs.

5.1.2 Methodology

The DCRDR review team will categorize HEDs for their potential to increase operator error during operations. As each HED is assessed, they will be assigned in one of the following categories:

1. Category I - HEDs Associated with Documented Errors

   HEDs which have been previously documented (as determined in the Operating Experience Review) as having contributed to a significant operating crew error will be assigned to Category I.

2. Category II - HEDs Associated with Potential or Interactive Errors

   HEDs placed in Category II come from two sources:

a. If it is judged that the HED degrades performance and if the effects of the HED are judged to be serious enough to cause or contribute to increasing the potential for a significant operator error, the HED will be assigned to Category II.

b. If it is judged that the HED has any cumulative or interactive effects with other HEDs, it will be assigned to Category II. Cumulative HEDs would be those that are placed in this category by their number of occurrences, such as improper labeling characteristics throughout the entire control room. Interactive HEDs would be those HEDs that augment each other such as improper scaling on a meter combined with the absence of a parameter designation.

3. Category III - HEDs Associated with Low Probability Errors of Serious Consequences

All HEDs that are judged by the DCRDR review team to have a low potential for error <u>but</u> could result in serious consequences if the error did occur would be placed in Category III.

4. Category IV - Non-Significant HEDs

All HEDs that are judged by the DCRDR review team to neither increase the potential for causing or contributing to a significant operating crew error, nor to have adverse safety consequences, nor to have any cumulative or interactive effects will be assigned to Category IV.

5.2 HED Corrections

5.2.1 Purpose

Recommendations for HED resolution or correction will be made by the Review Team for each identified HED. This will be done in an attempt to alleviate the human engineering problems that are associated with the HEDs.

5.2.2 Methodology

The following techniques are among the methods that may be utilized for the corrections of discrepancies.

Those HEDs resulting from the previously described activities will be addressed by the review team in the following manner: Starting with HEDs bearing the highest priority, the list will be evaluated. For those HEDs which appear to have a logical and straightforward resolution, a recommendation to the management team will be prepared. Before forwarding the recommendation, two additional steps will be performed: (1) verification that the recommended solution adequately addresses the HED, is feasible, cost effective, and adheres to accepted human factors principles and, (2) validation that this solution does not create another HED.

Those HEDs not readily responsive to a straightforward solution will be assigned either to a member of the review team, or to the supporting staff, to develop a conceptual solution. Those solutions will be evaluated by the review team and, if acceptable and meeting the needs of items 1 and 2 above, will be recommended to the management team for approval.

In the process of evaluation the review team may find it necessary to produce some form of mockup of the proposed resolution. For this purpose, either a partial mockup of the control board or a complete

mockup may be necessary. The need for such equipment will be decided by the review team.

Recommendations which receive the management team's approval will be forwarded to the engineering staff for detailed design and implementation in accordance with the Quality Assurance Program requirements.

Recommendations which do not receive management team approval will be returned to the review team for further action. It is assumed that the recommendations will be of two kinds:

1. There will be those whose solution is not approved. These will be evaluated by the review team and a new solution proposed and returned as a recommendation.

2. The management team may reject a recommendation on the basis that they do not agree with the severity or rating of the HED. This rejection will contain a detailed explanation for the disagreement.

These will be again evaluated by the review team taking into consideration the management teams' explanation. The review team may choose to reclassify the HED or return the rcommendation with a clearer explanation of the HED. If this second recommendation is rejected, it shall be reclassified in accordance with the management team's instructions. If the human factors engineer dissents, this will be documented.

If the second recommendation is accepted, it shall be forwarded by the management team to the appropriate engineering support services.

A description of the entire process will be included in the Summary Report. It will include a logging, tracking, and final resolution of these items from observation, to HED, to ultimate assignment to the proper group for implementation.

- Correction by enhancement: Enhancement techniques include changing control and/or display labels and annunciator title legends, or adding demarcation lines or mimic lines to existing arrays of controls and displays. These techniques will be mocked up via drawings. The review team will then judge their effectiveness in resolving the HED. If the enhancement correction is judged to be effective, it will be considered to be the appropriate resolution, and be so recommended to the management team.

- Correction by design change: HEDs that cannot be effectively corrected by enhancement may require a design effort, either in terms of component reconfiguration or rearrangement. These design changes will be verified by having operations personnel assess their effectiveness. This may be achieved by having operators walk through the portion of an EOP that involves the utilization of the component(s) that were reconfigured or rearranged to see if the design correction in fact did provide an enhancement; or other appropriate operational review methods. These recommended solutions will be forwarded to the management team for their approval.

- Correction by training, procedural modifications or operator task reassignment. Some HEDs can be resolved through methods that do not require physical modifications to instrumentation and controls. The lack of a required indication could be resolved by supplying this indication on the plant computer. Training programs could be initiated or supplemented to alert operators to particular control arrangements that not optimal but cannot be reconfigured due to space constraints or separation criteria, and Procedures could be modified to compensate for irreconcilable instrument and control layout or location. These solutions will be forwarded to the mangement team for their approval.

- Category IV HEDs will be documented but it is likely that no corrective action will be taken.

5.3 Implementation Schedule

A schedule for implementation of HEDs will be developed based on the category assigned, additional engineering study requirements, implementation complexity, and plant scheduling constraints.

