HUMAN FACTORS ENGINEERING
DETAILED CONTROL ROOM DESIGN REVIEW
IN-PROGRESS AUDIT

ROCHESTER GAS AND ELECTRIC CORPORATION
R.E. GINNA NUCLEAR POWER PLANT

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Human Factors Engineering

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In-Progress Audit
Rochester Gas and Electric Corporation
R.E. Ginna Nuclear Power Plant

1. INTRODUCTION

On May 14 through 17, 1985, an NRC in-progress audit was conducted of the Detailed Control Room Design Review (DCRDR) by Rochester Gas and Electric Corporation (RG&E) for the R.E. Ginna Nuclear Power Plant. This audit reviewed DCRDR status and activities to date in order to recommend to RG&E program modifications that will improve the DCRDR and further its ultimate acceptability to the NRC staff. Of particular interest were the areas of concern identified by the NRC evaluation [7] of the Ginna DCRDR Program Plan [6].

The audit team was composed of two persons from the NRC Human Factors Engineering Branch and two persons from the Lawrence Livermore National Laboratory, acting as consultants to the NRC.

During the course of the audit, the NRC audit team discussed all aspects of the DCRDR program with RG&E and their DCRDR consultant, ARD Corporation. Documentation of the Control Room Survey, Function and Task Analysis, Operator Survey, and HED Assessment process was reviewed in detail. Additionally, the NRC audit team visited the control room to audit the extent to which the survey discovered and documented human engineering deficiencies (HEDs), and to evaluate how well the Assessment process identified HEDs that are significant and warrant correction.

A discussion of RG&E activities in each DCRDR topic area, identified by Supplement 1 to NUREG-0737 [2], and the corresponding audit team assessment of each area follows.

2. DISCUSSION

2.1. DCRDR REVIEW TEAM

2.1.1. Requirement

Supplement 1 to NUREG-0737 requires the establishment of a qualified multidisciplinary review team to conduct a DCRDR. Guidelines for review team selection are found in NUREG-0700 [3], and Appendix A to Section 18.1 of the Standard Review Plan, NUREG-0800 [4].

2.1.2. Audit Team Observations

The Ginna DCRDR team is comprised of:

- A Senior Nuclear Engineer from RG&E who is also a former Senior Reactor Operator
- The Electrical Engineering Department Manager
- A station engineer
- The control room foreman who is responsible for Emergency Operating Procedure preparation
- The station instrument and control maintenance supervisor
- The Simulator Project Manager
- A assistant training coordinator
- A lead human factors specialist plus four supporting human factors specialists from ARD corporation

Three team members are licensed Senior Reactor Operators

Additional individuals with expertise from various disciplines are also available to support team efforts

2.1.3. Audit Team Assessment

The concerns about the Ginna DCRDR team make up raised by the Program Plan Review were resolved by the audit. It appears that the Ginna team composition complies with the DCRDR team requirements of NUREG-0737, Supplement 1.

The DCRDR Summary Report should provide detailed information regarding:

- The qualifications of each DCRDR team member
- The DCRDR responsibilities of each team member
- The degree to which each team member participated in each of the DCRDR tasks

2.2. FUNCTION AND TASK ANALYSIS

2.2.1. Requirement

Supplement 1 to NUREG-0737 requires the applicant to perform systems function and task analyses to identify control room operator tasks and to identify control room operator information and control requirements during emergency operations. Supplement 1 to NUREG-0737 recommends the use of function and

task analyses that have been used as the basis for developing emergency operating procedures technical guidelines and plant-specific emergency operating procedures to define these requirements.

2.2.2. Audit Team Observations

The Ginna system function and task analysis is based upon plant specific Emergency Operating Produces (EOP) developed from generic Westinghouse Owners Group Low Pressure Emergency Response Guidelines (Rev. 1) [8]. The EOPs evaluated by the task analysis encompass functional response guidelines and supplemental operating procedures required to support the EOPs, as well as the emergency procedures that directly address response to plant transients. It was noted however, that the remote shutdown procedure has not yet been included in the task analysis.

The EOPs were broken down into discrete task and a Master EOP Summary (MES) was prepared that listed only once each task implemented by the EOPs. This process minimized reanalysis of repetitive tasks and of tasks that are common to several procedures.

