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LOCAL CONTROL STATIONS*

by

William S. Brown,[1] James C. Higgins,[1] and Jerry A. Wachtel[2]

[1]Engineering Technology Division
Brookhaven National Laboratory
Upton, NY

[2]Division of Systems Research/Human Factors Branch
U.S. Nuclear Regulatory Commission
Washington, DC

This paper describes research concerning the effects of human engineering design at local control stations (i.e., operator interfaces located outside the control room) on human performance and plant safety. The research considered both multifunction panels (e.g. remote shutdown panels) as well as single-function interfaces (e.g., valves, breakers, gauges, etc.). Changes in performance shaping factors associated with variations in human engineering at LCSs were estimated based on expert opinion. By means of a scaling procedure, these estimates were used to modify the human error probabilities in a PRA model, which was then employed to generate estimates of plant risk and scoping-level value/impact ratios for various human engineering upgrades. Recent documentation of human engineering deficiencies at single-function LCSs was also reviewed, and an assessment of the current status of LCSs with respect to human engineering was conducted.

1.0 INTRODUCTION

Human engineering deficiencies at safety-significant local control stations have been shown to increase the potential for operator errors that could be detrimental to plant and public safety (e.g., Hartley, Levy, & Fecht, 1984). However, no analyses had been performed to evaluate the specific effects of local control station (LCS) design variations on human performance and or to determine to impact on plant risk of such variations. Thus, while human engineering deficiencies (HEDs) associated with LCSs have been identified, a basis for further regulatory action has not been established. The purpose of the local control stations project is to review the safety implications of human engineering design issues associated with local control stations in nuclear power plants and to assist NRC in the resolution of these issues.

LCSs were defined as any safety-significant operator interfaces not located in the main control room. The project proceeded in two phases. In Phase I, the local control stations considered were those at which multiple functions were provided for the purpose of supporting a given task (e.g., remote shutdown panels); stations consisting solely of single manually operated switches or valves were excluded. In Phase II, the review was expanded to include any local controls (valves, switches, breakers) or displays (meters, gauges, monitors) that are operated or consulted during normal, abnormal or emergency operations. The technical approach for both phases of project was the same:

1) Define important local control stations, human factors related LCS design variations, and typical human engineering deficiencies at LCSs.

2) Determine the effect of LCS design variations on human performance, i.e., on risk-significant human errors.

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3) Determine the effect of LCS-induced human performance variation on plant risk as measured by core melt frequency.

4) Determine whether upgrades in LCS design to mitigate human engineering deficiencies are feasible in a value-impact analysis.

A detailed account of the research performed during Phase I of the project has been given in NUREG/CR-5572 (O'Hara, Ruger, Higgins, Luckas, & Crouch, 1990). The results of the more recent efforts (i.e., Phase II) have been provided in technical reports to the NRC (Ruger, Brown, & Higgins, 1991; Brown & Higgins, 1992). It is expected that the entire effort will be described in detail in a forthcoming NUREG-CR report.

2.0 MULTIFUNCTION LOCAL CONTROL STATIONS

In Phase I, a human factors analysis was performed to assess how variations in the human engineering attributes of multifunction LCSs in nuclear power plants would affect both human performance and plant risk. Two attributes, panel design and functional centralization, were considered. Panel design refers to the degree to which favorable human engineering practices (e.g., the guidance in NUREG-0700) are evident in the operator interface. Functional centralization refers to the extent to which required functions are present at a given panel (as opposed to being distributed at various location in the plant).

2.1 Variation of LCS Designs

Functional centralization refers to the way in which safety functions handled by LCSs were distributed throughout the plant. Three levels of functional centralization were defined: low, medium, and high. The specific definition of high, medium, and low functional centralization was based on the number of local panels required to execute safe shutdown functions. Table 1 identifies characteristics of each level of functional centralization.

A plant with low functional centralization of its LCS would have a wide distribution of safety functions on many local panels throughout the plant. For purposes of this study, low functional centralization was identified as more than five LCS panels with no one panel serving as a primary safe shutdown panel. Crew communication would occur over the phone system with a supervisor coordinating procedural details. Actions at individual panels would be contingent on successful completion of actions at other panels. In addition, the control operations at some panels have poor feedback characteristics, i.e., the feedback required for regulation of control processes were not available at the local panel, so the control loop must be closed via communication lines to another operator located at a panel containing the appropriate display.