SECTION 6. DCRDR FINAL REPORT AND FUTURE APPLICATIONS

At the completion of the DCRDR project, a final report will be generated. This report will document, in summary form, the procedures utilized in the DCRDR. Any departures from the methodologies described in this Program Plan will be noted and justified.

The final report will summarize the results of the DCRDR review process. The HEDs that were identified during the Operating Experience Review, the Control Room Survey and the Task Analysis will be included along with the proposed modifications for correction and/or resolution for each HED. A tentative schedule for implementation of modifications to correct HEDs will be included. An actual implementation schedule will not be provided pending completion of design, bid specification, and award of contract for installation of modifications.

The final report will also address the integration of the DCRDR results with other areas of Supplement 1 to NUREG-0737, "Requirements for Emergency Response Capabilities, where they occur.

The results of the DCRDR will be incorporated into Vermont Yankee training programs as applicable. This will ensure that any implemented changes will be brought to operators' attention with regard to physical modifications or procedural alterations.

APPENDIX A

BWR OWNER'S GROUP CONTROL ROOM DESIGN REVIEW PROGRAM

APPENDIX A

BWR OWNERS GROUP

CONTROL ROOM DESIGN REVIEW PROGRAM

DEVELOPMENT AND METHODOLOGY

8/1/83

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1.0 INTRODUCTION

Increased awareness of the importance of the human element in reactor safety has recently spawned new regulatory requirements questioning the role of human factors in the nuclear power industry. NUREG-0660, Task 1.D.1 mandates design reviews of all nuclear power plant control rooms to identify human factors enhancements which may reduce the potential for operator error. The BWR Owners Group has responded to this requirement by formulating, as a cooperative effort between the Control Room Improvements Committee and General Electric Company, a generic control room review program for performance of these reviews. Utility participation is listed in Table I.

As illustrated in Figure 1, the BWR Owners Group Control Room Review program has been designed and instituted in six stages: (a) development of design review methodology; (b) training of review teams; (c) performance of a validation survey; (d) performance of control room design reviews; (e) results reporting; (f) implementation of control room modifications. Extensive manpower and expertise has been applied to each stage of the review process, with final results the culmination of many man-years of dedicated effort.

2.0 DEVELOPMENT OF DESIGN REVIEW METHODOLOGY

The BWR Owners Group Control Room Design Review Program was developed through a cooperative effort between the Control Room Improvements Committee and General Electric Company. After progressing through a series of design iterations and being subjected to several reviews by outside agencies, the program was given final approval by the Control Room Improvements Committee in January, 1981.

2.1 Task Force Membership

Initial work on the Control Room Design Review Program was performed by a multi-disciplinary task force within General Electric, working under the direction of the Control Room Improvements Committee. The composition of this group, detailed in Table II, was specifically selected to bring into play a wide cross section of General Electric's experience in reactor design. Included were members with

Table I

UTILITIES PARTICIPATING IN THE BWR OWNERS GROUP CONTROL ROOM DESIGN REVIEW PROGRAM

* Boston Edison Company
* Cleveland Electric Illuminating Company
Commonwealth Edison Company
* Detroit Edison Company
* Georgia Power Company
* Gulf States Utilities

Illinois Power Company
* Iowa Electric Light and Power Company

* Nebraska Public Power District
* Niagara Mohawk Power Company
* Northern States Power Company
Pennsylvania Power and Light Company
* Philadelphia Electric Company
* Power Authority of the State of New York
Taiwan Power Company
* Tennessee Valley Authority
* Washington Public Power Supply System
* Vermont Yankee Nuclear Power Company

*Participated on inter-utility survey teams

Table II

GENERAL ELECTRIC COMPANY CONTROL ROOM DESIGN REVIEW TASK FORCE COMPOSITION

Function	Qualifications
Program Management	(1) BS - Nuclear, UCLA PE - Alabama 16 years experience in startup testing and planning, reactor operations (2) BS - Mechanical Engineering, Union College PE - New York 27 years experience in systems design, training, operations, management
C&I Engineering	BS - Psychology, USF SRO License 21 years experience in reactor operations, training, control systems and design, human factors engineering, biotechnology
Training	SRO Certification 7 years experience in reactor operations, training
Systems Engineering	27 years experience in C&I engineering, panel layout and design, seismic evaluations, human engineering
Startup Test Operations	SRO License 31 years experience in startup engineering, training, project engineering, performance improvement
Mechanical and Nuclear Testing	BS - Chemical, U of I PE - Nuclear (Calif) 29 years experience in reactor operations, startup
Nuclear Services Engineering	BS - Electrical, Colorado 19 years experience in reactor operations, service engineering, maintenance and testing
Industrial Design	(1) BPA, Los Angeles 15 years experience in industrial design, human factors (2) BS - Industrial Design, SJS 15 years experience industrial design, human factors