Each operator task in the MES was analyzed to identify all specific action steps that might be used to accomplish the defined task. This analysis identified parameters to be monitored and control functions to be implemented in the performance of each step.

Each action step was evaluated to identify

- The most desirable mode of control or display, i.e.: discrete, continuous or trend
- The most desirable form of immediate feedback of proper control operation
- Instrumentation range, scale units and resolution
- The component identification number of the control or display to be used to accomplish the step if the required device exists in the control room

The task analysis information was entered into a computer data base system to allow automated comparison of control and display characteristic's with the control room inventory.

The audit team noted that the task analysis did not identify requirements relating to the operability of instrument and control loops under accident conditions (i.e. power supply quality and environmental qualification of equipment not in the control room, but in the loop). For example, it could not be verified that the task analysis would insure the availability of sufficient safety grade instrumentation to identify EOP entry conditions.

The audit team examined the task analysis worksheets relating to each step in

the procedure for Inadequate Core Cooling (FR 3.1). A number of inconsistencies among the EOP, the MES and the task analysis worksheets were identified.

2.2.3. Audit Team Assessment

The use of EOPs developed from Westinghouse generic ERGs as the system and functional basis for the Ginna task analysis is acceptable as discussed in NUREG-0800 Section 18.1 Appendix A. It appears that the process described for identifying control room information and control requirements and characteristics will fulfill the system function and task analysis requirements of NUREG-0737, Supplement 1 if the analysis is expanded to address instrument and control loop operability requirements under the abnormal plant conditions expected to result from the plant transients leading to performance of EOPs. This analysis should have the goal of verifying that sufficient controls and displays remain operable such that at least one shutdown path can be accomplished under abnormal power supply and environmental conditions. In addition the DCRDR team should take action to insure inconsistencies between the EOPs, MES, and the task analysis, of the type uncovered and noted during the audit are eliminated from the task analysis.

The Ginna summary report should discuss the actions taken to address the above comments.

2.3. COMPARISON OF CONTROL AND DISPLAY REQUIREMENTS WITH CONTROL ROOM INVENTORY

2.3.1. Requirement

Supplement 1 to NUREG-0737 requires the applicant to compare the operator display and control requirements determined from the task analyses with the control room inventory to determine missing controls and displays. Guidance in NUREG-0700 also calls for a review of the human factors suitability of instruments and controls used to satisfy operator information and control requirements.

2.3.2. Audit Team Observations

A complete inventory of control room controls and displays was developed prior to the DCRDR to support the construction of a plant specific simulator. This inventory was verified and updated by the DCRDR team via a control room walkdown. The updated inventory was input into a computerized data base.

An automated comparison between the instrument and control requirements from the task analysis and the control room inventory has been conducted. This comparison flagged all cases in which the control room capabilities do not equal or exceed the requirements defined by the system function and task analysis. The results of this comparison will be reviewed to screen out obviously spurious results such as items resulting from spelling or data entry errors. All other differences will be identified as HEDs.

2.3.3. Audit Team Assessment

The process for developing the control room inventory and comparing the inventory with the requirements identified by the system function and task analysis will satisfy the requirements of Supplement 1 to NUREG-0737. However, a detailed explanation of this process, as it was described to the audit team, should be provided in the summary report.

2.4. CONTROL ROOM SURVEY

2.4.1. Requirement

Supplement 1 to NUREG-0737 requires that a control room survey be conducted to identify deviations from accepted human factors principles. NUREG-0700 provides guidelines and criteria for conducting a control room survey. The objective of the control room survey is to identify for assessment and possible correction the characteristics of displays, controls, equipment, panel layout, annunciators and alarms, control room layout, and control room ambient conditions that do not conform to good human engineering practices.

2.4.2. Audit Team Observations

The Ginna control room survey was conducted using the survey checklists from NUREG-0700. In order to insure consistent evaluation, the entire control room was evaluated together for each criterion. A human engineering discrepancy (HED) was documented for each criterion that is not met throughout the control room and each specific criterion violation was identified as part of the HED.