The medium level of functional centralization was defined as the Oconee design. One main safe shutdown panel was present which provided the controls and displays for most of the required functions. A few "satellite" LCSs were distributed throughout the plant to handle functions not provided for on the main panel; thus, communication load was lower, in comparison with the low level of functional centralization, and most operations had adequate control feedback in that the primary functions were centralized onto a single panel with all required controls and displays.

The high level of functional centralization would correspond to a "back-up control room" concept. All safety-related functions were integrated into a single panel which contains all required controls and displays. Communication and crew coordination would be enhanced since all operators are in a single location.

Table 1. Definitions of LCS design variations.

DIMENSION	LEVEL		
	Low	Medium	High
Functional Centralization			
Number of Panels	>5	2 - 5	1
Feedback Characteristics	poor	moderate	good
Panel Design			
Location/Grouping	poor location no grouping	good location minimal group	good location func. group
Mimic Lines	absent	absent	present
Labels	missing, temp hard to read	small, some unclear	clear, distinct
Scales	hard to read, confusing	hard to read	easily read, clear
Environment/Lighting	poor	good	excellent

The second dimension along which panels were varied was referred to as panel design This dimension was chosen to reflect the human engineering characteristics of individual panels along criteria such as those provided in NUREG-0700. Again, low, medium, and high design levels were defined. Characteristics of each level are summarized in Table 1. When defining low, medium, and high characteristics for the LCS panel design dimension, the intention was to vary panel design along HED parameters in a manner that would impact operator workload. The parameters selected were (1) the location and grouping of controls and displays, (2) the presence of mimic lines, (3) labeling quality, (4) display scale characteristics, and (5) LCS local environment and lighting characteristics. These panel design parameters were selected because they have frequently been associated with LCS HEDs and are judged to effect operator workload.

A poorly designed panel was defined as one which included many of the HEDs typically found at local control stations including difficult access to controls and displays which are not generally grouped by function or procedures. No mimic lines were present to facilitate the execution of procedures. Instrument display scales were difficult to read and could lead to confusion due to problems such as parallax. The local environment did not facilitate the execution of procedures due to factors such as inadequate lighting. These HEDs were presumed to make the operators' execution of procedures difficult and to result in high workload. A typical medium panel design was considered a fairly good panel with no major HEDs. Mimic lines were still absent, but a general functional grouping of controls and displays was present. Displays and controls were located so they would be readily accessed, although some high density clustering was present. There were some problems with labels in that the labeling was small and not always clear in meaning. In a similar way, the display scales were sometimes difficult to read. The environment in the vicinity of the medium panel design was good and posed no significant restriction on operations. Relative to the other panels, this design was intended to provide moderate workload for the operators. A "high" panel design was assumed to have only minor HEDs, to be in compliance with NUREG-0700, and to be located in a favorable environment. The panel was intended to provide good support to the operator and thus was associated with relatively low workload.

A combination of three levels of each of the two general dimensions of functional centralization and panel design produced nine LCS panel design configurations. The Oconee LCS designs reflected in the PRA were assumed to be at the center of the defined variation, i.e., medium functional centralization, medium panel design. Thus, the other configurations represented systematic upgrades and downgrades of the modelled LCS design.

2.2 LCS Effects on Human Performance

The effect of LCS design variations on human performance, i.e., on the human error probabilities (HEPs) was accomplished by assembling a panel of appropriate experts and utilizing the Success Likelihood Index/Multi-Attribute Utility Decomposition (SLIM-MAUD) method to derive revised HEPs for each LCS design configuration. SLIM-MAUD utilizes a consensus approach to discriminating between panel designs along several performance shaping factors (PSF). In this study, three judges evaluated the panels along PSF dimensions of communications load, control panel configuration, training burden, and procedural complexity. The PSFs were weighted for relative importance by the judges. Weighted dimension ratings were combined to produce a Success Likelihood Index (SLI) for each panel configuration. SLIs were converted to HEPs once the SLI and HEP scales were calibrated. Each configuration's SLI value was used to uniformly modify all LCS-related HEPs in the PRA. Thus, since nine panel configurations were evaluated, a total of nine unique sets of HEPs were determined.

