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Evaluation of Nuclear Power Plant Operating Procedures Classifications and Interfaces

Problems and Techniques for Improvement

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Prepared for
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Commission

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ABSTRACT

This report presents activities and findings of a project designed to evaluate current practices and problems related to procedure classification schemes and procedure interfaces in commercial nuclear power plants. The phrase "procedure classification scheme" refers to how plant operating procedures are categorized and indexed (e.g., normal, abnormal, emergency operating procedures). The term "procedure interface" refers to how reactor operators are instructed to transition within and between procedures.

The project consisted of four key tasks, including (1) a survey of literature regarding problems associated with procedure classifications and interfaces, as well as techniques for overcoming them; (2) interviews with experts in the nuclear industry to discuss the appropriate scope of different classes of operating procedures and techniques for managing interfaces between them; (3) a reanalysis of data gathered about nuclear power plant normal operating and off-normal operating procedures in a related project, "Program Plan for Assessing and Upgrading Operating Procedures for Nuclear Power Plants"; and (4) solicitation of the comments and expert opinions of a peer review group on the draft project report and on proposed techniques for resolving classification and interface issues. In addition to describing these activities and their results, recommendations for NRC and utility actions to address procedure classification and interface problems are offered.

EXECUTIVE SUMMARY

Efforts by the NRC to upgrade procedures used to support nuclear power plant operations have highlighted the need to evaluate existing procedure classification schemes and problems affecting procedure interfaces, including interfaces between various classes of procedures. The term "procedure classification scheme" refers to the manner in which plant operating procedures are grouped together into categories of procedures, such as "normal operating procedures" or "emergency operating procedures." "Procedure interfaces" refers to the techniques by which reactor operators are referred to other procedures or to other sections of the procedure that they have been following. "Procedure interfaces" also refers to the necessity, for some tasks, that reactor operators track activities in more than one procedure at a time.

This report evaluates the results of a series of investigations of procedures and procedure use in the nuclear industry. Additional information bearing on classification and interface issues was collected through (1) an examination of relevant literature, (2) interviews with experts in the industry on the appropriate scope of different classes of procedures and techniques for managing interfaces, (3) reanalyses of human factor ratings of procedures gathered during a related project, and (4) solicitation of comments and expert opinions from a peer review group on the draft of this report and on the proposed techniques for addressing classification and interface issues.

The findings relative to classification issues suggest that standardizing classification systems across the industry is not viable. The existing regulatory guidance for identifying what activities should be included in sets of plant procedures does not specify the manner in which procedures should be classified. Classification practices, or the methods by which procedures are organized, are influenced by a number of factors including (1) differences in Owners' Groups' approaches to developing their technical guidelines for procedures, (2) differences between plants' hardware, and (3) differences in the operating philosophies of the personnel responsible for developing operating procedures at plants.

In general, Owners' Groups base their guidelines classification schemes on plant status. Plant status schemes yield procedure sets that generally correspond to normal, abnormal, and emergency operating procedures. Although plant status provides the underlying rationale for the classification schemes, the result of implementing Owners' Groups' guidelines at individual plants has yielded procedure classification systems that differ greatly between plants. Alternative classification systems and their advantages and disadvantages are discussed.

A key objective of a classification system is to facilitate the accessibility of the information contained within the system. The current systems of classifying procedures in the nuclear industry were not found to facilitate procedure use by plant personnel and, consequently, could negatively impact operator performance.

Interviews with industry experts indicated that interfaces also are deficient and cause operators difficulties, particularly when operators are required to use multiple sets of procedures. Operator problems with procedure classification schemes and interfaces have implications for the safety and reliability of plant operations.

A human factors rating of a sample of normal and abnormal procedures showed that current procedure writing practices affecting interfaces are deficient, e.g., directions to enter or exit procedures are vague and references directing operators to other procedures are incomplete. These deficiencies are found most frequently in procedures derived from the guidelines of a particular Owners' Group. Additional analyses showed that a relationship exists between interface deficiencies and forced outages, a measure of plant performance.

Solutions to interface problems are discussed. These solutions include improvements in operator training and in the human factors characteristics of procedure interfaces. The use of flowcharts as a solution to aid transition activities in interfaces is examined closely. Computerizing lists of procedure interfaces and procedure indexes also are considered as potential methods of managing these problems. The contribution of computer technology is limited by its current lack of availability throughout the industry, however. Consequently, computers cannot, at present, provide a major answer to interface problems. Finally, techniques addressing the classification and interface issues are presented.

ACKNOWLEDGMENTS

We gratefully acknowledge the time, efforts, and assistance of the experts who agreed to be interviewed, including representatives of General Electric, Westinghouse, Babcock & Wilcox, Combustion Engineering, and the U.S. NRC Federal Training Center in Chattanooga, Tennessee. In addition, we greatly appreciate the contributions of our project technical monitor at the U.S. Nuclear Regulatory Commission, Mr. James Bongarra. Mr. Leo Defferding, Mr. Robert Gruel, Mr. Jim Huenefeld, and Mr. Bryan Gore of the Pacific Northwest Laboratory and the members of our peer review group offered valuable guidance and input to the project. Mrs. Charleen Sager deserves special recognition for her much appreciated support and assistance throughout the project and in producing this report.

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1.0 INTRODUCTION

The purpose of this report is to present the findings of a project designed to evaluate current practices and problems related to procedure classification schemes and procedure interfaces in nuclear power plants. The term "procedure classification scheme" refers to the manner in which the plant operating procedures, used by reactor operators to conduct their activities, are organized and clustered into categories. "Procedure interfaces" refers to the manner in which reactor operators are referred to other procedures or to other sections of the procedure that they have been following. "Procedure interfaces" also refers to the necessity, for some tasks, that operators track activities in more than one procedure at a time. The report also presents recommendations and techniques for resolving the classification and interface problems identified in the course of the project.

1.1 Background

The Three Mile Island Action Plan, Item I.C.9, "Long-Term Plan for Upgrading of Procedures" required the Nuclear Regulatory Commission (NRC) to undertake a course of action to improve the quality of procedures in commercial nuclear power plants (NUREG-0660, NRC Action Plan Developed as a Result of the TMI-2 Accident, Volume 1, May 1980). The project described in this report is the most recent in a series of projects designed to evaluate current procedures practices in the nuclear industry and to make recommendations to the NRC about methods for upgrading nuclear power plant procedures.