The audit team conducted a control room inspection using NUREG-0700 checklists and independently identified 26 HEDs. Review of the Ginna control room survey results showed that 6 of these HEDs were not identified by the RG&E DCRDR. These were:

- Unlabeled scales were noted on FI-2011 and FI-2012
- Handwritten scales that do not meet legibility criteria were noted on FI-2011, FI-2012, TI-2091 and PR-420
- Protective covers over valve control switches obscured the switch escutcheons. The controls for PCV-480 and PCV-431 are two examples of this HED
- A few J handle switches were noted to be close to the front edge of the control panel benchboard, and subject to accidental activation
- A few control switches, the containment depressurization valve controls for example, were noted to have open/closed positions reversed from other control switches

- The control room survey did not identify readily apparent problems with control room lighting levels and glare on displays. For example, high luminance ratios between information and veiling reflectance was noted by the audit team and the operator survey but not by the DCRDR lighting survey

- Lighting provided for access to and operation of safe shutdown equipment did not appear to be sufficient to provide the minimum illumination levels recommended by the IES handbook and NUREG-0800, Section 9.5.1

Additionally, two cases were noted where the RG&E survey identified the generic HED noted by the audit team, but did not identify the specific cases noted by the audit team. These cases were:

- A valve control switch label that does not functionally describe the controlled device. "Valve No. 350"

- Breaker control pushbuttons on panel 5, that did not describe the function of the control

2.4.3. Audit Team Assessment

The process used to conduct the human factors engineering survey of the Ginna control room appears to fulfill the survey requirements of NUREG-0737 Supplement 1. However RG&E should repeat the control room lighting survey to address the deficiency noted above and should review the additional HEDs found by the audit team to determine if these findings are indicative of a systematic problem with RG&Es survey. The DCRDR summary report should discuss the actions taken to resolve these comments.

2.5. ASSESSMENT OF HEDs

2.5.1. Requirement

Supplement 1 to NUREG-0737 requires that HEDs be assessed to determine which HEDs are significant and should be corrected. NUREG-0700 contains guidelines for the assessment process.

2.5.1. Audit Team Observations

The DCRDR team plans to categorize HEDs into three safety significance categories:

1. HEDs associated with safety related systems, displays or controls

2. HEDs associated with non-safety related systems, displays or controls

3. HEDs that do not clearly fit into categories 1 and 2

The potential for human error will also be evaluated to be in one of three categories:

A. Significant potential for error

B. Moderate potential for error

C. Minimal potential for error

The above categorization will be used to aid in the placement of each HED into one of four correction categories:

W. Additional study is needed to determine most appropriate resolution

X. The HED should be corrected

Y. The HED need not be corrected

Z. The DCRDR team needs additional information to allow categorization

The correction category does not follow directly from the safety significance and potential for error categorization, rather the first two categories will be used by the DCRDR team as an aid in the assignment of a correction category. The categorization will be accomplished via meetings of the entire DCRDR team. Placement of a HED into a given category requires unanimous agreement of the DCRDR team.

No formal mechanism has been instated for addressing cumulative and interactive effects of HEDs. Currently RG&E is depending upon grouping of similar HEDs and continuity of membership in the DCRDR team during the assessment phase to identify cumulative and interactive effects. It was stated that a further review of HEDs that are not planed for correction will be conducted to verify that specific cumulative and interactive effects amongst HEDs have not been overlooked.

Only a portion of the HEDs identified by the control room survey, the operator survey and the operating experience review had been categorized by the DCRDR team prior to the audit. The audit team reviewed the categorization of these HEDs. It was noted that some HEDs which affect both safety and non safety systems were placed into safety significance category 3. Examples of HEDs in this category are lack of lamp test capability and inaccessibility of remote shutdown equipment. It was also noted that the following significant HEDs were not identified for correction:

- Numerous HEDs in the annunciator system such as inconsistent and undescriptive tile legends, inconsistent and difficult to read tile lettering, frequent use of a single window to indicate one of many alarm states and lack of window reflash capability

- Operator identified problems with manual control of steam generator water level during startup [9]

- Lack of lamp test capability

- Inaccessibility of remote shutdown equipment

- A number of operator survey HEDs concerning control display relationships

2.5.3. Audit Team Assessment

The HED categorization scheme discussed during the audit will satisfy the NUREG 0737 Supplement 1 requirements for HED categorization provided a more structured approach to evaluation of cumulative and interactive effects is developed and formalized. The evaluation of cumulative and interactive effects should not be limited to HEDs that are not identified for correction as this would mask interactions between HEDs in the "correct" and "do not correct" categories. Also it could result in the assignment of a inappropriately low priority to the correction of related HEDs in the "correct" category.