Variation along the LCS design dimensions (functional centralization and panel design) had considerable effects on human performance (i.e., estimated human error probability). There was an overall effect of LCS variations on performance. The transition from the worst to the best LCS configuration (on both dimensions) resulted in a reduction of 0.82 in mean HEP (reduction by a factor of 20). The functional centralization dimension had a large effect on performance. The transition from low to high levels of functional centralization was associated with a 0.46 (86%) reduction in mean HEP. The majority of the effect was accounted for by the transition from the low to medium levels. The panel design dimension also had an effect on human performance although not as large as functional centralization. Upgrading from a low to high panel design resulted in a 0.29 (69%) reduction in mean HEP. The transition from low to medium was more significant than the transition from medium to high. The functional centralization and panel design dimension were found to interact. The panel design and functional centralization findings of greater effects upgrading from low to medium as compared with medium to high was primarily due to the transition across levels of functional centralization at the low panel design level. For the medium and high panel design levels, the change in HEP across levels of functional centralization was fairly uniform.

2.3 LCS Effects on Plant Risk

The Oconee PRA (NSAC-60) was selected serve as the basis for an analysis of the plant risk associated with LCS design variations because it unambiguously modeled several human activities in the operation of the plant's safe shutdown facility and auxiliary shutdown panel. Both internal and external event sequences were used for this study. (The PRA represents Oconee in the mid 1980s, and subsequent plant modifications have improved the plant hardware and reduced

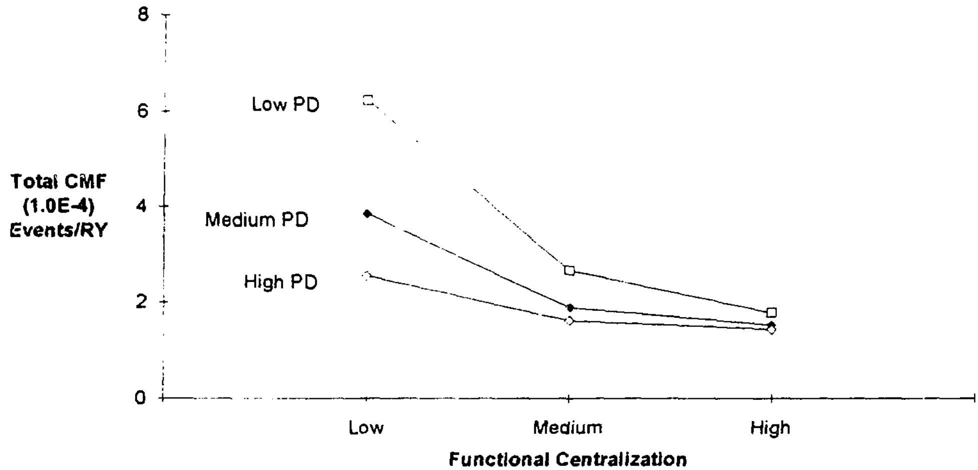

Figure 1. The effects of variations in functional centralization and panel design on total core melt frequency.

overall core melt frequency.) The Oconee LCS designs reflected in the PRA were determined to be at the center of the defined variations, i.e., both functional centralization and panel design were medium. Thus, the other configurations represented systematic upgrades and downgrades of LCS design.

The estimated HEPs for each configuration were entered into the PRA, and the CMF was calculated. A total of nine runs of the PRA were completed to identify the variation in plant risk associated with LCS configuration variation. Using the change in CMF as a measure of benefit, a scoping level value-impact analysis was performed. Data on the costs of upgrading local control panels were obtained from nuclear power plants.

The effects of LCS design dimensions on plant risk (core melt frequency - CMF) are shown in Figure 1. The overall effect of LCS variations on plant risk was sizeable. The Oconee baseline CMF is represented by the medium panel design, medium functional centralization point in Figure 1, and includes both internal and external events. The transition from overall worst to overall best LCS configuration was associated with a decrease in total CMF of 4.82E-4 events/RY. This is a decrease of 77% in CMF. The functional centralization dimension had a large effect on plant risk. Upgrading from the low to high level functional centralization resulted in a CMF reduction of 2.65E-4 events/RY. Most of the effect was associated with the upgrade from low to medium functional centralization. The results for the panel design dimension were similar to those for functional centralization. The transition from low to high panel design was associated with a reduction in CMF of 1.70E-4 events/RY. Most of the effect was achieved in the upgrade from the low to medium level. The functional centralization and panel design dimensions interacted noticeably. At low levels of functional centralization, panel design variations had a large effect. The panel design effects diminished considerably at higher levels of functional centralization. Also, for all levels of panel design, the transition from low to medium functional centralization provided greater risk reduction than the transition from medium to high. However, the magnitude of change in CMF across all levels of panel design progressively decreased as the level of functional centralization increased.

