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October 15, 1980

RECEIVED
OCT 1980
R. W. FROELICH

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Director of Human Factors Safety

Dear Sirs:

Our letter dated September 26, 1980, transmitted Preliminary INPO Comments on NUREG/CR-1580. We also said in that letter that Joseph L. Seminara was assisting us in preparing comments on NUREG/CR-1580.

This letter transmits the comments of Mr. Seminara. (These comments were discussed by Mr. Seminara at the NRC Staff/INPO Meeting on October 15, 1980, in Atlanta.)

We also stated in the September 26, 1980 letter that we expected to receive additional comments from INPO's workshop, held in Atlanta, October 2nd and 3rd, 1980. Many verbal comments were expressed during the workshop and we were fortunate to have Voss Moore respond to these during the wrap-up session at the close of the workshop. Written comments were also invited and some were received. However, these written comments were copies of comments being prepared for transmittal to NRC. Since you should now have such comments, we see no need to send another copy from INPO. We can, however, add that most of the comments on NUREG/CR-1580 expressed during the INPO workshop are covered in INPO's comments of September 26, 1980, to NRC and the attached comments of Mr. Seminara.

Sincerely,

Randall W. Pack
Acting Director
Criteria and Analysis Division

RWP/ne
Enclosure

cc: E. P. Wilkinson
J. L. Voyles
J. L. Seminara

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REVIEW OF NUREG/CR-1580, HUMAN ENGINEERING GUIDE TO CONTROL ROOM EVALUATION DRAFT REPORT, JULY 1980

Joseph L. Seminara

INTRODUCTION

The Institute of Nuclear Power Operations (INPO) has undertaken to comment on the subject document, using experience gained in preparation for the INPO Control Room Evaluation Workshop, October 2nd & 3rd, 1980 in Atlanta, GA. As part of this comment process, INPO has requested this writer to provide an independent assessment of the subject document. Due to time pressures, only one week was allowed for this review and the contents of this report should be judged accordingly.

BACKGROUND

The undersigned has had the opportunity of examining the human factors aspects of some twenty nuclear power plant control rooms in the course of conducting the following activities over the past five years.

A. EPRI RP 501-1 - Human Factors Review of Nuclear Power Plant Control Room Design, EPRI NP-309, November 1976.

B. EPRI RP 501-3 - Human Factors Methods for Nuclear Control Room Design, EPRI NP-1118:

SUMMARY REPORT, June 1979

- Volume I: Human Factors Enhancement of Existi-_ Nuclear Control Rooms, November 1979
- Volume II: Human Factors Survey of Control Room Design Practices, November 1979
- Volume III: Human Factors Methods for Conventional Control Board Design, February 1980
- Volume IV: Human Factors Considerations for Advanced Control Board Design, March 1980

C. EPRI RP-1126 - Human Factors Review of Power Plant Maintainability, IN PRESS

D. EPRI RP-769 - Performance Measurement System for Training Simulators, IN PROCESS
E. Consultant to the Rogovin Special Inquiry Group to review THE ESSEX TMI II Human Factors Study
F. INPO Human Factors Engineering Benchmark and Evaluation Criteria and Human Factors Audit approaches; including preliminary field testing of the NUREG/CR-1580 control room evaluation methods.

Prior to these activities the writer was engaged for twenty years in the application of Human Factors Engineering Guidelines and Standards to the development of advanced military and aerospace systems such as The Polaris Missile checkout system, the S3-A ASW Aircraft, The Lunar Mobile Laboratory, and The Space Shuttle Orbiter crew systems concept. This combined background in the application of aerospace standards and in exploring the needs of the power industry in the human factors area may qualify the writer to provide some meaningful insights and perspectives in reviewing the subject draft report.

HUMAN ENGINEERING GUIDELINES

An analysis was conducted of the Human Engineering Guidelines presented in the subject draft report. This analysis considered the source of each guideline, format, backfit recommendations, and the associated human error statements. In all, 251 guidelines are offered within nine major topical areas.