Under contract to the NRC, staff at Battelle Memorial Institute's Human Affairs Research Centers have been extensively involved in efforts to improve plant procedures. Prior projects conducted for the NRC have included assessments of plant maintenance procedures; emergency operating procedures (i.e., the written procedures that direct reactor operator actions under emergency conditions, such as a reactor trip); normal operating procedures (i.e., the procedures that guide reactor operator actions during such activities as plant start-up or power operations); and abnormal operating procedures (i.e., procedures that describe appropriate operator actions when, for example, plant alarms have been activated). Battelle staff also have researched and developed guidance for procedure-writers at plants to use when preparing emergency operating procedures, and are currently assisting the NRC in reviewing plant programs for rewriting and upgrading emergency operating procedures (i.e., Procedure Generation Packages or PGPs) in response to Supplement 1 to NUREG-0737, Requirements for Emergency Response Capability (Generic Letter 82-33), December 1982.

As a result of the information obtained during the course of the project intended to assess normal and abnormal operating procedures across the industry, "Program Plan for Assessing and Upgrading Operating Procedures for Nuclear Power Plants" (henceforward referred to as the Operating Procedures project), and the reviews of plant emergency procedures, it became apparent to staff at the NRC and at Battelle that procedure classification schemes affect procedure interfaces and that procedure interfaces have the potential to impair operators' task performance. One major task of the Operating Procedures project that evolved from these impressions was to conduct a preliminary assessment of procedure interface problems to determine their potential safety significance (Appendix A).

The findings of the preliminary assessment led to the present project. It appeared that some procedure classification schemes and interfaces pose such significant problems for operators in performing their tasks that further study was warranted. Thus, the current project was initiated to accomplish two objectives: (1) to evaluate the extent of the classification and interface problems across the industry, and (2) to identify and to present techniques for overcoming them.

1.2 Project Overview

The project consisted of four key tasks. These included: (1) a survey of the literature regarding problems associated with procedure classifications and interfaces, as well as techniques for overcoming them; (2) interviews with experts in the nuclear industry to discuss the appropriate scope of different classes of operating procedures and techniques for managing interfaces between them; (3) a reanalysis of data gathered about normal and abnormal operating procedures during the Operating Procedures project; and (4) solicitation of the comments and expert opinions of a peer review group on the draft report and on proposed techniques for resolving classification and interface issues.

1.3 Organization of This Report

The remainder of this report is organized into five major sections. Section 2.0 describes the methods of the data-gathering activities undertaken for this project, including a survey of the literature (Section 2.1), a survey of experts throughout the industry (Section 2.2), secondary analyses of information gathered during the Operating Procedures project that are relevant to the present project (Section 2.3), and the selection and convening of a peer review group to discuss and comment on project findings and recommendations (Section 2.4). Section 3.0 presents the information gathered regarding procedure classification schemes, and Section 4.0 describes findings regarding procedure interface issues. Section 5.0 presents conclusions and recommendations pertaining to classification and interface issues, while Section 6.0 presents the techniques for addressing the classification and interface issues identified in the course of the project.

2.0 PROJECT METHODOLOGY

Several data-gatherings activities were undertaken to achieve the objectives of this project. These activities included (1) a survey of literature regarding problems associated with procedure classifications and interfaces within and between procedures, as well as techniques for overcoming them; (2) interviews with experts in the nuclear industry to discuss the appropriate scope of different classes of operating procedures and techniques for managing interfaces between them; (3) a reanalysis of data gathered about nuclear power plant normal operating and off-normal operating procedures in a related project, "Program Plan for Assessing and Upgrading Operating Procedures for Nuclear Power Plants"; and (4) solicitation of the comments and expert opinions of a peer review group on the draft project report and on proposed techniques for resolving classification and interface issues. In this section we provide a detailed description of these four project activities.

2.1 Survey of the Literature

The initial objective of the literature survey was to identify information relevant to procedure classification and interface problems and to identify key contributors to the literature who could be contacted for assistance with the project. We were initially drawn into the extensive military guidance available on job performance aids and the relevant human factors criteria for writing procedures. One recurrent observation that surfaced in both the literature and our discussions with experts was that flowcharts appear to be useful in resolving some of the recognized interface problems. Consequently, we began a second search for literature pertaining to flowcharting techniques and their applicability to resolving interface problems.

Several different methods were used in attempting to extract the desired information from the literature. Manual searches of likely sources yielded contributions from a wide spectrum of fields including nursing, computer science, and telephone operations. In addition, computer searches were conducted in several databases (e.g., Compendex, National Technical Information Services, the Social Science Citation Index, Psych Info, INSPEC, and Aerospace Abstracts). Although little information was found that directly addresses classification or interface issues, a variety of information was gathered regarding effective techniques for presenting information in ways that support optimal performance. A list of sources reviewed for the project is presented in Section 7.0.

2.2 Survey of Experts

Three groups of industry experts were contacted by project team members to discuss procedure classification and interface issues. Experts were sought who possessed in-depth knowledge of nuclear power plant procedures as well as a broad perspective on nuclear power plant operations across the industry. Experts who met these criteria included reactor operator license examiners, nuclear steam supply system (NSSS) vendor representatives, and trainers at the Federal Technical Training Center operated by the NRC in Chattanooga, Tennessee.

2.2.1 Discussions with License Examiners

The discussions with the license examiners were held in a working meeting between the examiners and project staff. The day-long meeting was conducted at the beginning of the project to elicit the examiners' input on the interface and classification issues and their suggestions for types of individuals to serve on the peer review panel. The three examiners who participated in the meeting were from Battelle's Pacific Northwest Laboratory in Richland, Washington, and were qualified to test operators on Westinghouse, Babcock & Wilcox, and Combustion Engineering reactors.

The license examiners provided the project staff with a unique and valuable perspective on nuclear power plant procedures. First, because examiners use the procedures from each plant at which they conduct operator examinations as the bases for their written and oral exams, they are familiar with procedures from numerous plants. Further, because the exams often include observing license candidates using procedures in a control room simulator, the examiners also have many opportunities to observe operators making transitions within and between procedures. In addition, the three examiners who participated in the working meeting have all been involved in reviewing the Procedures Generation Packages (PGPs) required of each plant by the NRC (Supplement 1 to NUREG-0737, Requirements for Emergency Response Capability, Generic Letter 82-33, December 1982) to guide the development of their emergency operating procedures. These PGPs describe each plant's program for preparing technically accurate and usable emergency operating procedures and include (1) information about the technical bases of the procedures, (2) a procedure-writers' guide, (3) a description of how the procedures are to be verified and validated, and (4) a description of how operators will be trained to use the new procedures. As a result of their experiences with exams and with reviewing PGPs, the examiners offered extensive knowledge of procedures in the nuclear industry.

In addition to their substantive comments on the classification and interface issues, the license examiners provided specific input on the types of expertise that should be represented on the peer review panel. They recommended that the project staff seek a panel of individuals:

- Who are familiar with current practices in developing operating procedures in the nuclear industry.
- Who possess a military, NASA, and/or commercial aviation background in procedures.
- Who are knowledgeable about cognitive processes such as information-processing and decision-making, but are not necessarily involved in the nuclear industry.