The audit team is concerned that safety significance category 3 is being used to replace careful evaluation of the safety significance of HEDs that are difficult to categorize. RG&E should insure that all HEDs that affect the performance of safety related systems are categorized as safety related.

The audit team is also concerned that the HEDs noted above, but not planned for correction, indicate that the expected cost of correcting specific HEDs is being given too much weight during the categorization process. RG&E should be careful to insure that the DCRDR team equally weighs both cost and benefit when deciding whether a specific HED warrants correction.

The difficulty with maintaining steam generator water level while under manual control at low power was identified as a HED from the operator survey and has resulted in two reportable events at Ginna in the recent past. Ineffective steam generator water level control can result in loss of the most desired reactor heat sink and unnecessary challenges to engineered safety features. The audit team believes that the demonstrated problems with the operator interface to this system combined with the consequences that could result from these problems warrant a careful evaluation of this HED by fully qualified personnel.

The Ginna DCRDR summary report should address the resolution of the above comments.

2.6. SELECTION OF DESIGN IMPROVEMENTS

2.6.1. Requirement

Supplement 1 to NUREG-0737 requires selection of control room design improvements that will correct significant HEDs. It also states that improvements that can be accomplished with an enhancement program should be done promptly.

2.6.2. Audit Team Observations

The process for selection of design improvements that is discussed in the program plan has not yet been implemented and has not changed from that described in the program plan.

2.6.3. Audit Team Assessment

The audit team could not evaluate the effectiveness of the process for selecting design improvements. RG&E should identify in the DCRDR summary report design solutions planned to resolve significant HEDs and the schedule for implementation of each modification. Any revisions to the selection process described in the program plan should be discussed.

2.7. VERIFICATION OF CONTROL ROOM DESIGN IMPROVEMENTS

2.7.1. Requirement

Supplement 1 to NUREG-0737 requires verification that selected control room design improvements will provide the necessary corrections of HEDs, will introduce new HEDs into the control room, and will not result in increase risk, unreviewed safety questions, or temporary reduction in safety.

2.7.2. Audit Team Observations

The process for verification that modifications implemented to correct HEDs indeed correct the identified human factors problem and do not create new HEDs is not yet fully defined. The process will, however, include the development of a human factors manual and a listing of standard nomenclature and abbreviations for use by the station engineering staff. RG&E plans an ongoing human factors program to insure human factors considerations are incorporated into future plant design modifications.

2.7.3. Audit Team Assessment

The process for verifying human factors design improvements could not be assessed by the audit team. RG&E should submit the details of the verification process as part of the summary report.

The audit team believes the development of the human factors manual, nomenclature standards, and the commitment to implementation of an ongoing human factors program are positive steps that reflect a good understanding of human factors concerns on the part of RG&E.

It is suggested that when Ginna's plant specific simulator becomes available, it should be used as part of the verification process in order to insure complex modifications are completely evaluated prior to implementation on the plant control boards.

2.8. COORDINATION OF CONTROL ROOM IMPROVEMENTS WITH OTHER PROGRAMS

2.8.1. Requirement

Supplement 1 to NUREG-0737 requires that control room improvements be coordinated with changes from other programs; e.g., safety parameter display system, operator training, Regulatory Guide 1.97 [5], and emergency operating procedures (EOPs).

2.8.2. Audit Team Observations

RG&E is relying upon participation of management level personnel in the various NUREG 0737 activities to provide coordination of DCRDR with other programs. No formal methodology for coordination is in place. The audit team noted the following evidence of insufficient coordination:

- There is no plan to validate the functional integration of all control room modifications resulting from NUREG-0737 emergency response initiatives

- There is no methodology defined to incorporate EOP revisions into the system function and task analysis. This deficiency has resulted in inconsistencies between the procedures and task analysis as noted in section 2.2

- The system function and task analysis appears to have provided little input to the development of the listing of Type A variables for the Regulatory Guide 1.97 study

2.8.3. Audit Team Assessment

RG&Es process for coordinating NUREG 0737 activities does not appear to fully satisfy the coordination requirements of Supplement 1 to NUREG-0737. A more formal and through process should be developed and discussed in detail in the summary report.