SOURCE OF THE GUIDELINES

Of the 251 guideline statements, 144 or 57.4%, reference MIL-STD-1472 B or C. In many cases, other sources in addition to this standard are provided, however, the majority of the guidelines can be derived from MIL-STD-1472 B or C. In some cases MIL-STD-1472 B or C is not referenced with regard to specific guidelines when in fact the standard does cover the guideline in question. For example, Guideline CON-26 is entitled ROTARY CONTROL DIRECTION OF ACTIVATION and the guideline is stated as follows:

To minimize error, the rotary control setting valves should increase with a clockwise rotation.

This guideline is attributed solely to Van Cott and Kincade's Human Engineering Guide when MIL - STD - 1472 B, page 59, paragraph 5.4.1.2.1 which deals with direction and consistancy of control movement states:

> In general, movement of a control forward, clockwise, to the right, or up or pressing or squeezing a control shall turn the equipment component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up. Valve controls are excepted (see 5.4.1.2.4).

While time did not permit a review of all such cases where the proposal guidelines are available through MIL - STD - 1472 B or C, it is estimated that at least 75% can be derived from the basic military standard.

Other sources invoked as sources for the standards are as follows:

Van Cott and Kincade	32.7%
Woodson and Woodson and Conover	25.0%
McCormack	11.2%
Kubokawa	9.6%
MIL Handbook 759	8.4%
Miscellaneous	20.7%

APPLICABILITY OF THE GUIDELINES

As noted earlier, in many cases, multiple sources are noted in each guideline, What is of special interest here is that in only 8 cases, or 3.2% of the guidelines, were power industry - specific guidelines provide:

ANSI ANS-N2.3 .... 3 cases
EPRI NP - 309 .... 4 cases
ESSEX Reviews of Control Rooms .... 1 case

The general conclusion is that the guidelines in their totality, may not be sufficiently industry - specific to serve as the basis for upgrading existing control rooms. While many of the guidelines are certainly applicable and can serve a useful purpose, greater selectivity and specificity are needed to provide useful guidance to the industry. This need has been recognized by EPRI and by the ESSEX Corporation, as well as others. For example, EPRI has recently awarded the ESSEX Corporation a major contract for the development of a Human Engineering Guide for power plant control rooms design.

Since the proposed guidelines are based primarily on military standards and other than industry-specific documents it is appropriate to consider the intended use of these standards and documents by their originators. The forward to MIL - STD - 1472 B, dated 31 December 1974, states:

> This standard established general human engineering criteria for design and development of military systems, equipment and facilities. Its purpose is to present human engineering design criteria, principles, and practices to be applied in the design of systems, equipment, and facilities...

In a subsequent statement of the scope of MIL - STD - 1472 B, the following statement appears:

> 1.1. SCOPE -
> This standard establishes general human engineering criteria for development of military systems, subsystems, equipment and facilities.
>
> 1.2. PURPOSE -
> The purpose of this standard is to present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the system, subsystem, equipment, and facility, and achieve effectiveness, simplicity, effeciency, reliability, and safety of system operation, training, and maintenance.
>
> 1.3. APPLICATION -
> This standard shall be applied to the design of all systems, subsystems, equipment and facilities. Nothing in this standard shall be construed as limiting the selection of hardware, materials, or processes to the specific items described herein.

Similary, the foreword to the Van Cott and Kincade Human Engineering Guide states that the objective of the guide was "... to develop a comprehensive specification or handbook for guidance in applying human engineering techniques to new equipment and systems design". (underlining is by the writer)

The point to be made here is that the standards and guidelines developed earlier for military or space applications have always been primarily intended for use in the design and development process and not for widespread application on a remedial or backfit basis. The application of human factors engineering on an "after-the-fact" basis is considerable more risky and difficult than during the design process, before metal has been bent. In fact, there are obvious and inherent dangers of further degrading a system when human factors guidelines are applied on a compromise-ridden, remedial basis.