- Who have confronted procedure issues in the nuclear industry for boiling water reactors (BWRs) and for pressurized water reactors (PWRs).

The examiners suggested that persons with these areas of expertise would ensure that peer review group discussions are relevant to the nuclear industry but also benefit from a variety of perspectives on procedure problems.

2.2.2 Discussions with Vendor Representatives

Representatives from each of the four largest NSSS vendors (i.e., Westinghouse, General Electric, Babcock & Wilcox, and Combustion Engineering) also were interviewed by project staff. The individuals interviewed are all involved with the procedures subcommittees of their respective Owners' Groups, but in three different capacities. One interviewee from each of the four vendors is responsible for overseeing the development and validation of the technical guidelines provided to utilities to form the bases of their plant emergency operating procedures. Several others interviewed train operators on the vendors' generic simulators, and one interviewee from each of the vendors works at plants with plant personnel to translate the vendor technical guidelines into emergency operating procedures. Because the vendor representatives work with all member utilities in their Owners' Groups, they possess a breadth of knowledge about the industry that is particularly useful for this project. Further, because the vendor technical guidelines often are used nearly verbatim as plant emergency operating procedures, the approaches taken by these vendor personnel to classification and interface issues are reflected in the procedures of the plants of their type.

Vendor representatives were identified with the assistance of our NRC project monitor. One individual at each of the four vendors was contacted first by telephone and then sent a follow-up letter describing the project, the types of questions to be asked during the discussions, and the types of persons with whom we wanted to meet. All discussions took place in a group setting.

Six major topics were addressed during each meeting. The topics included (1) the frequency of transitions within and between operating procedures, (2) problems associated with transitions, (3) possible solutions to interface problems, (4) current classification schemes used in the technical guidelines provided by the vendors to plants for their emergency operating procedures and for operating other vendor-supplied equipment; (5) current classification schemes used at plants, and (6) optimal classification schemes. The specific questions asked for each of these topics can be found in the interview guide presented in Appendix B. The discussions with each vendor group lasted for two or more hours and covered a variety of additional topics that will be noted in later sections of the report.

2.2.3 Interviews with Federal Trainers

Four trainers from the NRC Technical Training Center in Chattanooga were interviewed individually by project staff members. Because our prior work with operating procedures of all types indicated that procedure interfaces are particularly difficult for inexperienced operators to manage, and because the trainers work with inexperienced individuals (e.g., new NRC staff members, contractor representatives), project staff believed the trainers would be quite knowledgeable about the effects of procedure interfaces on the performance of novice operators. Further, the four trainers interviewed were highly experienced in plant operations at various utilities before joining the NRC, and so they also were familiar with plant procedure classification practices. The interviews with the trainers covered topics similar to those discussed with the vendor representatives.

2.3 Secondary Data Analyses

A third information source for the present project was data collected by project staff under the earlier NRC project that was designed to assess practices and problems related to procedures that guide operator actions under normal and abnormal conditions in nuclear power plants ("Program Plan for Assessing and Upgrading Operating Procedures for Nuclear Power Plants."). Three major activities were undertaken for that project, including (1) site visits to operating nuclear power plants in each region of the U.S. to interview procedure writers, reactor operators, and operator trainers about normal and abnormal operating procedures; (2) the selection and meetings with a peer review group of industry experts to comment on the project design, findings, and recommendations; and (3) an evaluation of the the usability of normal and abnormal operating procedures from a large sample of plants.

Although not the primary focus of that project, information regarding procedure classification and interface issues was obtained during the course of the Operating Procedures project. Where pertinent, those data are incorporated into the body of this report. In addition, a complete summary of a preliminary assessment of interface problems based on those data is included in Appendix A.

For purposes of the present project, several reanalyses of the usability evaluation data from the Operating Procedures project were conducted. To evaluate the usability of plant operating procedures, a set of four procedures for operating under normal conditions (NOPs) and two for operating under abnormal conditions (AOPs) was requested from all operating plants across the U.S. as part of the Operating Procedures project. The six procedures collected were selected by members of the peer review group for that project and included (1) a plant start-up procedure (NOP); (2) a condensate and feedwater start-up procedure (NOP); (3) a reactivity balance calculation procedure (NOP); (4) a reactor coolant leak rate calculation procedure (NOP); (5) a loss of condenser vacuum procedure (AOP); and (6) a loss of component cooling procedure (AOP). These procedures were identified by peer review group members as common to both PWRs and BWRs and as representative of typical NOPs and AOPs. Fifty-five percent of the sites contacted responded.

The usability of each of the six procedures obtained from the plants was evaluated by a project team member using a procedures evaluation checklist. Among the items on the checklist were several that pertained to how interfaces were managed in the procedures. The rater was asked to assess:

- Whether instruction steps contained complete reference(s) to other procedures.
- Whether references to other procedures specified the section or step of the referenced procedure to go to.
- Whether subsequent actions to be taken upon completion of the procedure were clearly identified (e.g., was a follow-on procedure specified, a person identified to be notified, etc.).
- Whether the procedure clearly indicated when it was complete.
- Whether source documents, technical specifications, etc., used as background for the procedure were referenced.
- Whether source documents for action instructions were referenced in the procedure.
- Whether placekeeping aids were provided for operators to use when transitioning between procedures.

In addition, the procedure class to which each procedure was assigned by the plant was recorded. The checklist data were stored for use on a microcomputer and were analyzed with Statistical Package for the Social Sciences software.

For the purposes of the present project, three types of secondary data analyses were conducted. First, Chi-Squares (a measure of statistical association) were calculated to assess any differences between how interfaces are presented in procedures from plants belonging to different Owners' Groups. The results of these reanalyses are reported in Section 4.1.2.1 of this report. Second, additional Chi-Squares were calculated to assess the relationship between the interface checklist items and the number of forced outages experienced in 1984 at the plants from which the procedures were solicited. The forced outage data were obtained from 1984 editions of NUREG-0020, Licensed Operating Reactors: Status Summary Report, issued monthly. The results of these reanalyses are summarized in Section 4.1.2.2 and presented in greater detail in Appendix C. The categories to which the procedures were assigned for each plant also were evaluated to assess the degree of consistency in categorizations across plants. This information can be found in Section 3.2.1.

2.4 Formation of the Peer Review Group

A peer review group was formed to provide expert input to project staff regarding the interface and classification issues and the techniques for addressing them presented in Section 6.0 of this report. The six individuals invited to serve were selected in consultation with the NRC project monitor, on the basis of the recommendations of the license examiners.