When considering the change in CMF across all nine LCS configurations from worst to best, reduction in CMF appeared to asymptote at LCS configuration with medium panel design and functional centralization. Upgrades to this configuration from configurations judged to be worse were sizeable, but upgrades beyond this LCS configuration were considerably smaller.

2.4 Scoping Value-Impact Analysis Results

Value-impact analyses were made only for transitions between selected LCS designs, since some transitions were either of negative value (in CMF terms) or illogical from an engineering design change standpoint. Using standard CMF conversion factors, the per-plant Public Benefit or Value was calculated. The total per-plant impact or cost in $million per plant of the proposed action was then obtained from the sum of the three impact attributes: Industry Implementation including training, NRC Development, and NRC Implementation. Finally, the value-impact ratios of the LCS upgrades are given in terms of person-rem/$ million. In these units, a ratio of 1000 person-rem/$$10^6$ is equivalent to the normally used cost-benefit acceptance criterion of $1000/person-rem.

There was a degree of uncertainty in the analysis of plant risk and the value-impact calculations, as well as in the generalization of these findings to other LCSs and NPPs. In view of these uncertainties, the value-impact ratios (VIRs) were divided into three categories. VIRs of > 1900 were considered clearly significant and VIRs of < 460 were considered clearly insignificant. VIRs between the values of 460-1900 were considered close enough to the 1000 criterion to be borderline. The identification of the specific cutoffs defining these categories was somewhat arbitrary and based upon what appeared to be natural clusters in the VIR data.

This categorization led to several conclusions. First, upgrades in panel design only were clearly cost beneficial. All panel design upgrades were had significant VIRs with the exception of those coupled with a high degree of functional centralization. (These cases are in the borderline category.) Most upgrades in functional centralization had insignificant VIRs. Upgrades along both dimensions were split between borderline and insignificant VIRs. Generally, upgrades from poor LCS configurations had borderline VIRs. Combination panel design and functional centralization upgrades from most other LCS configurations had insignificant VIRs.

Thus, this analysis indicates that while upgrades in functional centralization had greater risk significance than panel design upgrades, their cost was much greater and resulted in generally low VIRs. Relative to changes in functional centralization, upgrades in panel design are inexpensive, and since panel design upgrades were also associated with notable risk reduction, comparatively high VIRs were achieved. Combination functional centralization and panel design upgrades were mainly influenced by the costs of functional centralization changes which, as discussed, were more expensive and thus led to lower VIRs.

2.5 Conclusions

The overall results of this phase of the research demonstrated that safety-related local control stations can have a significant effect on plant safety. Furthermore, it is evident that relatively inexpensive human engineering upgrades, e.g., improvements in the design of multifunction local control panels, can be effective in reducing human error and thereby decrease plant risk.

3.0 SINGLE-FUNCTION LOCAL CONTROL STATIONS

In Phase II, the effect of human engineering design variations on human performance and plant risk was assessed for single-function LCSs. Various NRC, industry and general human engineering source documents were reviewed to identify dimensions along which these LCSs might vary. The dimensions considered were labeling, indication, control, environment, and communication. The likely effects on HEPs of variations along these dimensions were estimated by means of expert judgement as in Phase I. The HEPs were applied to the appropriate human errors in the PRA and core melt frequencies were re-calculated as before. Costs associated with upgrading LCSs were obtained from a variety of sources. A scoping level value/impact assessment was then performed.

The value/impact assessment showed some of the upgrades to be clearly cost beneficial; however, not enough information was available regarding actual current LCS status to determine the costs of implementing upgrades. Concerns were also raised regarding the actual impact on plant operations of poor human engineering at LCSs. It was therefore necessary to gather additional information. Two sources of information were considered. First, a literature survey was performed to identify, document and categorize cases in which human engineering deficiencies at LCSs have contributed to reportable events in nuclear power plants. Second, assessments were conducted at a representative sample of nuclear power plants to determine the current industry-wide status of local control stations with respect to human engineering considerations. These efforts are described in detail in the following sections.

3.1 Literature Review

3.1.1 Characterization of Human Engineering Deficiencies

Human engineering deficiencies at component-level LCSs were categorized into five types. A brief description of each of these categories along with examples of typical deficiencies are given below.