The guidelines should be carefully studied to determine their applicability with regard to remedial action on existing operational plants as opposed to their relevance to preoperational plants where the control board designs are still on the drawing boards. For example, it is quite evident that most control boards have located one entire band of meters running across the breadth of the boards, in excess of recommended anthropometric limits established by the requirements to accommodate the fifth percentile male operator (a female operator makes this requirement even more stringent). Do the guidelines imply or mandate that all such meters be relocated to lower ground? Is a foot stool acceptable? Should operator height be used as a selection criterion to ensure that only 75th percentile or larger operators are permitted to operate the boards? When we examine the present density of most boards there simply is not sufficient spare space to relocate meters. Where space does exist, the space is not typically available where it should be to functionally relate meters to associated panel elements. Consequently a total board rearrangement and redesign is required to being all deviant meters down to the recommended height. In declaring a given zone of the existing boards "off limits" the total useable space in the boards is reduced considerable and the main console may no longer be large enough to accommodate all required panel elements, judging by the present extensive use of back panels, remote areas of the control room, and peripheral consoles. The main consoles are generally too small to start with (or panel elements are too large). The ramifications and complications in attempting to implement anthropometric guidelines on a backfit basis could be elaborated further. It is possible to apply such guidelines in accepting or rejecting a design in its formative stages, but it is impractible and potentially dangerous to levy such requirements on an existing control room in any blanket fashion. Each guideline should be examined carefully in terms of remedial implications and guidelines should be differentiated as to their relevance to new designs vs. backfits.

TYPICAL BACKFITS

The subject document goes beyond the existing military standards by proposing "typical backfits" in association with each specific guideline. An analysis was conducted of the first one hundred "typical backfits". Typically these recommendations are in the form of crisp statements such as "modify or replace", "relocate controls; replace panels", "write software", "change or modify labels", etc. In fact, 43 of the 100 guidelines reviewed offered "modify or replace" one liner or phrase advice. In the light of the discussion in the foregoing paragraph, such abbreviated statements are virtually useless and belie the blood, sweat, tears, and money (i.e., trade-offs) necessary to effect most remedial actions. There are a few exceptions, such as Guideline VD-26, that deals with Instrument Illumination. In this case, five pages of descriptive information (Chapanis 1965) are offered to the reader. This case stands out in sharp contrast to the overwhelming majority of "rearrange", "relocate", "modify or replace", "adjust", "typical backfit" statements that provide little or no guidance.

HUMAN ERROR STATEMENTS

Another embellishment on MIL - STD - 1472 offered by the subject document is a statement of HUMAN ERROR associated with lack of compliance to each specific guideline. These human error predictions are in the form of terse phrases such as: failure to respond, failure to detect, interpretation errors, incorrect control settings, substitution, etc. There are 36 visual display guidelines. In each case, the human error is designated as "misreading errors", "reading errors", "incorrect display reading and interpretation". These statements are not distinguishable, one from the other, and add little if anything by their repetition as a postscript to each guideline. If it is necessary to admonish the reader that a mproperly designed visual display can lead to reading errors, then perhaps such a statement might be offered as a preamble to each group of guidelines. In like manner, one general human error statement might introduce the 81 Control Design guidelines to advise the reader of the prognosis that improperly designed controls could lead to maloperation of controls.

DOCUMENTATION STATEMENTS

Each guideline statement provides a reference as to its source. This is an extremely valuable addition to the material extracted from MIL - STD - 1472 since it allows the reader to pursue each guideline in further detail.

COMPLETENESS OF THE GUIDELINES

As noted above, the proposed guidelines are based almost entirely on military standards. Consequently, they do not adequately address many of the most pressing issues in nuclear power plant control room design. For example: The design of current annunciator warning systems is one of the most troublesome operational areas from the human factors standpoint. However, massive arrays of annunciator lights distributed across the breadth of the control consoles are more characteristic of the process industries than military or space systems. Consequently, the guidance offered by existing human engineering standards and guidelines is only marginally relevant (see EPRI NP - 1118 for a more detailed review). Many operators have expressed the view during structured interviews that in the midst of a transient the annunciator - warning system in their control room is more of a hindrance than a help. They would opt for an annunciator system disable capability beyond the receipt of information provided by first-out displays in the initial moments of the transient. It is obvious that a sensory overload situation occurs during any major transients. When the annunciator matrices light up en masse, the operator is merely engaged in, or distracted by, repeatedly silencing auditory alarms rather than extracting useful information from the annunciator warning system.