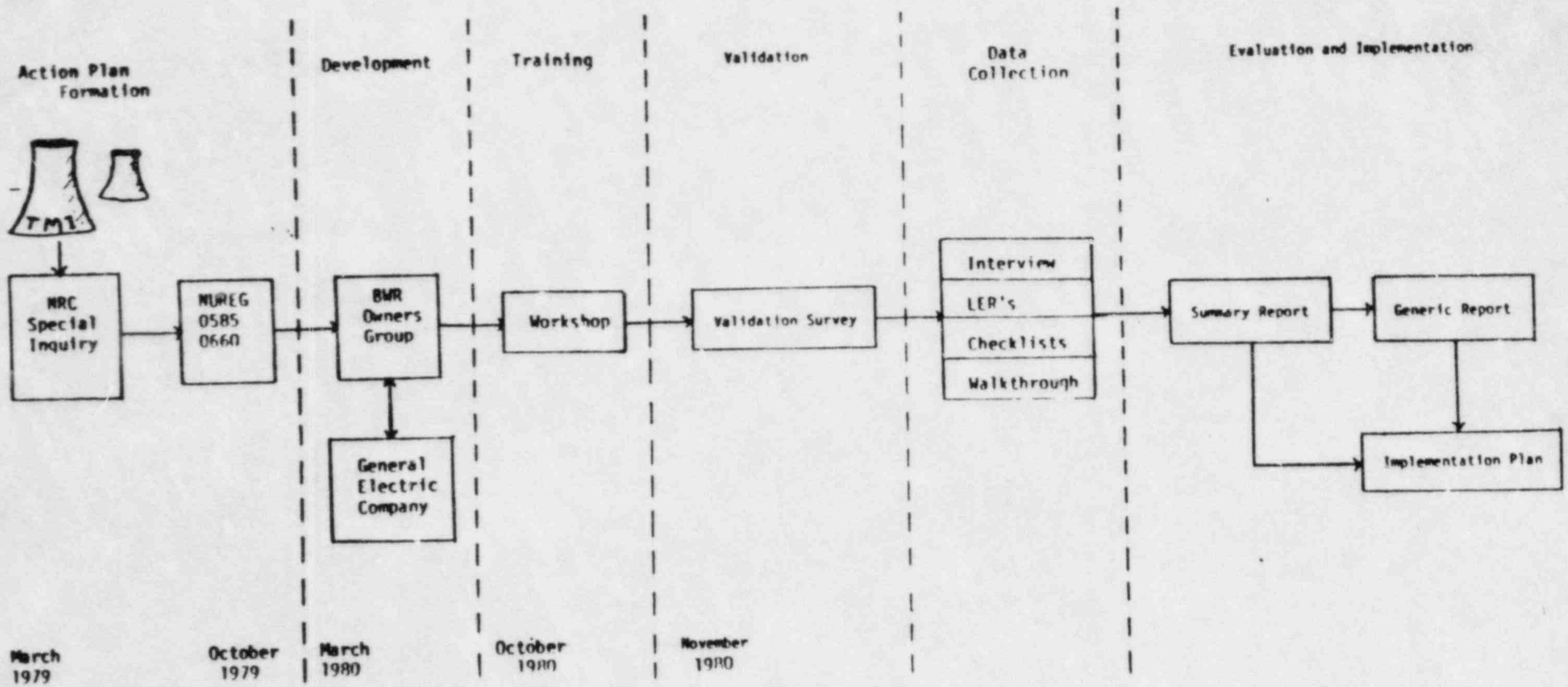

Figure 1

Control Room Design Review Timeline

knowledge of reactor operations, human factors engineering, control systems and design, service engineering startup, testing and operations, training, industrial design, and control and instrumentation engineering. Additional human factors support was provided by a team of specialists associated with the Massachusetts Institute of Technology, including Dr. T. B. Sheridan, Dr. D. D. Lanning, Dr. J. M. Christensen and Dr. P. J. Nicholson. Total manpower was approximately thirty people.

2.2 Program Development

The scope of the Control Room Design Review Program was carefully defined to insure a complete human factors review of BWR control rooms addressing all aspects of the requirements of NUREG-0660, Task 1.D.1. However, it was recognized that other requirements related to human factors and control room design are currently being considered in parallel, and that there already exist many specific control room design requirements. To avoid duplication of effort and repetition of reviews already performed, subjects included in the Control Room Design Review were selected to eliminate overlap. For example, because a detailed review of training programs is required by NUREG-0660, Task 1.A.2, training program content was not addressed in the Control Room Design Review Program.

Figure 2 illustrates the series of reviews performed in the development of design review checklists, all steps being under the direction and subject to the approval of the Control Room Improvements Committee. Using the sources listed in Table III and the experience of General Electric engineers as a data base, a preliminary set of checklists was developed. Items included in these checklists were selected based upon the criteria that each (a) was within the defined scope of the task requirements specified by NUREG-0660, Task 1.D.1, (b) was applicable to BWR control rooms, and (c) could potentially cause or contribute to operator error. Then followed an exhaustive series of design iterations incorporating comments from comprehensive internal and external reviews. This process was intended to verify that all task requirements were satisfied, that the approach used was valid, and that all necessary aspects of control room design were addressed.