Each review group member was sent a copy of an earlier version of this report to review and was invited to attend a two-day meeting to provide their input to the project. The peer review group meeting was held on February 26 and 27 in Seattle, Washington, at the Battelle Human Affairs Research Centers. At the review group meeting, the individual opinion of each expert was sought, rather than a consensus opinion of the group. Review group members were brought together to permit the free flow of all available information that contributed to the formulation of individual expert opinions. Review group members' comments on the project activities and findings and their recommendations for revising the report are included throughout this document and, where appropriate, the project team has reported the team's perceptions of an average or consensus of the Peer Review Group members' individual opinions. Appendix D provides a list of peer review group members and the agenda for the review group meeting.

3.0 PROCEDURE CLASSIFICATIONS

Five major classification questions related to nuclear power plant operating procedures were of interest in the present project. These questions include:

- What is the current scope of and delineation between operating procedure classes across the industry? In what ways are procedure classification schemes consistent across plants? In what ways are they inconsistent?

- Could current classification schemes be improved by changes? If so, what might those changes be?

- What are the benefits and disadvantages to standardizing the scope of operating procedure classes across plants?

- What changes, if any, should be made to classification practices?

- What, if any, implications are there of current classification practices for safe plant operations?

In this section, the information gathered in response to these questions is presented.

3.1 The Classification Problem

The primary function of any classification scheme is to organize apparently unrelated pieces of information into groups or clusters that are meaningfully related. Information that has been organized in such a manner is substantially easier for people to remember than information that has not been classified, and it can be retrieved from memory much more quickly (Miller, 1956; Chase and Ericsson, 1981). In fact, one characteristic of growing expertise in a field appears to be that people adopt or develop increasingly sophisticated classification schemes for the knowledge they possess in that area (Norcio, 1981; deGroot, 1965; Anderson, 1979, 1981). Further, as people are required to deal with increasing amounts of information, their need for organization increases to allow them to understand what they perceive, to be able to retain it, and to be able to retrieve and act upon it quickly (Wickens, 1984; Chase and Simon, 1973). Thus, classification schemes can substantially impact knowledge-based performance of the type required of control room operators in nuclear power plants (Pew, Miller, and Feehrer, 1981).

In the nuclear industry, large amounts of complex technical and procedural information must be absorbed by operators to enable them to safely operate their plants. Summarized very simply, they must know how to start up the plant, bring it to full power, maintain it in a steady state at full production, respond to any anomalies, and shut down the plant for refueling and maintenance. Extensive sets of procedures have been produced to assist operators with these tasks, and schemes for classifying the procedures have been developed and implemented at each plant.

There is little evidence to suggest, however, that the classification schemes currently in use in most power plants have been developed with any human factors considerations in mind, such as aiding operator memory and retrieval. Further, as will be discussed in the following sections, it appears that some current classification practices interfere with operator performance and may increase the likelihood of human error that could affect plant safety. Therefore, this portion of the present project was designed (1) to identify current classification schemes; (2) to evaluate their human factors characteristics (i.e., their usability); (3) to recommend any improvements that might be necessary to support safe operator performance; and (4) to examine the viability of developing a standardized procedure classification scheme for use across the industry.

3.2 Current Classification Practices

In this section, we present the findings of our data-gathering activities regarding the procedure classification schemes currently employed throughout the industry. We also discuss the factors that appear to affect the procedure classification schemes developed in plants.

3.2.1 Consistencies and Inconsistencies Across Plants

Depending upon the observer's perspective, plant procedure classification schemes can appear to be similar or to be highly dissimilar. Although the standards governing the types of procedures that each plant should have are consistently observed across the industry and plant classification schemes are generally based on operating conditions (i.e., normal, abnormal, emergency), the number of classes defined at each plant and the content of those classes vary widely.

From the most general perspective, all plants' procedure systems comply with the guidance provided in ANSI/ANS-3.2, Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants (1981), as endorsed by NRC Regulatory Guide 1.33. This standard describes the development and implementation of three types of procedures in plant operations--system procedures, general plant procedures, and emergency procedures. System procedures are defined as:

> . . . instructions for energizing, filling, venting, draining, starting up, shutting down, changing modes of operation, returning to service following testing (if not contained in the applicable testing procedures), and other instructions appropriate for operation of systems important to safety . . . [and] . . . procedures for correcting off-normal conditions . . . for those events where system complexity may lead to operator uncertainty. (p. 98)

General plant procedures are defined as providing "instructions for the integrated operations of the plant" (p. 98), and are to include start-up procedures, shutdown procedures, power operation and load changing procedures, process monitoring procedures, and fuel-handling procedures. Emergency procedures are intended "to guide operations during potential emergencies" (p. 107), with emergencies to be defined by each utility. In addition, ANSI/ANS-3.2, Appendix A, provides a list of typical procedures for each category, but does not specify that plants classify them as they are classified in the ANSI standard.

At the plant level, procedures with the content specified in ANSI/ANS-3.2 have been written and are in use, but the category labels assigned to describe procedure classes and the procedures included in different classes vary widely. The inconsistency across plants of procedure category labels is demonstrated by a brief review of the procedures indexes for five of the plants visited as part of the Operating Procedures project. This review yielded the variety of classes of operating procedures shown in Table 3.1. The inconsistency across plants of procedure assignment to categories is evident in Table 3.2. This table shows the class into which each procedure collected for the Operating Procedures project was assigned by its plant of origin. As can be seen in Table 3.2, procedures with essentially the same content have been classified by different plants as abnormal, system, special, operating, and emergency operating procedures.

Thus, although ANSI/ANS-3.2 provides some guidance regarding the types of tasks that are to be proceduralized and offers suggestions for developing a complete body of procedures, it does not specify the manner in which procedures should be organized. At the plant level, where operators are required to interact with procedure classification schemes, a multitude of different systems are used. Consequently, the current scope of and delineation between procedure classes at plants across the industry cannot be defined, except to note that plant procedure classification schemes are highly variable.

3.2.2 Sources of Variability

The interviews with the license examiners, vendor representatives, and federal trainers indicated that differences in plant procedure classification schemes are the consequence of several factors. These factors include: (1) differences in vendor approaches to procedure classification; (2) differences among plants in plant equipment, even within the same Owners' Groups; and (3) differences in the personal philosophies of the plant personnel responsible for developing operating procedures.

All of the interviewees concurred that the classification schemes used by vendors for their emergency procedure technical guidelines and other technical information provided to plants exert a significant influence on the schemes used by plant personnel to categorize their procedures. In fact, reviews of plant procedures for the Operating Procedures project suggest that plant personnel often simply reformat vendor technical information, without changing any of the content, and publish the results as plant operating procedures.