The guidelines offer little direction in overcoming such problems. Other gaps in the guidelines include human factors aspects of control room maintenance, shift rotation practices, clearing and tagging devices and practices, watch turnover practices, overtime effects on performance, habitability features of the control room, factors that affect operator vigilance, communications practices (e.g. is it appropriate for the operator to become the plant's switchboard operator after normal day shift?), stress, monotony, division of responsibilities between shift team members, job structure, confinement effects, supervisory-subordinate relationship (chain of command), operator modifications to be control room or configuration control practices, organizational interfaces, special design guidelines for panels remote from the control room (e.g. emergency shut down panel), etc.

CONTROL ROOM EVALUATION PROCESS

The evaluation methodology outlined in volume I of NUREG/CR-1580 Draft Report is systematic, rigorous, and well defined. It is possible to raise questions regarding level of effort, choice or prioritization of methods, evaluation team member qualifications, and evaluation strategies. However, in raising such questions, there is no intent to detract from the excellent and systematic work reflected in Volume I.

Control Room Evaluation Planning

In defining the team members required for the evaluation process it is clear that a multi-disciplinary effort is envisioned. However, what is not evident is the magnitude of specialized human factors support needed. At least one human factors specialist should be involved in all phases of the evaluation process. This presents problems for the industry since there are about two dozen bona fide human factors specialists in the U.S. who have any depth of exposure to the unique concerns of the utility industry. What's more, those human factors specialists that do exist are not all available to participate in the evaluation process. It becomes important, as a matter of practical necessity, to place reliance on in-house utility personnel, exposing them to human factors methods to the greatest extent possible. The EPRI and INPO Human Factors Workshops were intended to provide this form of training to utility personnel. It is equally, if not more, important to formulate and provide a training program for human factors specialists that have had no prior exposure to the power industry. In this manner, suffecient numbers of experienced human factors specialists with transferable experience could be made available to support the industry. In fact, it would be far easier to train human factors specialists to be productive in the power industry then to transform utility personnel into human factors experts. Unfortunately, a number of self-proclaimed "human factors specialist" are appearing on the scene to take advantage of the present shortage of qualified people.

Evaluation Methods

Essex has selected, developed, or refined a good assortment of human factors data gathering tools. No human factors specialist is likely to question the value of structured operator interviews, human engineering checklists, surveys, task analyses, walk-throughs and photo-documentation. These techniques have proven extremely valuable in the earlier-referenced EPRI human factors sutdies. One can, however, question the magnitude of data-gathering effort, (e.g., the magnitude of task analysis is clearly excessive), the extent of documentation, and the priority that should be assigned to one data gathering approach as another. Also, several methodologies that have not been mentioned might also be included in the repertoire of data collection methods.

This writer personally finds the structured interviews of greatest value in acquiring insights into operational problems that bear further human factors scrutiny. It is recommended that at least one-half the operational staff be interviewed. Task analyses are typically conducted to systematically derive control-display requirements in developing new systems. The use of task analysis as an evaluation tool proved of some value in EPRI - NP - 309 but the power of this tool is constrained by its time-consuming nature. It is no exaggeration to state that it might take two to four man-years to examine every operator task by the laborious task analysis method. Further, this is one method that relies heavily on human factors expertise and is difficult to assign to non-specialists. We can limit the tasks to be analyzed to a presumed meaningful sample, or perhaps the better approach might be to attempt task analyses on a more generic basis. Does it make sense for each GE plant to conduct its own laborious task analysis or wouldn't it be more expeditious for GE to conduct a generic task analysis so that the basic control/display requirements for GE reactors, etc. were verified and validated by task analyses methods. Using these more generic vendor task analyses as the foundation, then each plant could verify that basic control/displays requirements derived on the basis of human factors task analysis methods had been satisfied. Assuming that the more generic task analysis were conducted on a vendor-by-vendor basis, then abbreviated and manageable task analysis approaches could be applied at the specific plant level to evaluate procedures, check the arrangement of required control/display elements, determine operator work load problems, reveal special operator response problems, highlight control room arrangement difficulties, etc. These more abbreviated task anlayses could substitute for the proposed walk-throughs, especially where no simulator exists that corresponds to the control room in question.