- *Labeling* refers to the identification of controls and displays. Examples of poor labeling include lack of labels, stamped metal tags with component numbers, labels that are difficult to read, improvised or temporary labels, and labels with low contrast or poor visibility.

- *Indication* pertains to the quality of meters and gauges or of elements of components (e.g., valves, breakers) that reflect their state (i.e., open/closed). Indication is deficient if there is no means of locally determining the state of the equipment, if units or scales on meters or gauges are inconsistent or inadequate for the indication required, or if the indication is ambiguous for any reason.

- *Control* refers to the operation (as opposed to the identification or status) of equipment. A poor control interface might operate in a manner inconsistent with population stereotypes or other controls of its type in the plant, be subject to inadvertent operation, or require excessive force.

- *Environment* includes issues of normal and emergency lighting, noise, temperature and humidity, physical access to equipment and radiation exposure. A poor environment is one in which supplemental lighting or hearing protection is required, continued presence at the LCS subjects the operator to discomfort or risk, or the location of equipment requires unsafe or uncomfortable working postures, use of ladders, etc.

- *Communication* concerns the exchange of information with others either nearby or in other areas of the plant, e.g., the control room. For example, communication could be considered poor if the paging system is inadequate, if headsets are unavailable or difficult to use, or if the use of radios is precluded in the area of the LCS.

3.1.2 Review of Source Documents

The review included a number of sources, including Emergency Operating Procedure (EOP) inspection reports and Licensee Event Reports (LERs). In this section, the procedure used in reviewing each type of source material is described and general findings are described.

EOP Inspection Reports. NRC EOP inspections typically include in-plant walkdowns of the procedures. Conditions in the plant that might hinder the execution of the procedures are noted in the inspection reports. Since many operator activities called for in EOPs take place at LCSs, the inspection reports often describe human engineering deficiencies at LCSs. These deficiencies are notable since they occur in LCSs which are important enough to be included in the EOPs.

Inspection reports were obtained and reviewed in order to identify human engineering deficiencies relevant to component-level LCSs. Reports were sampled from 1988 and 1990. Descriptions of human engineering deficiencies at LCSs were noted and assigned to the categories in the previous section. No attempt was made to analyze the sample of reports quantitatively; i.e., the frequencies with which the categories of deficiencies occurred in the reports was not recorded. This information was not deemed meaningful since the way in which deficiencies are reported differs among reports. (Some reports individually enumerate multiple deficiencies of a given type, while others cite a general inadequacy in a certain area.) Also, the EOP inspectors stated that the reports often do not detail all of the deficiencies found at LCSs. That is, only representative deficiencies were documented. Insofar as can be judged by this global view, the relative prevalence of the type of human engineering deficiencies is similar in the two samples (i.e., 1988 vs. 1990). Based on the EOP inspection reports, it can be concluded that human engineering deficiencies, notably inadequate labeling and poor environmental conditions, are not uncommon at those local control stations utilized in the implementation of the EOPs.

In order to gain a better appreciation of the state of LCSs, a meeting was arranged between the BNL LCS project staff, the NRC Project Manager, other interested NRC personnel, and EOP inspection team members. Problems typical of each category of LCS human engineering deficiency were discussed. Rough estimates of the prevalence of human engineering deficiencies at LCS based on the experience of EOP inspection team members were in accord with the conclusion drawn from the EOP survey. The estimated percentages of plants containing LCSs deficient in each of the categories identified above were:

Labeling	95%
Indication	80%
Environment	>60%
Communication	60%
Control	<60%

It was the opinion of the EOP inspection team members that, within the environment category, the inaccessibility of equipment and the lack of adequate emergency lighting were prevalent and of particular consequence.

Licensee Event Reports. A comprehensive review of December 1990 LERs identified 14 events with human engineering deficiencies (HEDs) related to LCSs out of a total of 183 Licensee Event Reports (LERs). This indicates that these events are currently occurring at a notable frequency. In addition, LERs from 1987, 1988, and 1989 were reviewed for incidents pertaining to HEDs at LCSs.