Table 3.1. Operating Procedure Classes Used at Different Plants

Plant Conditions	Plant 1	2	3	4	5
EMERGENCY	Emergency	Emergency Operating	Emergency	Emergency Operating	Emergency
ABNORMAL	Abnormal Annunciator Correction	Abnormal	Abnormal Alarm	Abnormal	
NORMAL	System	Operating	Plant System	Refueling Systems Verification	Instrument Operations Power Operations

Table 3.2. Number of Plants Assigning Procedures in Different Classes (N=119)

Procedure Class	Procedure Title					
	Plant Start-up	Condensate Feedwater Start-up	Reactor Coolant Leak Rate Calculation	Reactivity Balance Calculation	Loss of Condenser Vacuum	Loss of Component Cooling
Normal	2	1				
Abnormal/ Off-normal					7	12
System Operating		3	1	1	1	1
General Operating	6	1				
Operating	6	3		1	1	1
Special Operating				1		1
Emergency					1	1
Surveillance			7	4		
Procedure Does Not Indicate	16	14	11	13	9	11

Of the four vendors visited for the present project, all base their procedure classification schemes on plant status, generally corresponding to normal, abnormal, and emergency operating conditions. For example, Combustion Engineering (CE) provides plants with technical guidelines that describe plant start-up and shutdown, power operations, abnormal operations, and emergency recovery actions. As can be seen in Figure 3.1, CE plants are encouraged to develop four subcategories of procedures for off-normal operations, including alarm response procedures, abnormal procedures, functional recovery procedures, and optimal recovery procedures (Combustion Engineering Emergency Procedures Guidelines, 1984). Westinghouse also offers guidelines for operating under normal and abnormal conditions, in addition to emergency operating guidelines that assist the operators to diagnose events, and emergency response guidelines that describe mitigation actions. The emergency response guidelines are further subdivided into function restoration guidelines, optimal recovery guidelines, and critical safety function status trees. Thus, although plant status provides the underlying rationale for the classification schemes used by each vendor, the number and content of the classes defined by the vendors differ and so contribute to differences between the classification schemes of plants belonging to each Owners' Group.

Differences in the equipment used by plants and how it is configured also contribute to inconsistencies in procedure classification schemes. As one vendor representative pointed out, whether or not a plant has installed main steam isolation valves (MSIVs) significantly affects the actions required to respond to a steam generator leak and the seriousness of a leak. All of the vendor representatives agreed that the specific equipment used in a plant and its configuration impact (1) which procedures must be written to operate the equipment, (2) the content of the procedures, (3) the safety-relevance of the procedures, and (4) the procedure class to which each procedure is likely to be assigned.

The third source of variation in classification schemes identified by the experts interviewed for this project was differences in the philosophies and preferences of the plant personnel responsible for developing procedures. One federal trainer noted that plant personnel, such as the operations superintendent, often prefer to organize operating procedures according to the plant systems to which they pertain, rather than according to plant status. A vendor representative suggested that plant staff members' experience in operating fossil fuel plants may affect how they view the task of operating a nuclear plant and, consequently, the task of organizing operating procedures. He noted that the one plant in his Owners' Group that most frequently deviates from the vendors' recommendations and from the other plants' practices is staffed primarily by persons with fossil fuel backgrounds. Peer review group members pointed out that plant staff with Navy nuclear experience may apply Navy classification practices to their plant's schemes as indicated by the fact that operating procedures on nuclear submarines also are classified according to normal, abnormal, and emergency operating conditions.

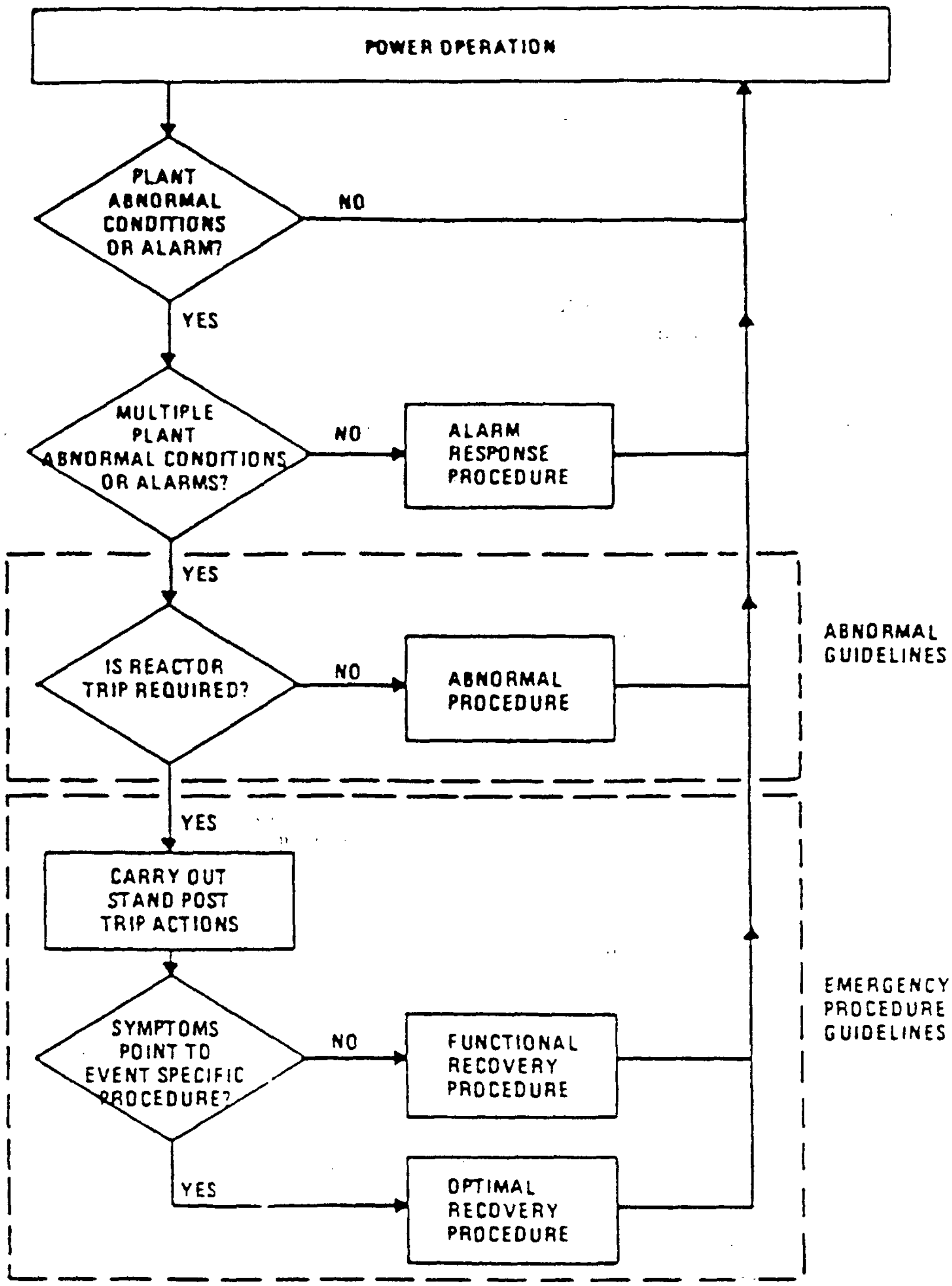

Figure 3.1. Sequence of Decisions for Off-Normal Operations at Combustion Engineering Plants