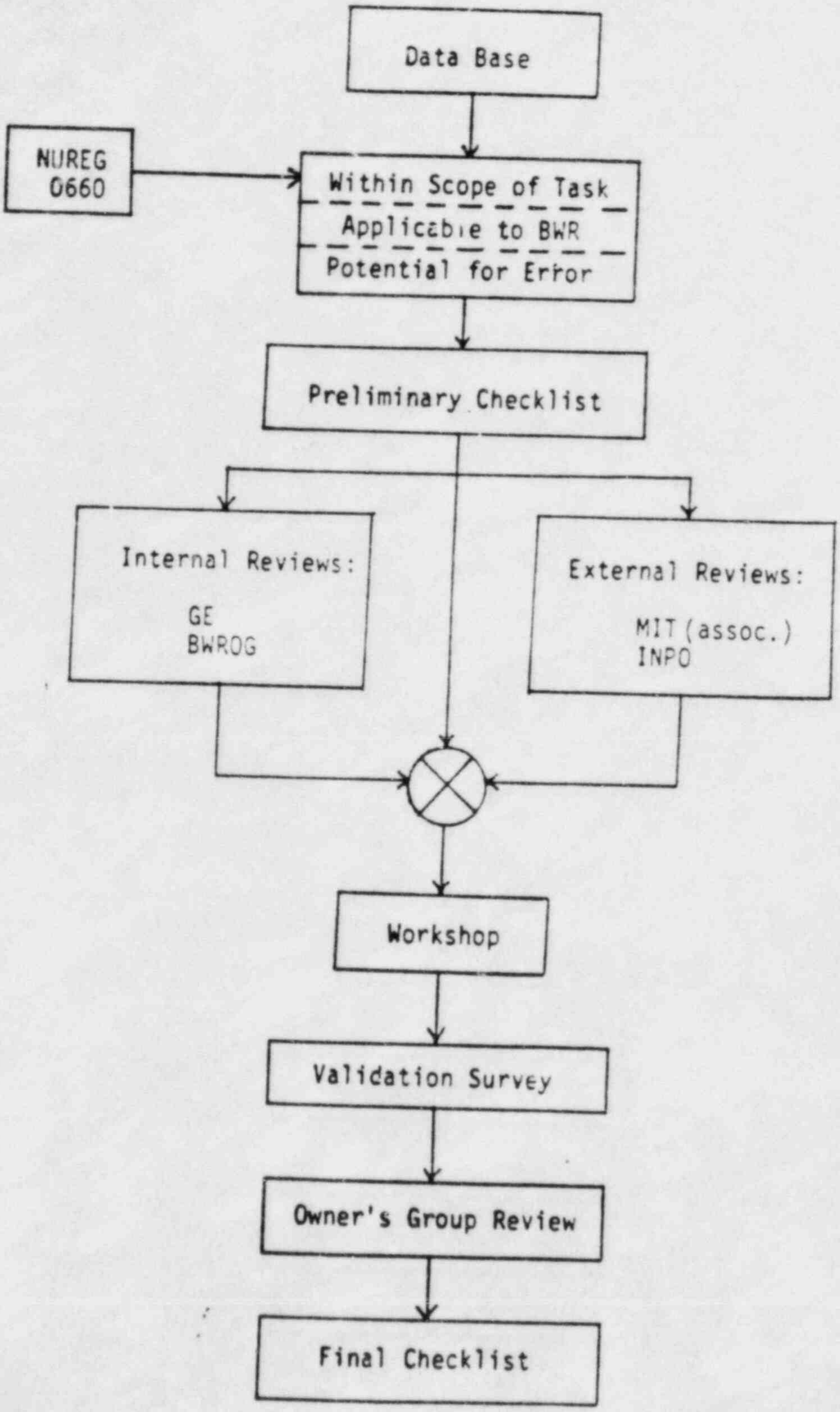

Figure 2

Control Room Design Review Program Development

Table III
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Table III (Continued)

12. Woodson, W. E. and D. W. Conover, Human Engineering Guide for Equipment Designers, Ind. ed., University of California Press, Berkeley, CA, 1964.

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14. IEEE Std 567-1979, "Criteria for the Design of the Control Room Complex for a Nuclear Power Generating Station."

15. MIL-STD 803A-1 (USAF), "Human Engineering Design Criteria".

16. MIL-STD 1472-C, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities."

17. NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report and Short-term Recommendations."

18. NUREG-0585, "TMI-2, Lessons Learned Task Force Final Report".

19. NUREG-0660, "Action Plans for Implementing Recommendations of the President's Commission and Other Studies of the TMI-2 Accident."

20. NUREG-0659, "Staff Supplement to the Draft Report on Human Engineering Guide to Control Room Evaluation."

An independent six week review of the BWR Owners Group program was performed by a consultant team consisting of seven contributors from two departments of the Massachusetts Institute of Technology. This team tested the program for completeness, adequacy and validity. Comments were also received from a review performed by the Institute of Nuclear Pcwer Operations.

The revised program resulting from this series of reviews was utilized in a six day workshop for utility personnel, and validated through a trial survey. Feedback from these sessions was incorporated into the final version of the BWR Owners Group Control Room Review Program, approved by the Control Room Improvements Committee in January, 1981. This final version was used in performing all subsequent design reviews.

3.0 TRAINING OF REVIEW TEAMS

In October of 980, a six day workshop was held at the General Electric BWR Training Center in Morris, Illinois to present the design review program to utility personnel and provide instruction in human factors evaluations. This training program encompassed all phases of the review process and included practice time on General Electric's BWR-3 simulator.

4.0 VALIDATION SURVEY

Validation of the design review process was performed at the Duane Arnold Energy Center in November of 1980 with representatives from General Electric, MIT and other universities, and three utilities present. Feedback from this first review, and inputs received during the workshop, were incorporated into the final version of the BWR Owners Group Control Room Design Review Program.