Table 2. Breakdown of LERs by SCSS Watch List Code for 1987 - 1989

	Human Action	Commun. Problem	Human Error	Poor Ergonomics
1987:				
Human Action	26	0	0	0
Communication Problem	--	66	26	0
Human Error	--	--	1050	5
Poor Ergonomics	--	--	--	20
1988:				
Human Action	19	0	0	0
Communication Problem	--	36	25	1
Human Error	--	--	847	14
Poor Ergonomics	--	--	--	10
1989:				
Human Action	13	0	0	0
Communication Problem	--	26	36	2
Human Error	--	--	875	9
Poor Ergonomics	--	--	--	18

LERs with the following Sequence Coding Search System (SCSS) watch list codes were considered:

030 Human Action
032 Communication Problem
035 Human Error
038 Poor Ergonomics or Human Environment

A total of roughly 3,100 LERs resulted from this selection; a breakdown appears in Table 2. (Counts along the diagonal represent LERs that carried only one of the selected watch list codes; those above the diagonal carried more than one code.) LERs coded as involving "human action" and "poor ergonomics or human environment" were reviewed individually for events relevant to HEDs at LCS. None of the 58 reports carrying the "human action" code described human actions at LCSs that were pertinent to this review. Those coded as "poor ergonomics or human environment" contained many events that could be identified as having occurred outside the control room and as a result of a specific human interface deficiency. The events typically pertained to labeling and environment, notably problems with physical accessibility of equipment. It should be noted however that roughly half of these events occurred at equipment accessed only in the course of testing or calibration. Some of this equipment (e.g., terminal blocks inside electrical panels) is considered to fall outside of the definition of LCS used in this study.

Based on a sample of the LERs carrying the "communication problem" code, it was concluded that these typically refer to failures of procedural or administrative communications. The causes of "miscommunication" among operators are not usually specified, so that it is not possible to infer any deficiency in the means of communication or the environment in which it took place.

The abstracts of the LERs coded "human error" number over 2,000, and hence, were searched by means of a computer for key words pertaining to incorrect human actions and to the classes of human engineering deficiency identified in Section 3.1. In many of the reports, the incorrect local action was attributed to lack of attention to detail on the part of personnel. Although it is not unreasonable to infer that some portion of these errors were contributed to by less-than-optimal human engineering, many others were found that cited specific local human engineering deficiencies as a contributing cause or improvements at the LCS as a means of preventing recurrence.

3.1.3 Conclusions

A review of recent inspection reports, event reports, and reviews of operating experience records was performed to determine the extent and nature of human engineering deficiencies (HEDs) at component-level LCSs in nuclear power plants. Numerous instances of HEDs were identified, representing all five of the categories defined earlier (i.e., labeling, indication, control, environment, and communication). A sampling of significant HEDs from each category appears in Ruger, Brown & Higgins, 1991.

It was concluded from this review that HEDs at single function LCSs and multifunction LCSs exist quite commonly across the industry. Additionally, these HEDs are significant in that they relate to equipment specified for operation in EOPs; they have caused or contributed to notable operational events, and they continue to be noted as needing corrective actions in various types of reports.

3.2 On-Site Assessment of Local Control Stations

3.2.1 Preparation

Plant Sample. A sample of ten plants was chosen to represent the industry with respect to plant NSSS vendor and age. The original group of plants identified were chosen primarily from the Northeast in an attempt to facilitate scheduling visits and to minimize travel costs. (Persons experienced in Emergency Operating Procedure inspections had stated that there was no reason to expect systematic differences in plants associated with geographic area or NRC region).

The NRC Project Manager made the initial contacts - first with the NRC Licensee Project Manager (LPM) for the plant, then with utility or plant personnel when appropriate. In several cases, for a variety of reasons, the LPM indicated that either the selected plant had declined to participate, or the NRC did not want the plant included in the study. When a number of "substitute" plants also proved to be unavailable, a concern arose that the final sample might exhibit a "self-selection" bias, i.e., that the plants agreeing to participate might be those that tended to fare better in regulatory evaluations. Thus, an attempt was made to achieve a sample that was representative in terms of plant performance as well as plant vendor and age. When final arrangements were made, without exception, plant site personnel were very cooperative in providing information and conducting plant tours.

Identification of LCSs to be Examined. The variety of plant types and designs in the sample and the diversity of LCSs between plants made it impossible to identify in advance a standard group of local control stations to be examined in each of the plants visited. Nevertheless, it was considered desirable to ensure that the stations examined 1) included a broad range of plant equipment and local operator actions, 2) did not represent only those areas chosen by plant personnel, and 3) were in some way comparable across plants. The identification of local control stations to choose was guided by reference to two plant operating procedures: shutdown from outside the control room and station blackout. (Licensees provided information copies of the procedures to BNL for review prior to the site visit). These procedures were chosen because they were expected to contain the greatest number and variety of important local operator actions. The procedures not only identified the LCSs to be observed, but also provided the details and context of operator actions required at the station. While touring the LCSs referred to in the procedures, other nearby LCSs were also observed.