Although project team members expected that plant personnel would attempt to develop easily understandable procedure classification and indexing systems that promote procedure accessibility, differing levels of concern for the usability of classification schemes were not cited as sources of variability among plant schemes. In fact, the vendors interviewed stated that they have not evaluated the human factors implications of how they have classified their guidelines. Further, none of the experts interviewed identified any plants at which procedure classes were designed to aid operator understanding of their plant's procedure system or to increase accessibility to the procedures. It appeared to the experts that the focus of the industry's and the NRC's efforts has been on ensuring that plants possess complete procedure sets to govern all tasks that may impact safe operations, rather than on the manner in which those procedure sets are organized.

3.2.3 Summary of Current Classification Practices

In summary, then, procedure classification practices throughout the industry can be seen as similar from a general perspective and as highly dissimilar when specific plant schemes are compared. All plants' schemes meet the standards of ANSI/ANS-3.2 for system, general, and emergency procedures, and, following the vendors, procedure classes are often based on plant status corresponding to normal, abnormal, and emergency operating conditions. Within Owners' Groups, most plants employ classification schemes similar to those published by vendors in their technical guidelines. When the scope, delineation, and labeling of procedures classes are compared across plants, however, very little consistency can be observed. Further, human factors principles for organizing information for ease of use do not appear to have been applied to the development of either vendor or plant classification schemes.

3.3 Implications of Current Practices

There are several consequences of current procedure classification practices. Both the inconsistency of plant classification schemes and the lack of human factors input to classification schemes affect activities in the nuclear industry in a number of ways, some of which may degrade the safety of plant operations.

3.3.1 Effects of Inconsistency

Three consequences of differences in plant procedure classification schemes were identified by the individuals interviewed for this project. The consequences included (1) effects on NRC regulatory activities, (2) effects on the communication of operating experience between plants, and (3) effects on the manpower available to staff plants.

One major consequence of the inconsistency in current classification practices is that NRC regulatory effectiveness is limited at some plants. At present, NRC staff review and evaluate the technical adequacy and usability of plant emergency operating procedures only, as part of the emergency procedures upgrade program initiated in response to the TMI incident (NUREG-0660, NRC Action Plan Developed as a Result of the TMI-2 Accident, 1980). As previously noted, however, the scope of the class of emergency procedures is not standardized across the industry, with two results that impact NRC effectiveness.

First, procedures that are similar in content but are classified differently at different plants currently do not receive the same degree of NRC scrutiny. Because NRC staff does not evaluate the usability of abnormal or normal operating procedures under the TMI upgrade program, a procedure that is classified as abnormal at one plant will not be required to meet the guidance provided in NUREG-0899 (Guidelines for the Preparation of Emergency Operating Procedures, 1982) and will not be evaluated by NRC staff, whereas the same procedure classified as an emergency procedure at another plant will be carefully reviewed. Thus, although the potential impact on safety of the two procedures is the same at both plants, and the stressful conditions in which the procedures will be used are similar, only the procedure that is classified as an emergency procedure must meet current usability requirements. Because abnormal operating procedures typically are poorly organized, vague, and difficult to follow (NUREG/CR-3968, Study of Operating Procedures in Nuclear Power Plants: Practices and Problems,) the exclusion of procedures from the emergency class at some plants may lead to operator errors and, subsequently, to challenges to plant safety systems.[1]

Second, because the scope of the class of emergency procedures is not standardized, plant personnel may choose not to develop an emergency procedure for particular events or some sets of circumstances. As a result, operators' responses to off-normal events may be incorrect or delayed because they lack specific instructions for taking appropriate mitigating actions, as occurred during the recent Rancho Seco overcooling incident (NUREG-1195, Loss of Integrated Control System Power and Overcooling Transient at Rancho Seco on December 26, 1985, 1986), and the safety of plant operations may be impaired.

Another consequence of the differences between plant classification schemes that was identified by the experts interviewed for this project is that procedural problems and improvements often are not communicated between plants. If personnel at one plant discover some new and improved technique for conducting a plant start-up, for example, there is currently no NRC-mandated method for ensuring that the technique is disseminated to other plants. Further, if personnel at one plant discover a need for a procedure in response to some form of human error, no formal mechanism currently exists for other plants' personnel to be informed of the problem and the solution. Representatives from all four vendors noted that

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[1] It should be noted that personnel at other plants have recognized the need for usable abnormal procedures and have begun to upgrade procedures in the abnormal class in addition to upgrading their emergency operating procedures. Programs to improve abnormal procedures are not yet widespread across the industry, however.

increased standardization of the scope of procedures classes would increase the likelihood that such information is made available across the industry. Although there currently is no evidence to suggest that public health and safety are compromised by the lack of such information-sharing, it is clear that increased communication of this type between plants would contribute to improved safety.

A third consequence of inconsistent procedure classification practices identified by some of the experts interviewed for this project pertains to the availability of trained personnel. Significant differences between plant procedures and procedure systems prevent the easy transfer of personnel from one plant to another. Consequently, personnel shortages at one plant cannot be met until new staff can be trained in the particular characteristics of the individual plant and relicensed. Some of the experts interviewed suggested that by increasing inter-plant consistency in procedures and procedure classification schemes, the labor pool of knowledgeable and highly experienced operators would grow for plants of similar design. This larger labor pool could reduce personnel shortages and so contribute to the safety of plant operations.

3.3.2 Human Factors Issues

The lack of human factors considerations in procedure classification practices has led to usability problems with plant procedures that also are likely to affect the safety of plant operations. Several sources of information for this project reported classification practices that have created problems for operators in accessing and using procedures at some plants.

One common practice identified is clustering a large number of procedures into one class without any subcategorization or meaningful organization of the procedures within the class. Operators at three plants visited for the Operating Procedures project noted that the large number of normal operating procedures at their plants increased the time they need to find a particular procedure and discouraged them from using normal operating procedures whenever possible to avoid it. Because there were only about 30 abnormal operating procedures at each plant (as opposed to hundreds of normal operating procedures), the operators felt that their abnormal procedures were easy to access. One federal trainer interviewed as part of the present project also pointed out that the failure to organize procedures within classes can decrease procedure accessibility, particularly for the inexperienced operator who must use plant procedure indexes rather than being able to rely on past experience to go directly to the desired procedure.

