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MEMORANDUM FOR: H. R. Denton, Director
Office of Nuclear Reactor Regulation

V. Stello, Director
Office of Inspection and Enforcement

FROM: R. B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER #124
CONTROL ROOM ALARMS AND ANNUNCIATORS

A-6719
J Jenkins

This Research Information Letter (RIL) transmits the results of research relevant to the display and utilization of control room alarm and annunciator systems. The research is part of Task I.D. 4.a(1) of the TMI Action Plan. Enclosure 1 is the detailed documentation, NUREG/CR-2147, on which this RIL is based.

1. Introduction

The operating crews at Three Mile Island-2 and at other nuclear power plant control rooms have experienced the importance to safety of the design of alarm/annuciator systems. Several investigations (1-3) have identified these systems as weak links in the man-machine interface for the safe monitoring, control and operation of nuclear power plants.

The purpose of the research described here was to:

a) identify specific problems in the design, use and maintenance of alarm and annunciator systems;
b) provide recommendations and suggest generic solutions;
c) recommend future research for improvements.
d) confirm the conclusions and recommendations of prior investigations (1-3,5).

2. Methodology

The approach used for this research was to compare current practices and methods of alarm/annunciator systems in reactor facilities with a recognized source of design criteria, MIL-STD-1472B, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities."(4)

Data to enable this comparison were collected by a team of nuclear engineers, systems engineers and human factors scientists who visited control rooms of four plants: the

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Advanced Test Reactor, the Engineering Test Reactor and two commercial pressurized water reactors. Structured interviews with 39 licensed reactor operators and senior reactor operators were conducted. Photographs and design documents were obtained. The results of this survey and the responses to the operators' questionnaire were compared with MIL-STD-1427B.

3. Results

The control room analyses of all four plants revealed deficiencies in presently installed alarm/annuciator systems that potentially degrade operator performance by increasing operator error probabilities in responding to true alarms, and require excessive time and effort for plant status surveillance and casualty response by operating personnel.

The following specific problems were identified:

a. Design - color codes are inconsistent in meaning; symbology and abbreviations were not standardized; legends and lettering were often difficult to read; acoustic frequency and timbre of aural alarms were not distinct one from the other.

b. Organization of annunciators - number, placement and relationships among annuniciators failed to give regard to their importance, function, response requirements and value in announcing a deviation from the normal; some annunciators were lit when a particular system was working normally.

c. Maintenance - some systems did not allow indicating light bulbs to be changed with ease; system checking and press-to-test features were lacking in some systems; unsatisfactory alarm disabling procedures were used; annunciator logic cards with low resistence to thermal shock were used resulting in poor reliability.

d. Operator loading - operator response requirements to lit annunciators were increased due to multiple secondary alarms to a primary cause; phantom acoustic alarms occured and legends were difficult to interpret.

Several short-term and long-term recommendations are provided and areas of potential pay-offs from additional research are discussed in Enclosure 1. The contractor's major recommendations are:

a) Establish design standards and guidelines for alarm/annunciator systems for both backfit applications and for new control room designs.

b) Provide aids, either through training or by means of hardware, to assist the operator in prioritizing or screening information from the system.

c) Develop acceptable methods and techniques which allow alarm/annunciator systems to be optimally formatted, structured and physically organized to aid in diagnostic response action to events.

d) Implement both short-term corrective actions along with other control room modifications, and long-term research and analysis in coordination with industry, INPO or EPRI.

4. Discussion

The specific deficiencies identified in Enclosure 1, together with informed comments from the near-term operating license reviews by the Division of Human Factors Safety, NRR, and other analyses (1-3,5) conclusively demonstrate widespread inadequacies of present alarm/annunciator systems. The specific solutions for existing plants, for control rooms under construction and for future designs require several different approaches. Many existing control rooms contain hard-wired, point-to-point, dedicated signal paths and few interfaces with central data distribution systems or even modular control units are minimal. Central computer processing and automatic monitoring of system functions are available in only a few plants. Short-term solutions must consider the existing operating plants and the unique design features in their control rooms. The intention of RES is to consider the recommendations for additional research and use them as a basis for continuing investigations of annunciator systems.

5. Recommendations

NRR should use Enclosure 1:

a) especially the problem definitions and descriptions as a guide in the NTOL and other power station control room reviews;

b) to assess the depths of coverage for alarm/annunciators set forth in draft NUREG-0700, "Guidelines for Control Room Design Reviews, and change it as needed;

c) in conjunction with NUREG/CR-1270 (Ref 2) and the Lockheed report (Ref 3) on the same subject, as information sources in the review of any licensee's proposed changes or upgrading of alarm/annunciator systems;

d) to advise RES on the completeness and scope of its research, especially proposed research programs aimed at alarm/annunciator system performance improvements.

RES should use Enclosure 1 to:

a) prepare a formal plan of research and request for NRR endorsement directed toward development of design and regulatory guidelines for alarm/annunciator systems in present and future control rooms;

b) incorporate to the extent possible in on-going research, analysis of alarm/annunciator problems and potential solutions, including aids to operators in prioritizing or screening information from the systems and improvements in the design of existing or new systems.

c) modify the human error analyses and risk assessment programs to include error and risk directly due to alarm/annunciator design and use by the operator.

d) establish with NRR, DOE and INPO or EPRI a cooperative review of additional control rooms' alarm/annunciator systems.

The RES technical contact for this research is Mr. James P. Jenkins, HFB/DFO, X35942.

6. References

1. NUREG-0585, "TMI-2 Lessons Learned Task Force Final Report" USNRC, October 1979.

2. NUREG/CR-1270, "Human Factors Evaluation of Control Room Design and Operator Performance at Three Mile Island-2," Essex Corporation, January 1980.

3. EPRI NP-1118, "Human Factors Methods for Nuclear Control Room Design, Volume 3," Lockheed Missiles and Space Company, March 1980.

4. MIL-STD-1472 B, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities "Department of Defense, December 1974.

5. NUREG-0659," Staff Supplement the Draft Report on Human Engineering Guide to Control Room Evaluation," USNRC, March 1981.

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Enclosure: NUREG/CR-2147

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Original signed by:
ROBERT B. MINOGUE

Robert B. Minogue, Director
Office of Nuclear Regulatory Research

Enclosure: NUREG/CR-2147

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RECORD NOTE: Per Jenkins, distribution of RIL was delayed pending changes in NUREG/CR-2147 by DOE.

TMI TASK I.D.4.a(1)
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