The necessity for videotaping walk-throughs is questionable. There is no denying that video tapes provide valuable insights, but if a line must be drawn somewhere, videotaping can be dispensed with. We could recommend heart rate measures as an index of stress, eye-movement recordings to assess efficiency of display placements, link analyses to evaluate control panel arrangements, or sociometric methods to determine operational shift teaming efficiencies. However, such techniques would probably represent an undue burden for value received.

One technique that may deserve greater consideration is the so-called "critical incident" technique, coupled with a review of LER's. The critical-incident technique is time-honored in the aerospace community and it is d. 'bed in EPRI NP-309. It provides special insights into the causality of actual operational errors and, more importantly, the near mishaps that go unreported. Similarly, when LER's are reviewed, on location, through the special perspective of human factors engineering, important clues to required enhancements can be derived.

Another technique that should be considered is the Potential Error Approach. This involves a detailed examination of the error potential associated with each procedural element of an operator task. A form is prepared listing each step of a procedure in sequence. Alongside each step there is space allocated for recording a LO/MEDIUM/HI error potential as judged by an operator (or trainer) based on his personal experience or his observations of others. When a MEDIUM or HI potential error step is identified, the operator is asked to describe the factors that may lead to errors. Concurrently, the HF data-gatherer notes where control board design deficiencies may be causal factors associated with operator errors.

The control room survey procedures, e.g., noise, illumination, and protective garments, are well-defined and should offer no problem in implementation. In fact, it is recommended that they be extended beyond the control room to other important areas of the plant. It is essential that the emergency shut-down panel be located in a viable operational environment. Similarly, when the control room operator must interact with and depend on auxiliary operators during emergencies the operational environment for the auxiliary operator should also be surveyed by the same survey procedures proposed for the control room.

EVALUATION OF HUMAN ENGINEERING DISCREPANCIES

In the writer's experience, it is relatively easy to find human engineering discrepancies in existing control rooms. It is considerably more difficult to find solutions for such problems and it should be recognized that some remedial attempts may further degrade the situation. Consequently, the evaluation and prioritization of discrepancies becomes an extremely important task.

Human Engineering Discrepancy Reports

Some method for documenting discrepancies is needed. The HED reporting system provided in the subject document is quite thorough...perhaps too thorough. There is always the danger in these types of activities that the focus will be diverted from correcting obvious problems to amassing file cabinets full of paper to justify what was or what was not accomplished. This tends to happen on some "bureaucratic" military programs.

In my view the emphasis should be on "generic HED's" and generic fixes. For example, a specific HED might be written to document everyone of 200 discrepant J-handle controls, thereby creating a very impressive file of paper, or one generic HED could encompass the lack of coding on the 200 J-handle controls. Similarly, one generic HED could cover all annunciators that are not properly located in association with related control board segments.

Prioritizing Human Engineering Discrepancies

Prioritization schemes tend to be largely judgemental or subjective and of questionable reliability. This generalization applies equally to the scheme presented in Section 4.2 of Volume I of the subject document, and to a preliminary prioritization scheme developed by this writer for INPO. While no formal tests of the reliability of priority rating has been performed, the writer has been dismayed at his own unreliability in judging the magnitude of a given problem from day to day or week to week. The lack of rater reliability becomes even more evident when a room full of "experts" attempt to answer questions such as those posed in paragraph 4.2.2 of Volume I.

It might be the better course to examine each guideline and assign it a target priority rating from the outset. For example, the lack of functional demarcation of panel elements could be assigned a target Category 2 or Category 4 rating from the outset, depending on the safety related, or not, distinction. In fact, the distinction between safety related and reliability related is often open to question and may be an artificial one in terms of overall human factors concerns. Do we confine ourselves to shape coding J-handle controls on the Engineered Safeguards panels and adopt a different set of design conventions for turbine generator controls? Do we relocate misplaced annunciators when they are safety-related and leave the remainder alone, even when they create general operational problems? Do we provide a new improved display coding scheme for the Safeguards panel and live with a contradictory color coding approach for other panels? I personally am more inclined to resolve all human factors problems that can be remedied across the entire control boards.