2.9. OTHER REVIEW RESPONSIBILITIES

2.9.1. Operator Survey

NUREG-0700 recommends that control room operating personnel be surveyed to draw out knowledge of problems and positive features that have been noted during operations or preparation for operations. The individuals selected for survey should encompass the full range of experience levels.

RG&E surveyed all licensed operators, selected non-licensed operators and selected non-operations personnel to draw out special knowledge of control room problems and strong points. The survey was administered via a self administered multiple choice questionnaire with provisions for additional written comments relating to each survey question. Survey topics covered the range of topics suggested by NUREG-0700. Multiple choice responses were evaluated by developing a histogram for each question in order to highlight the predominate opinions of the surveyed personnel. Essay responses were grouped together where possible and ambiguous survey responses were followed up through interviews by the human factors consultant. All survey findings were listed and the findings were reviewed to identify problems that could degrade operator performance. These items were designated as HEDs. More than 100 HEDs resulted from the survey process.

The audit team concluded that RG&Es operator survey made a strong positive contribution to the DCRDR process. It was noted, however, that the survey responses contained a number of valid and useful remarks that are not HEDs. The audit team suggests that RG&E review these items to determine if any of the issues raised by these operator responses warrant resolution independent of the DCRDR process.

2.9.2. Historical Document Review

NUREG-0700 recommends that plant and industry operating experience be reviewed to identify conditions that have historically caused human engineering problems.

RG&E conducted a review of operating history to identify human engineering problems at Ginna or other similar Westinghouse plants that have resulted in significant operational problems. The review was conducted for events occurring in the previous five years and included:

- Licensee Event Reports
- INPO Significant Event Reports
- INPO Significant Operating Experience Reports
- In house reports of Ginna operating experience

Items from these sources were selected as HEDs if they involved control room equipment, procedure steps that are normally performed in the control room, or involved a personnel error that occurred in the control room, and if they were applicable to the Ginna control room.

The audit team concluded that the historical review also made a valuable contribution to the DCRDR process. The audit team determined, however, that the human engineering problems identified as a result of the Ginna steam generator tube rupture event and documented in NUREG-0909 [9] were not included in the historical review process. It is recommended that the NUREG-

0909 findings be factored into the DCRDR process.

2.9.3. Safe Shutdown Capability

NUREG-0800, Section 18.1 recommends that the scope of the DCRDR include a human factors evaluation of remote shutdown capability.

The Ginna control room survey also included a human factors engineering survey of the remote shutdown capability ("Areas of Review," Section 16.1 of NUREG-0800). Review of the HEDs developed confirmed that the remote shutdown stations were included as specific problems related to many HEDs. Walkthrough of several safe shutdown stations by the audit team confirmed that numerous and severe human factors problems exist with the current safe shutdown stations.

It is understood that RG&E plans extensive modifications to Ginna's safe shutdown system design in the near future. The audit team suggests that this presents an excellent opportunity to infuse human factors principles into the safe shutdown system design from the beginning using human factors experts. It is particularly important that conventions and nomenclature be consistent between the control room and the safe shutdown stations.

Additionally, it is recommended that system function and task analysis be conducted as part of the safe shutdown system modification design process in order to assure that all necessary controls and displays are included. Since the initial actions following control room evacuation involve several closely timed and coordinated manual actions on the part of operators at physically separated safe shutdown stations, it is suggested that special task analysis techniques, such as a time line analysis, may prove beneficial to insure that staffing, illumination, communications and access are sufficient to allow the necessary sequence of actions in an error free and timely manner.

CONCLUSIONS

RG&Es DCRDR program appears to be well directed towards fulfilling the DCRDR requirements of NUREG 0737, Supplement 1. The development of a human factors engineering manual for Ginna and the commitment for an ongoing human factors program to assess future design modifications reflects a good understanding of the significance of human factors issues on the part of the utility.