3.2.2 Site Visits

Collection of Upgrade Information. Two BNL staff visited each plant; one member of the team was a human factors specialist, the other was experienced in nuclear power plant operations (e.g., SRO-qualified or ex-NRC resident inspector). To ensure consistency, a total of only three people were involved in the site visits. Plant personnel coordinating the site visits were requested to arrange for the BNL team to speak with individuals familiar with human-engineering upgrades (in progress, recently completed, or planned) at local control stations. Prior to the tour of local control stations, the project team interviewed plant personnel (e.g., human factors specialists, labeling coordinators, etc.) regarding these efforts. The BNL team specifically sought information regarding relabeling programs, upgrades to normal or emergency lighting, improvements to communication systems, noise surveys or noise abatement efforts, and efforts to improve accessibility of components (e.g., installation of platforms). Costs associated with upgrades were noted whenever plants were able to provide them.

LCS Evaluation. Local control stations and their surroundings were examined from a human engineering standpoint. Observations were made with respect to labeling, control and indication, lighting (including emergency lighting), accessibility, etc. A checklist was used to facilitate the recording of this information. At each local control station, operator/guides talked through the appropriate portions of the procedures. During this process, the BNL team noted such items as agreement of terminology in procedures with in-plant labels, requirements for and availability of feedback indication, availability and need for communications devices, etc. Notes were recorded on the checklists and in the procedures. These were consolidated after the plant walkdowns were completed. When requested by plant personnel at the end of the site visit the BNL team provided a summary description of important observations that were made during the tours.

3.2.3 Findings

Summary of Evaluations. After each site visit, the members of the BNL team reviewed their notes and independently generated summary ratings of the local control stations with respect to labeling, indication, control, environment, and communications. These are the same categories used in earlier tasks. For each category, overall conditions at a plant were designated either low (i.e., deficiencies present), medium (i.e., less than optimal), or high (i.e., favorable elements present). The human engineering design of the remote shutdown panel(s) and of important manual valves was also separately rated. The dimensions used for the remote shutdown panel ratings were those identified in Phase I of the project - panel design and functional centralization.

Human Engineering Upgrades at Local Control Stations. All of the plants visited were able to cite current or recently completed human engineering upgrade efforts. The most common such effort was relabeling. It was noted, however, that the scope and the quality of the "relabeling programs" varied widely both from plant to plant and even within plants. A few plants were making a concerted effort to place a new, well-designed, consistent, informative tag on everything of any significance in the plant. In other cases the "relabeling program" might better be described as selective label replacement.

Although many efforts to upgrade local control stations are undertaken in response to regulatory activity (e.g., emergency operating procedure inspections), the majority seem to be initiated from within the plant, typically based on input from operators or in response to operating problems. Some plants noted INPO efforts to encourage labeling upgrades. Examples of such upgrades are given in the next section.

Operator Comments on Upgrades. An attempt was made to determine the opinions of operators regarding improvements to human engineering that had been made to LCSs in their plants. When possible, equipment operators out in the plant were questioned as to the desirability and effectiveness of the upgrades. They were also asked to identify the upgrades they found most beneficial.

In general, the responses of operators to human engineering improvements was positive. Such responses were expected, since, as noted above, improvements were often initiated at the suggestion of operating personnel. Examples of such improvements include platforms to facilitate access to valves, sound-attenuating enclosures at pager stations in high noise areas, and pre-staged, color-coded sets of jumper wires. There were, however, instances in which human engineering "improvements" missed the mark according to operators. Some such instances were related to relabeling of components, an effort which one might have expected to be welcomed by operators. In one plant, for example, operators did not view the new labels as an improvement. This may have been because although the new color-coded, engraved metal labels carried more information (e.g., component name) than the older stamped metal tags, neither style was very easy to read; furthermore, the operators were not familiar with the new color-coding scheme. In another plant, large stamped metal "license plates" carrying the component numbers of overhead valves were being replaced by more informative labels (i.e., tags containing the name of the component in addition to its number, a bar code identifier, etc.). Unfortunately, the new labels were made too small to be read at typical viewing distances.