5.0 PERFORMANCE OF DESIGN REVIEWS

5.1 Program Elements

As illustrated in Figure 3, the BWR Owners Group Control Room Design Review Program consists of four phases: (a) obtaining direct operator input through operator interviews; (b) an evaluation of

Phase	Function	Method
I Operator Interview	Direct Operator Input	Representative Selection Prepared Questionnaire Cross-reference to Checklists
II LER Analysis	Historical Review Identify Known Problems	LER's Previous 2 years Review for Operator Errors Cross-reference to Checklists
III Control Room Survey	Compare Engineering Aspects with Established HFE Criteria	Checklists and Surveys All Inclusive Review
IV Emergency Procedure Task Analysis and Walkthrough	Evaluate Operational Aspects of Control Room Design	Selected Emergency Procedure Task Analysis Traffic Patterns Videotape

Figure 3

Control Room Design Review Methodology

plant operating experience through analysis of Licensee Event Reports (LER's) and scram reports; (c) an evaluation of control panel design utilizing a series of prepared checklists compiled from recognized human factors standards; and (d) task analyses and walkthroughs of selected procedures. These techniques were selected from known human factors evaluation methods and closely conform to those used in previous successful review efforts. Data collected in each of the four review phases are collated into plant summary reports.

5.1.1 Operator Interviews

The operator interviews are designed to obtain directly the benefit of day-to-day plant operating experience. Since many aspects of panel design may not be readily apparent without actual involvement in plant activities, interviews represent an integral part of the survey process.

Approximately one-third of the licensed operators at each plant were selected to participate in interviews. This sample size was judged sufficient to encompass a wide variety of operator opinion, determine areas of common concern, and provide for accumulating data on operators' physical characteristics. An attempt was made to include a complete spectrum of operator experience, education, ability, and physical size.

Because experience has demonstrated that more complete responses are obtained when operators are allowed time to deliberate the questions, a prepared questionaire was devised for the Control Room Survey. Operators were asked to complete these questionaires prior to the arrival of the survey team, based upon their own knowledge and experience and without consulting other operators. Their responses then served as topics for more detailed discussions during a later, in-depth oral interview with a survey team member.

Topics included in the interview questionaire were carefully selected to allow for operator input on a wide variety of subjects and to address the concerns for which operating experience must serve as the primary source of information. To assure maximum credibility,

persons with experience in operations were chosen to conduct the interviews. Generally, the interviewer would not be an employee of the host utility to provide for a free flow of information.

5.1.2 Licensee Event Report (LER) Analysis

Aspects of control room design which have been contributing factors in past operator errors may sometimes be identified through analysis of plant operating experience. In the Control Room Design Review program, this information is obtained through operator interviews and through review of plant LER's and scram reports for the two year period preceding the survey. These documents were searched for examples of operator error possibly caused, or compounded by, design related considerations. Any events so identified were designated for further review during the survey process (checklist evaluations, task analyses, and procedure walkthroughs).

5.1.3 Control Room Survey

The Control Room Design Review Program uses, as a central evaluative technique, a series of checklists compiled from accepted human factors standards and adapted specifically for BWR's. As such they comprise a generic program directly applicable to the product line being surveyed. Extensive consideration has been given to assuring that, while all desired aspects of control room design are addressed, superfluous, redundant, and non-applicable items were eliminated. Where possible, the emphasis has been placed on verifying that the functional requirements of panel components are satisfied, rather than recommending specific types or designs of hardware.

The checklists of the Control Room Design Review were structured to cover the subject areas listed in Table IV within the intended scope of the survey requirements. Checklist sections addressing (a) panel layout and design, (b) instrumentation and hardware, and (c) annunciators are used in performing evaluations of individual panels. Sections addressing (d) computers, (e) procedures, (f) environment, (g) maintenance activities, and (h) training and manning apply to the control room as a whole.

Table IV

CHECKLIST SUBJECT AREAS

A. PANEL LAYOUT AND DESIGN

Anthropometrics and control room layout
Demarcation lines and mimics
Control/Display grouping
Color codes
Labels
Temporary modifications
Traffic patterns and panel arrangement

B. INSTRUMENTATION AND HARDWARE

Controllers
Indicators
Recorders
Indicating lights
Switches
Emergency switches
Key-lock switches

C. ANNUNCIATORS

Grouping
Window design
Visual alarm
Audible alarm
Acknowledgement
Visual alarm
Procedures
Maintenance
Nuisance alarms

D. COMPUTERS

Console
Capability
CRTs
Typers

E. PROCEDURES

Availability
Access and recognition
Format
Content
References
Revision
Logkeeping

F. CONTROL ROOM ENVIRONMENT

Communications
Auditory displays
Lighting
Heating and ventilation
Fire control
Emergency situations
General

G. MAINTENANCE AND SURVEILLANCE

Operator functions
Jumpers and lifted leads
Permanent modifications
Tags
Spare parts
Procedures

H. TRAINING AND MANNING

Training
Control room manning
Shift change

5.1.4 Procedure Walkthroughs and Task Analyses

Task analyses and walkthroughs of selected emergency procedures are performed in order to evaluate operational aspects of control room design. Included in this evaluation are control/display relationships, availability of information, visual and communication links, traffic patterns, and manning levels.