A second practice described by the same federal trainer and one vendor representative is the failure to link how procedures are identified with any organizing concept or principle. Systems of simply numbering procedures in the order in which they are written, for example, do not provide the operator with information that is of use to him in attempting to identify the correct procedure for the task at hand.

A third practice that impairs the usability of procedure systems is the failure to link operator training with plant procedures systems. Vendor training personnel interviewed for this project, and plant training personnel and peer review group members interviewed for the Operating Procedures project, all reported that neither the manner in which plant procedures are organized nor methods of locating desired procedures are taught to operators as part of plant or vendor training programs. Further, one Operating Procedures project peer review group member emphasized that no matter how well plant procedures are organized and how well an indexing system is designed, operators must understand the system to use it effectively, especially under such time pressure as may exist during an emergency.

Two additional usability problems are related to the current practice of classifying procedures on the basis of plant conditions (i.e., normal, abnormal, and emergency). One consequence of the plant status-based scheme is that operators often are required to transition between procedure classes during the course of a single plant evolution. Thus, to return the plant to a safe, stable condition following some abnormal or emergency event, operators may be required to locate and to use procedures from two or more classes of plant operating procedures, rather than having at-hand all of the procedures they need to guide their activities. Further, because procedures in the different classes of a plant status-based scheme are usually formatted differently, the need to transition between procedure classes means that operators also must transition between procedure formats. As will be discussed in greater detail in Section 4.0, individuals interviewed for the Operating Procedures project stated that transitions between procedure classes and formats are particularly difficult for inexperienced operators to manage and have confused operators at all experience levels.

The extent of these human factors problems throughout the industry cannot be reliably estimated from the data available at this time. Given that the license examiners, federal trainers, and vendor representatives indicate that human factors have not played a part in the design of any procedure classification systems of which they are aware, however, it is likely that these and similar problems are quite common.

3.3.3 Safety Significance of Current Practices

It appears, then, that the inconsistencies in procedure classification schemes between plants and the lack of attention to the usability of procedure classification schemes can affect the ability of operators to correctly perform their tasks. The experts interviewed and this project's peer review group members indicated that the safety significance of these consequences of current classification practices varies, however.

The experts interviewed and the peer review group members suggested that a lack of usability in normal and abnormal operating procedures could present a serious threat to plant safety in some circumstances. One peer review group member from the NRC reported his impression, for example, that 20 to 30% of the incidents at plants that are reviewed in daily NRC meetings result from inadequacies in normal and abnormal operating procedures. The importance to safety of procedures in these classes was underscored by another peer review group member who reported that it appears to him that the majority of off-normal events at plants are initiated by operator errors in executing normal and surveillance procedures. Although the experts and the peer review group members familiar with utility operations noted that not all normal and abnormal procedures are equally important to safety and that the procedures that are safety-relevant differ between plants, they concurred that some normal and abnormal operating procedures should receive as much utility and NRC scrutiny for technical accuracy and usability as do emergency operating procedures.

Peer review group members concluded, however, that the categorization of procedures as abnormal at some plants and as emergency procedures at others (with the result that the NRC does not review the procedures classified as abnormal) is not a safety-significant problem, per se. Rather, the experts and peer review group members emphasized that how a procedure is classified means little compared to the safety significance of the procedure's content. Thus, although the usability of operating procedures in all classes was considered to be of substantial concern, the manner in which plant procedures are classified was not.

The experts and peer review group members also agreed that the usability of procedure indexes based on procedure classification schemes can significantly impact the safety of plant operations. The classification practices identified by the experts that reduce the accessibility of operating procedures (e.g., classifying a large number of procedures in one category, failing to train operators in how plant procedures are organized) were viewed with great concern by peer review group members. Clearly, if operators cannot find the procedure they need to perform a task or are discouraged from looking for it by an inadequate procedure indexing system, then neither the usability nor the accuracy of the procedure will prevent the operator from committing errors that challenge plant safety systems. Although the operator's knowledge may allow him to perform familiar or simple tasks without procedural assistance, his performance of complex, highly detailed, or infrequently performed tasks is likely to be degraded without a procedure to organize his actions and prompt his memory. And while not all of the errors the operator commits will be significant, operating experience in the nuclear industry has repeatedly demonstrated the potentially serious outcomes of seemingly minor operator errors (NUREG-1190, Loss of Power and Water Hammer Event at San Onofre, Unit 1, on November 21, 1985, 1986; NUREG-1154, Loss of Main and Auxiliary Feedwater Event at the Davis-Besse Plant on June 9, 1985, 1985; NUREG-1195, Loss of Integrated Control System Power and Overcooling Transient at Rancho Seco on December 26, 1985, 1986). Therefore, increasing the availability of plant operating procedures by improving the usability of procedure classification/indexing schemes was viewed by the experts and by peer review group members as important to safety across the industry.

For several reasons, the participants in this project were less concerned with the issue of whether or not every plant has developed the same emergency procedures. The experts and the peer review group members involved in operator training repeatedly emphasized that procedures cannot be written for every possible set of circumstances at a plant and that it is one purpose of operator training programs to ensure that operators have the knowledge to respond appropriately to conditions that are not covered by procedures. Another peer review group member pointed out that events outside the current scope of plants' emergency procedures classes eventually should lead operators into existing emergency procedures when plant conditions degrade, as occurred in the aforementioned Rancho Seco event (NUREG-1195, Loss of Integrated Control System Power and Overcooling Transient at Rancho Seco on December 26, 1985, 1986).

Further, experts and peer review group members stated that because there are such large differences between plants in equipment, the safety significance of the decision not to develop a particular procedure at a plant can only be evaluated on a plant-by-plant basis rather than as an industry-wide issue. Thus, the adequacy of operator training, the wide applicability of current emergency procedures, and the fact that plants are not equally likely to experience the same events all suggest that inconsistencies between plants in the procedures developed for emergencies do not represent a safety-significant issue across the industry.

Peer review group members and some of the experts interviewed were similarly skeptical about the impact on public health and safety of procedure classification schemes as they affect communication between utility personnel and the availability of trained operators. Project participants indicated that neither of these issues appear to impair plant operations now and that changes to procedure classification schemes, such as standardization, are unlikely to improve communication or increase available manpower. Peer review group members pointed out that opportunities to communicate about procedures already exist (e.g., the Institute of Nuclear Power Operations program, Owners' Group Procedures Subcommittee meetings) and that some operating experiences currently are exchanged by these means. Further, because procedures and procedure classification schemes represent only a small portion of the information an operator must absorb to understand a plant's workings, inter-plant consistency in classification schemes would not substantially ease the transfer of operators between plants, according to peer review group members. Therefore, changes to current classification practices were viewed as unlikely to affect plant safety through increasing inter-plant communication or the availability of trained personnel.