Good Practices. Noteworthy examples of good human factors practices at local control stations were observed in all of the plants visited. As shown in the upper panel of Table 3, these efforts were varied. Some reflected implementation of current human engineering "good practices," while other were unique plant responses to individual circumstances. The practice with perhaps the greatest potential to generally improve human factors "out-in-the-plant" was a program in one plant to enlist the aid of operating personnel in evaluating the adequacy of local control stations. Operators walking down procedures were provided with "Local Action Checklists" on which they could record for each procedure step the accessibility of the component, the adequacy of the lighting, possible radiological hazards, the staffing required to perform the action, and any other information bearing on the ability of operators to perform the local action. Upgrades were then designed based on the results of the checklists.

Common or Significant Areas for Improvement. The human engineering weaknesses observed were as varied as were the strengths; examples of poor practices could be identified even in plants that were rated highly overall. Examples appear in the lower panel Table 3. One observation common across plants was that, with the exception of the (re)design of remote shutdown panels, plant (or utility) human factors specialists are almost never involved in human engineering activities outside the control room. This is not to say that it would be desirable for all upgrades to originate with human factors personnel. As noted earlier, effective upgrade efforts usually grow out of input from the operating staff. However, the lack of human factors input can lead to unforeseen problems or less than optimal results. For example, the arbitrarily assigned colors used to code trains in one plant's otherwise exemplary labeling program were not the same colors used to code trains in the control room. In another plant, new labels were being placed without taking viewing distance into account.

Table 3. Examples of Good and Poor Practices Observed During Site Visits.

GOOD

- hanging flashlights at various remote S/D stations
- radiation symbol on valve label in radioactive systems
- piping flow direction labels
- high-visibility labels for EOP-related components
- prepared sets of color coded jumpers keyed to procedures
- color coded piping
- radio repeaters to prevent communications "dead spots"
- posting on door of equipment/layout within rooms
- computer-driven parameter displays at remote shutdown panel
- operator evaluations of local stations/actions
- color codes by unit in dual unit plants
- locator tags pointing to out-of-the-way valves
- operator aid postings, such as procedures, drawings, color coding, and labeling conventions
- special labels such as normal and tripped position on EDG trip lever, set screw on EDG governor, and indication of normal oil levels

POOR

- human factors personnel not involved outside control room
- multiple color coding schemes, numbering systems
- contaminated switchgear
- paint overspray obscuring valve label or position indication
- valve operating contrary to handwheel markings
- construction tags (e.g., "component turned over") on equipment
- parameters/units not indicated on instrument faces, labels
- outdoor LCSs
- operating panels secured closed with large number of bolts
- valve position indication poorly placed, not labeled, or out of calibration

Other common areas for improvement included:

- In general, labeling programs were not organized and cohesive throughout the plant.
- It was not uncommon for discrepancies to exist between terminology or numbering conventions used in the procedures and those found on the component labels.
- Existing labels are often not removed when new labels are placed.

It was noted that most plants were quite proud of their upgrades and their LCSs in general, even those which had clear and obvious problems. That is, those involved with the LCSs were often unaware of what a good design should be and of the good practices that many other plants have instituted.

3.2.4 Conclusions

The industry-wide status of LCSs with respect to human factors can best be described as variable. As noted previously, the quality of LCSs varied considerably from plant to plant. This was true even for plants operated by the same utility. Human engineering was not found to be reliably better in new plants than in older plants, which seemed in some cases to have benefitted from upgrades undertaken based on operating experience. Variability was also observed within plants; it was not unusual to find examples of very good and very poor practices in the same plant. The variability was also found within the dimensions on which LCSs were evaluated. For example, labeling of switchgear might have been very good while labeling of valves was poor. In summary, many instances of good or even exemplary human factors practice were observed, but there were also numerous opportunities for improvement. This is an important fact since the review of inspection/operating experience sources revealed many instances of plant-level problems or events caused by inadequate human factors at LCSs.

The status (i.e., the variability) of LCSs may be due in part to the fact that licensee human factors personnel are not typically involved in the design of operator interfaces outside of the control room. Furthermore, plant personnel generally seemed unaware of how control stations in the plant would compare to typical industry practices or accepted human factors principles. Many instances were observed where licensee personnel believed that existing poor interfaces were actually quite good. All of the plants visited had made some effort to improve human engineering at operator interfaces outside the control room. The fact that such efforts are sometimes not as effective as they could be points to the need for plants to take advantage of existing sources of guidance regarding local control station design, e.g., NRC and industry reports, EOP inspection reports, general human engineering standards, etc.

4.0 References

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