Using written plant procedures as a guide, task analyses are prepared using the format shown in Figure 4. Each sequential step identified within the procedure is then evaluated according to instructions provided with the form (Figure 5). This analysis consists of the following steps:

(1) Operating events are defined

(2) Operator tasks are identified for each event under consideration

(3) Control and instrumentation requirements are specified for each operator task

(4) The completeness of the control room inventory is verified through comparison with instrumentation identified in the task analysis

(5) The task sequences are validated with walkthroughs of scenarios encompassing the events being considered. Traffic patterns, communication requirements and manning levels are also considered.

As a minimum, walkthoughs are performed of existing plant procedures for a scram and a loss of coolant accident.

Because the event-oriented procedures currently in use will soon be replaced with symptom-based procedures, task analyses performed during the design review are centered primarily around the Emergency Procedure Guidelines developed by the BWR Owners Group. While plant

Task (1)	Device/Location (2)	Associated Devices/Location (3)	Assistance/ Communications (4)	Notes (5)

Figure 4

Task Analysis Format

(1) TASK

The task sequence is developed from the procedure being evaluated and the predetermined scenario. Each required operator action is listed as a separate task with diagnosis considered the first task for emergency procedures. Subtasks are listed in the same column, identified by indentation.

(2) DEVICE/LOCATION

For each task or subtask considered in Column (1), the primary control or display utilized by the operator in accomplishing this task is identified and located.

(3) ASSOCIATED DEVICES/LOCATION

Listed is this column are any devices associated with the primary control or display listed in Column (2). This may include backup instrumentation, indicating lights, alarms, etc.

(4) ASSISTANCE/COMMUNICATIONS

Notation is made in this column if assistance is required by the operator to complete the task or if a communication must be made.

(5) NOTES

Any item found discrepant in the walkthrough will be listed in this column. For each task, columns (1) through (4) are analyzed in terms of the following considerations:

- Is the sequence valid and complete?
- Is sufficient information immediately available to the operator to complete the task?
- Does each critical control and display identified in columns (2) and (3) conform to checklist evaluation criteria?
- Do control/display relationships meet checklist criteria?
- Are shift manning levels adequate to perform the task?
- Are traffic patterns unobstructive?
- Is direct feedback used to verify control functions?

Figure 5

Task Analysis Instructions

specific procedures based upon these guidelines are not yet available, the analyses performed provide much useful information on the adequacy of present control room instrumentation and the ability of the operator to respond in accordance with the Guidelines within the framework of existing control room design. As such, they serve as a valuable method of integrating procedure and control room upgrade efforts. More detailed analyses are expected to be performed at the time actual plant specific procedures are prepared.

5.2 Evaluation Methods

An in-depth analysis of control room design requires review of every panel containing controls and displays normally used by operators, including auxiliary and back panels. Evaluations are therefore performed on a panel-by-panel basis, checklist Sections A, B, and C being completed separately for every panel.

Each checklist item is evaluated by means of two numerical ratings: (1) a "compliance factor" indicating the degree to which the panel under consideration complies with that criterion, and (2) a "potential for error factor" representing the relative likelihood that non-compliance with that checklist item could cause or contribute to operator error.

A graded system of compliance evaluations is employed because a simple yes/no judgement of design compliance with a given human factors standard may provide only limited information when a wide spectrum of actual design effectiveness is possible. Therefore, each panel is rated on a scale of one to four for each checklist item. "One" indicates full compliance with a given criterion on the panel being reviewed, "two" indicates that the criterion has been "mostly" complied with, "three" indicates "somewhat" compliance, and "four" indicates total non-compliance. A "zero" signifies that the criterion is not applicable to that panel.

The "potential for error factor" has been preassigned for each checklist item, based on the work of a task force consisting of approximately thirty General Electric and utility engineers from

a wide variety of disciplines. Each item was independently evaluated by each task force member, based upon his own knowledge and experience. From this data base, a final value was assigned based upon the statistical frequency distribution of the ratings.

Each rating factor was reviewed and approved by the Control Room Improvements Committee of the BWR Owners Group. The resulting factors ranged from one to three, "three" indicating "high" potential for operator error, "two" a "moderate" potential, and "one" a "low" potential for causing or contributing to operator error.

These two rating factors, the degree of compliance assigned by the survey team, and the predetermined potential for error, are multiplied together to obtain a final Evaluation Product. These Evaluation Products are then utilized in forming preliminary prioritization recommendations for control room enhancements (see Figure 6). Final corrective action will be determined in an item-by-item review of these suggested areas, addressing safety significance of the components and systems involved, frequency of use and the consequences of required operator retraining.

5.3 Survey Teams

The BWR Owners Group Control Room Design Review is intended to be performed by inter-utility review teams composed of members with expertise in a variety of disciplines.

Four such teams have currently been formed, each typically consisting of representatives from three or four utilities with backgrounds in operations, control and instrumentation or engineering, a human factors consultant and a General Electric engineer. The host utility provides additional support as required in the areas of computers, operations, engineering, maintenance, and training. The resulting team structure thus includes expertise in all necessary fields. One utility employee is designated as the "team leader," responsible for scheduling the review and coordinating review team activities. Individual team member responsibilities are listed in Table V.