With experience in applying the guidelines and in exploring the feasibility of remedial options, a pattern of priorities will emerge that will be largely consistent from plant to plant. As the guidelines are updated, each specific guideline could include a target priority rating to guide the industry.

IMPLEMENTATION

Section 6.0 of the subject document, Vol. I, provides some cautionary statements to the effect that the utilities should not underestimate the magnitude of required remedial effort. I share this concern that some are seeking a "magic bullet" that will solve all the problems. However, I have a further concern, expressed elsewhere above, that backfits may not be instituted in a manner that will help the situation. In fact, the reverse may occur. This concern is based on first hand observations of typical backfits implemented by operational personnel, e.g., chart recorders mounted upside down so that an earlier view of pen recordings can be obtained, numerous add-on multi-colored dymo tape labels placed haphazardly on the boards, inconsistent coding of meters to reveal normal reading zones and limits, impromptu safeguards actuation cues in place of summary displays, etc. In observing attempts to implement recommendations offered in EPRI 118, Vol. I, it is surprising to note the number of ways in which the recommendations have been misapplied.

Based on these observations, I think that Section 6.0 should be expanded to provide guidance on implementation strategies and verification techniques. One method for ensuring a systematic enhancement effort would be to develop a full or half-scale mockup of the control board faces based on photographs of the existing configuration. All proposed remedies would first be attempted on the mockup. Rather than piece-meal, and potentially inconsistent, fixes on the operational boards, a whole series of fixes would first be integrated on the mockups. The mockup would ensure consistency of approach, allow for evaluation of candidate fixes, and permit operations and engineering personnel to provide inputs into the backfit process. The mockup would also serve as a design review tool both for internal reviews and during external audits. Finally, the mockup would provide a valuable training aid so that operators could be properly briefed before any change to existing control room took place. Where a corresponding control room simulator is available, the enhancement measures can be pretested on the simulator for some assurance that the remedial measures are properly designed. The simulator would allow dynamic simulation exercises to test the operational impact of proposed modifications. The proposed mockup would provide valuable, but more limited, static simulation data.

GENERAL REMARKS

There is little doubt that present generation nuclear power plant control rooms are deficient in varying degrees with regard to human factors engineering considerations. The Human Engineering Guide to Control Room Evaluation is a laudable first step in attempting to remedy the situation. However, there are many issues to be resolved before the intent of the subject document can be achieved. Several of these issues will be explored here.

The subject documents offers guidelines based largely on military standards. There is a world of difference between guidelines and standards. Guidelines are usually advisory and discretionary. Standards are considerably more binding, at least on military programs. It becomes extremely important to know whether the draft report guidelines will be treated as such or whether they are intended as standards. This, in turn, raises the question of NRC and/or INPO audit plans. The utilities have no clear notion in regard to such matters and it is difficult to proceed in an orderly manner until everyone understands "the rules of the game". It becomes important to include an audit plan in the subject report so that the remedial effort can be conducted in a manner that will satisfy regulatory requirements. In much the same manner that present day operator training programs have been shaped by NRC licensing exams, the application of remedial human factors to control rooms will be largely determined by the character of NRC, and/or INPO audits that ensue.

The problems that are found in present generation control rooms are largely repetitive or generic. It makes little sense, nor is it possible, to solve such problems on a case-by-case basis. It is too expensive and redundant to do so. Such problems must be solved on an industry-wide basis and the solutions must be verified. Otherwise, we are usually better off leaving things as they are. Some basic problems that should be attacked on an industry-wide basis include:

1. Enhancement of existing annunciator-warning systems
2. Improved diagnostic approaches, e.g., DAS systems
3. Summary displays for Engineered safeguards.
4. Distinctive shape-coding for controls.
5. Logical color coding of displays.
6. Improved job-practices, e.g., shift schedules, over-time, division of team responsibilities, clearing and tagging of equipment, watch turnover and job structure.
7. Improved use of computers and more reliable computers.

There are limits to the extent that an existing design can be enhanced (or crutched). EPRI NP-1118 Volume I provides some indication of the dramatic improvements that can be achieved by means of minor, inexpensive, surface changes to the boards. When we go beyond such changes, the best approach may well be to leave the dedicated hand-wired boards as they are and supplement them with advanced computer-based display capabilities located at a supervisory station. The petrochemical industry has followed this course and hybrid control rooms are also springing up in nuclear plants.