A number of concerns with the DCRDR process were identified as a result of the audit. The audit team submits the following recommendations to enhance RG&Es DCRDR program and further it's ultimate acceptability.

- The specific qualifications and responsibilities of each DCRDR team member along with their level of effort in each DCRDR task should be documented in the final summary report.

- The system function and task analysis should be expanded to define instrument and control operability requirements (e.g., instrumentation needed to identify EOP entry conditions must be operable under power supply and environmental conditions that result from the transients requiring use of the EOPs).

- A methodology for incorporating revisions to the EOPs into the task analysis should be developed and formalized.

- The task analysis should be reviewed to verify consistency with the existing EOPs in order to eliminate the types of "mechanical problems" identified by the audit team.

- The DCRDR summary report should include the details of the control room inventory process as described to the audit team.

- RG&E should review the implications of the HEDs identified by the audit team, but not by the DCRDR control room survey, in order to determine if these findings imply a systematic problem with the survey process. Conclusions, and corrective actions should be discussed in the summary report.

- The control room lighting survey should be repeated.

- The process for assessing cumulative and interactive effects of HEDs should be better defined and formalized. The ultimate process for identifying these effects should be described in the summary report.

- RG&E should be careful that benefits of HED correction are given full consideration along with cost during the process of determining which HEDs should be selected for correction.

- RG&E should reevaluate the desirability of correcting the various annunciator problems identified, the lack of lamp test capability, and the difficulty in accessing remote shutdown equipment.

- The assessment of control-display relationship HEDs, particularly those related to Engineered Safety Features, should be reviewed.

- The HED relating to the difficulty of maintaining steam generator water level during low power operation should be carefully assessed considering the historical problems with the control system, the potential consequences of misoperation, and the operators' comments about their problems with operation at low power.

- Care should be taken to insure that the "Other" safety significance category is not inappropriately used during the HED assessment process. Any HED that affects the operator's use of a safety related display or control should be categorized as a safety related HED.

- Once the plant specific control room simulator becomes available, RG&E should take full advantage of that facility to evaluate the suitability of proposed control room modifications.

- The processes for coordinating other NUREG-0737 activities with the DCRDR process must be better defined and formalized. The specific problems identified by the audit must also be resolved. The specific actions taken to resolve the coordination issue should be discussed in the DCRDR summary report.

The process for selecting design improvements and for verifying that modifications implemented to correct HEDs fully resolve the identified problem and do not create new HEDs were not sufficiently developed to allow assessment by the audit team. RG&E should insure that the summary report addresses these items in sufficient detail to allow NRC review and determination whether the DCRDR requirements of Supplement 1 to NUREG-0737 have been met.

Finally, the audit team submits the following suggestions for RG&Es consideration in areas not directly related to the DCRDR requirements of NUREG-0737, Supplement 1.

HEDs identified by the review of the response to the Ginna steam generator tube rupture event (NUREG-0909) should be factored into the DCRDR process.

Operator survey comments that were not evaluated as HEDs should be otherwise considered by RG&E.

The design modifications made to the remote shutdown capability should employ conventions and nomenclature that are consistent with those used in the control room.

A system function and task analysis should be conducted for the remote shutdown system. This analysis should address the coordination and timing of manual actions to be accomplished by the station operators.

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3. "Guidelines for Control Room Design Reviews," NUREG-0700, September 1981.

4. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," NUREG-0800. September 1984.

5. "Instrumentation for Light Water Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident," Regulatory Guide 1.97, Rev. 3. May 1983.

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7. Letter; J.A. Zwolinski (NRC) to R.W. Kober (RG&E) "Review of Detailed Control Room Design Review for Ginna Nuclear Plant", April 16, 1985.

8. Memo; H. B. Clayton (NRC) to D. L. Sieman (NRC); "Meeting Summary - Task Analysis Requirements of Supplement 1 to NUREG-0737 - March 29, 1984 Meeting with Westinghouse Owners Group (WOG) and Other Interested Persons," April 5, 1984.

9. "NRC Report on the January 25, 1982 Steam Generator Tube Rupture at the R. E. Ginna Nuclear Power Plant," NUREG-0909, April 1982.