III CONTROL ROOM REVIEW

COMMENT FORM

This form is to be used during the performance of the Control Room Review to identify, for each specific checklist item as necessary, the scope of review, items or components of non-compliance, or any qualifying statements appropriate to the evaluation of that checklist item. When this form is used, the checklist item number is to be entered here, and a note is to be made in the space following the checklist item to identify the use of this comment form, assuring proper cross-referencing. This form is to be placed in the survey package directly following the page on which the checklist item appears.

Item	Comment

III CONTROL ROOM REVIEW

Panel ________

A PANEL LAYOUT and DESIGN

A1 For control panels:

A1.1 does the design generally meet measurement standards per the attached anthropometric diagrams (complete and attach) — 4 3 2 1 0 x 2 = ____

A1.2 are they of the same layout and design on multi-unit plants (not mirror image) — 4 3 2 1 0 x 2 = ____

A1.3 when panel components are permanently removed, are spaces covered to prevent debris or dust from entering panel internals and repainted to avoid visual distinctiveness — 4 3 2 1 0 x 2 = ____

A1.4 have sharp corners and edges been eliminated? — 4 3 2 1 0 x 1 = ____

A2 Are lines of demarcation, mimics or other graphic displays:

A2.1 used to distinguish between commonly shared systems or components in multiple unit control rooms — 4 3 2 1 0 x 2 = ____

A2.2 used to enclose related displays — 4 3 2 1 0 x 3 = ____

APPENDIX C

RESUMES OF DCRDR TEAM MEMBERS

ROBERT J. LIDDLE
Manager, Human Factors Power Services

EDUCATION

M.S , Industrial Engineering and Operations Research, Virginia Polytechnic Institute and State University

B.S., Psychology, Virginia Polytechnic Institute and State University

EXPERIENCE
1980 - Present

General Physics Corporation

Mr. Liddle is a human factors engineer responsible for managing power plant control room design review methodology, staffing, and training programs. He provides in-house staff instruction in technical and administrative aspects of control room reviews. Mr. Liddle serves as project manager for several human factors projects and has had experience with utility/Nuclear Regulatory Commission negotiations involving human factors issues.

- Program Plan Development
  Developed program plans for various utilities which present detailed methodologies utilized in the performance of control room design reviews. The program plans encompass management, staffing and data collection and interpretation issues.

- Control Room Design Review
  Managed detailed control room design review projects at the Pennsylvania Power and Light Company Susquehanna Steam Electric Station and Washington Public Power Supply System No. 2; acted as lead human factors engineer in control room design review for Georgia Power Company's Plant Vogle, Unit 1, and managed human factors review at Long Island Lighting Company's Shoreham Nuclear Power Station.

- Selection Testing
  Administers General Physics Basic Mathematics and Science Test (BMST) for operator training and selection; assists in human reliability analysis with emphasis on nuclear plant applications and the accompanying task analytic procedures.

- Development of Human Engineering Standards
  Compiled and developed standards, in control coding, legend plate design, mimic and demarcation lines, and color coding practices.

- Human Factors Training
  Instructs utility and industrial personnel in topics of performance evaluation techniques, experimental methodology and control room reivew procedures.

1977 - 1978 **Virginia Polytechnic Institute and State University**
In his research project, Mr. Liddle investigated the use of videotape recording apparatus in an assessment center process. He assisted in scheduling and debriefing participants, data collection and interpretation, and report writing.

PROFESSIONAL AFFILIATIONS Member, Human Factors Society

PUBLICATIONS

Applied Human Factors in Power Plant Design and Operation, General Physics Corporation, 1980, Coauthor with D. C. Burgy, P. A. Doyle, H. F. Harsam.

Susquehanna Steam Electric Station Detailed Control Room Design Review Program Plan, General Physics Corporation, 1982.

Shoreham Nuclear Power Station Detailed Control Room Design Review Program Plan, General Physics Corporation, 1983, Coauthor with D. C. Burgy.

June 1984

RICHARD L. BRANCH

Assistant Operations Supervisor - Vermont Yankee

Experience

Mr. Branch has amassed an impressive list of experience in power plants beginning in 1946 as a member of the US Navy. Eleven years in various marine engine rooms were followed by two years as Engineer on a diesel submarine. This, in turn, was followed by a year of training in the US Navy Nuclear Power Training Unit at West Milton, NY, and the Westinghouse Bettis Laboratories. Six years of on-board experience followed on the USS Robert E. Lee and the USS George Bancroft where he served as Engineering Watch Section Supervisor.

Following his retirement from the US Navy, with twenty years service, he was employed by General Dynamics, Electric Boat Division in Groton, Connecticut, as a Technical Aide.

He joined the Vermont Yankee Nuclear Power Corporation staff in 1968 as a Shift Supervisor. This was during the early phases of plant construction. During the ensuing two years he was loaned to the Millstone Point Company as a Shift Supervisor and assisted them during the construction and start-up periods.

At the completion of his Millstone assignment he returned to Vermont Yankee as a Shift Supervisor during the late construction period and participated in completion and start up of this plant. He continued as Shift Supervisor until 1976. Since then he has servced as Assistant Operations Supervisor and Operations Supervisor.