The proposed guidelines offer an atomistic approach to solving acknowledged human factors problems. While all such remedial actions will reduce the probability of human error, this writer for one, does not have any confidence that, in toto, they will address basic underlying problems, namely, what are the optimal levels of system automation vs. manual control, how can we improve the diagnostic process so that the operator proceeds unerringly to the correct diagnosis and solution to the wide multitude of anticipated and unanticipated problems that can arise. These problems are being addressed on several fronts and it might be advisable to wait for the answers to such questions before going beyond surface changes to existing boards.

This suggests that remedial efforts be conducted in different stages. At the outset, all possible short-term surface changes to remedy the boards should be effected within a prescribed period of time (perhaps one year). Mid-term remedies, e.g., redesign of specific panels or restructuring or annunciator-warning systems within two years, and long-term remedies, e.g., adding advanced control-display computer based capability within three years.

With regard to mid-term and long-term remedies, it is essential that substantive design verification approaches be applied prior to industry-wide implementation. Existing or special purpose simulators should be used as test-beds to verify the value of proposed mid-term fixes to existing control room problems.

SUMMARY OF RECOMMENDATIONS

1. The proposed guidelines should be designated as preliminary in nature with the expectation that industry-specific guidelines will be developed and presented in subsequent periodic revisions of the guidelines.

2. Each specific guideline should be clearly tagged to differentiate those applicable to new control room designs or consoles added to existing control rooms, from those guidelines that may be applicable on a remedial basis.

3. The guideline statements should be simplified by eliminating superfluous, "typical backfit" and "human error statements associated with each specific guideline. A summary statement before each group of guidelines would serve as well and the guidelines, in their totality, would appear less awesome.

4. Major voids in the guidelines should be identified. The reader should not be left with the impression that compliance with the stated guidelines is a total solution to all human factors problems.

5. Experienced human factors specialists should participate in the implementation of the guidelines and in subsequent audits. Special training programs should be made available to allow human factors specialists from the other walks of life to make a contribution to the needs of the power industry.

6. Task analysis should be conducted in a more generic basis in each major vendor. This method will yield better data since human factors specialists would then be teaming up with more knowledgeable systems designers. Besides a more valid output of control-display requirements, a large economy of effort

would result. In this manner, a far more abbreviated task analysis effort would be required at the plant level.

7. The repertoire of data gathering approaches should be expanded to include other useful methods such as the "critical-incident" techniques. At the same time it should be made clear that, while a battery of methods is advisable, not all methods need to be employed to achieve the objectives of the guidelines.

8. The HED reporting system presented seems overly cumbersome. Greater use of generic HED's is recommended.

9. The scheme for prioritizing HED's appears rather subjective. All such schemes, including those generated by this writer, need to be verified by actual field trials. ESSEX admits to not having pretested the prioritization scheme. The utilities should be allowed to develop and apply their own prioritization measures if we cannot offer them one that has been validated.

10. The manner in which backfits have been instituted in control rooms to date are less than satisfactory in terms of human factors considerations. There is little assurance that future changes that will be made in the name of human engineering, will not future degrade the situation. A systematic mockup or simulator design verification program is strongly recommended to evaluate and integrate enhancement efforts.

11. The utilities need to be apprised of the forthcoming NRC audit process. This audit plan will largely shape the nature of the control room enhancement effort.

12. Some of the problems facing the industry require substantive research for an adequate solution, e.g. effective annunciator warning systems. These problems should be attacked on an industry-wide basis. There is little assurance that expensive, piecemeal, and untested case-by-case fixes will make the annunciator system any better, if not worse. Such modifications should be deferred until we have confidence in the proposed fixes. The enhancement recommendations offered in EPRI 1118 Vol I reveal dramatic improvements that can be implemented almost immediately. When we go beyond this level of enhancement we should have some reassurance, based on sound research, that we are indeed ameliorating the situation. There are limits to the extent to which we can "crutch" an existing control room design.