Licenses

Mr. Branch holds or has held the following licenses and ratings:

1. AEC Senior Operators License for Millstone 1
2. AEC Senior Operators License for Vermont Yankee (currently in force)
3. Senior Chief Engineer USN
4. Operating Engineer USN
5. Engineer USN

Education

Mr. Branch completed a High School Equivalency program while in the US Navy. He has completed a total of 12 US Navy training school, among which were included:

Machinist Mate School
Class A Engineman School (Diesel)
Class C Engineman School (Diesel)
Ground Control Approach School (Engineman)
Basic Nuclear Power School
Training Unit S3G
Nuclear Power Plant School (Bettis)

In civilian life he has completed:

BWR Reactor Operator Training Program (Morris, Ill.)
Program of Reactor Experiments (Argonne National Lab.)
In three different years ('77, '78, '79) he has requalified on the Browns Ferry Simulator and the GE BWR Simulator.

[illegible]

[illegible]

BACKGROUND

1980 - present — YANKEL ATOMIC ELECTRIC COMPANY

Senior Engineer with Yankee Atomic Electric Company. Responsible for Instrument & Control projects in the Plant Engineering Department. These include Yankee Control Room Design Review, Vermont Yankee Control Room Design Review, Seabrook Equipment Qualification program and the preparation and review of EDCRs.

1977 - 1980 — UNDERWRITERS LABORATORIES

Project Engineer responsible for the coordination, cost estimates for project and performance of a five member team investigating numerical controllers, programmable controllers, AC and DC speed controllers, energy management equipment motor control centers, starter, contactors, relays, switches, etc. In addition worked on development of standards and test programs for industrial control equipment.

1975 - 1977 — GIBBS & HILL, INC.

Associate Electrical Nuclear Engineer on a 2300 MW dual unit nuclear power plant utilizing pressurized water type reactors. Technical responsibilities include development of control philosophy, preparation of electrical sketches, review and approval of electrical elementary and block diagrams, vendor drawings, preparation of electrical division specifications for solid state and conventional equipment, technical and commercial comparison of bids. In addition, interfaced with other project disciplines to coordinate electrical and control equipment requirements.

1973 - 1975 — STONE & WEBSTER ENGINEERING CORP.

Control Systems Engineer on 2000 MW dual unit nuclear power plant utilizing pressurized water type reactors. Technical responsibilities included instrument application, preparation of control loop diagrams, logic diagrams, logic system descriptions, electrical diagrams, review and approval of vendor drawings, preparation of control systems diagrams and specifications, technical and commercial comparison of bids and preparation of Preliminary Safety Analysis Report.

EDUCATION

A.A.S. in Electrical Technology - Queensboro Community College - 1970

B.E.E., Bachelor of Electrical Engineering, Pratt Institute - 1973

RESUME
February 29, 1984

[illegible] Marsolais
Review [illegible] Program Manager

Mr. Marsolais' experience in power plant operation, control boards and control rooms started in 1942 when he began operating marine power plants in the United States Merchant Marine fleet. His six years as operator includes both licensed and unlicensed experience in steam engines and turbines, boilers, turbo-electric drives and diesel engines.

In 1948, he turned to shoreside, or stationary, plants and spent two years operating industrial plants before joining the electric power company.

In 1951, he joined the New England Electric System as a Watch engineer/switchboard operator in the generating station at Newburyport, MA. In 1955, he became a Watch engineer at the generating station in Lawrence, MA.

In 1959, when the Yankee plant was nearing completion, he joined the staff as a control room operator, subsequently becoming a Shift Supervisor in 1961, serving in this position until 1970.

In 1970, he was assigned Operations Supervisor at the nearly completed Vermont Yankee plant. Following a training period at the General Electric BWR simulator in Morris, IL, he was loaned to Northeast Utilities to assist in the completion of the Millstone I nuclear plant.

In 19[illegible], he was transferred to the Yankee Nuclear Service Division's Systems Engineering Group. During the ensuring period, he was responsible for the design/management of several major items such as the Vermont Yankee reactor building crane replacement, the fire hazards evaluation for all the Yankee plants, system safety classification for all plants; and responsible for coordinating the Vermont Yankee plant responses for the issues resulting from the Three Mile Island plant incident.

In 1980, he became the Vermont Yankee Project Manager, responsible for procurement and delivery of all engineering support services by the Yankee Nuclear Services Division on behalf of Vermont Yankee. As such, he was also directly responsible for the receipt and delivery of all licensing communication with the NRC.

He is currently a Principal Engineer in the Plant Engineering Department of Yankee Nuclear Services Division.

EDUCATION

Mr. Marsolais has completed programs at the following institutions:

U.S. Maritime Services Training School (Eng.)
Marine Engineers Beneficial Assoc. Eng. Training School
Hawley-Mullane School of Steam Engineering
Merrimack College
Lawrence Industrial School

Yankee Operator Training Program
GE BWR Simulator Operator Training Center
Northeastern University
Worcester Polytechnic Institute (Project Management Seminars)
Battelle Institute (Management Seminars)

CREDENTIALS

Mr. Marsolais holds, or has held, the following:

2nd Assistant Marine Steam Engineers License
3rd Assistant Marine Diesel Engineer
* Massachusetts First Class Power Plant Operating Engineer
* Massachusetts Nuclear Power Plant Senior Supervising Engineer
Senior Control Room Operators License (Yankee)
Senior Control Room Operator Equivalent (BWR Simulator)
* Associate Degree in Heat Engineering (Northeastern)

* Currently in force