3.3.4 Summary of Implications of Current Practices

In summary, current procedure classification practices have several implications for nuclear power plant operations, some of which are of greater safety significance than others. The consequences of inconsistencies between plants in how procedures are categorized currently appear to be of little importance to safety (e.g., limited communication between plant personnel and lack of trained personnel) or are the result of a larger problem (i.e., the limited usability of normal and abnormal operating procedures). The consequences of a lack of usability of procedure classification/indexing schemes, however, are of substantial importance to safety, as procedure indexing techniques can significantly affect the accessibility of procedures to operators and the likelihood that they have available the information necessary to perform their tasks correctly.

3.4 Alternative Classification Schemes

Two alternative schemes for classifying procedures were identified by the experts interviewed for this project as possible improvements to the current plant status-based approach. These organizing methods can be described as evolution-based and system-based.

3.4.1 An Evolution-Based Classification Scheme

The evolution-based approach was proposed by the license examiners during the working meeting with project staff. This scheme would use major plant evolutions, such as plant start-up or a reactor trip, to organize the procedures that cover the activities necessary to return the plant to some safe, stable level. With this approach, all procedures pertaining to an evolution would fall into the same category, regardless of whether they describe activities under normal, abnormal, or emergency conditions.

The license examiners noted several benefits of this scheme. First, they suggested that this approach would require that all procedures within a class be consistently formatted so that operators would not be required to transition between different procedure formats during one plant evolution, as is currently the case. Further, they suggested that the same standards for usability and technical accuracy now applied to emergency operating procedures would apply to all procedures in a particular category, because there would be no reason to discriminate between procedures in the same class. The examiners pointed out that current requirements for only emergency procedures to be of high quality ignores the fact that abnormal and normal operating procedures also frequently are used in responding to plant emergencies. The license examiners also suggested that categorizing and binding together all procedures relevant to a particular evolution would reduce operators' difficulties in locating and accessing procedures. Finally, they noted that an evolution-based scheme would conceptually follow the natural sequence of activities involved in an evolution, as taught in operator training courses, and so might be easier for operators to learn to use.

The license examiners and others interviewed for this project pointed out some serious disadvantages to the evolution-based approach, however. The most significant disadvantage is that the scheme requires operators to identify the current plant evolution. For pre-planned, intentional evolutions such as plant start-up, this diagnostic task obviously does not present a problem. For off-normal and emergency conditions, however, such a scheme would require operators to diagnose the type of event that is occurring before they could know which procedure class to enter. The negative consequences of requiring operators to diagnose events during an emergency are well-known (Fuchs, Engelschall, and Imlay, 1981; Zach, 1980).

A second disadvantage is that an evolution-based procedure classification system would not assist operators to prioritize emergencies. If two or more events were to occur simultaneously, the operator would be required either to choose one class of procedures to follow while ignoring the others or to follow procedures in more than one class at a time. Operator indecision and confusion would be the likely result of a procedures system that does not provide an integrated response to emergency events.

A further limitation of the evolution-based approach is the difficulty of ensuring that all likely emergency situations and combinations of situations are addressed by the procedures. This problem is common to all procedure systems that must be designed to deal with unexpected events, but may be more serious for a classification system completely based on the identification of plant evolutions.

3.4.2 A System-Based Classification Scheme

Two of the federal trainers interviewed for this project described a system-based approach to procedure classifications. Under this system, all procedures pertaining to a particular plant system would be classified together, again regardless of whether they describe activities under normal, abnormal, or emergency plant conditions.

Three advantages to this approach were identified by the trainers. First, organizing procedures according to the system to which they pertain would ensure that operators have easily available, in one or two manuals, all the material relevant to the system with which they are working. Second, locating and accessing specific procedures from among all plant operating procedures would be made easier because of the conceptual link between a particular physical system and a procedure class. Further, as noted for an evolution-based scheme, a system-based scheme could decrease operator difficulties in learning to use the procedures, if operator training courses also are organized by plant system.

A system-based approach suffers from many of the disadvantages of the evolution-based system described above, with some additions. First, in an abnormal or emergency situation, a system-based classification scheme would require operators to identify the system that has failed before they could select a procedure to respond to the failure. Just as it is not always obvious which type of emergency event is occurring, it is not always obvious which system has failed to the operator in the control room. Consequently, an operator's responses may be delayed while he attempts to identify the failed system and the appropriate procedure class.

Another disadvantage of the system-based approach is that it would create difficulties for operators faced with multiple system failures. As noted for the evolution-based approach, the system-based scheme does not assist operators to identify the failure that should be addressed first. Further, multiple failures in different systems would require operators to coordinate activities within several classes of procedures concurrently, and concurrent execution of procedures has been shown to lead to operator error in emergency simulations (Cauley and Schroeder, 1985).

A system-based approach also would require the concurrent execution of procedures under normal operating conditions. For any task that involves more than one plant system, operators would have to execute procedures from each class in parallel. The lack of an integrated approach could promote operator errors that challenge plant safety systems or harm expensive equipment.

3.4.3 Summary and Conclusions Regarding Alternative Classification Schemes

Clearly, neither the plant status-based scheme currently in use nor the two classification schemes proposed here present a perfect solution to problems associated with procedure classification schemes. It does appear, however, that a combination of elements of all three schemes may be best able to resolve a number of classification problems. For example, the present plant status-based scheme could be improved (1) by organizing and indexing normal operating procedures according to the plant system to which they pertain, and (2) by ensuring that any procedures likely to be used together during a single plant evolution are at the same, high level of technical accuracy and usability. Such changes to existing procedure classification systems could substantially improve operator access to procedures and the usability of procedures.

3.5 Reducing Variability in Plant Classification Practices

Although a combination of approaches to classifying procedures may overcome some problems resulting from current classification practices, it is not clear that even a hybrid classification scheme is appropriate for use in all plants. In this section, we review the advantages and disadvantages of standardizing procedure classification schemes and discuss factors to consider in reducing variability across the industry.

As noted in Section 3.2.1, procedure classification schemes within the commercial nuclear industry can be viewed from different conceptual levels defined by the extent to which the schemes are responsive to differences in plant equipment. At the most general level are the classification approaches described in the previous section as plant status-, evolution-, and system-based. These general approaches to classifying procedures can be applied to any commercial nuclear plant. At a more specific level are the classification schemes developed by the vendors for their technical guidelines. An even more detailed approach is represented by the procedure classification schemes actually used at plants. The results of our interviews with experts suggest that the viability and value of standardizing procedure classification systems may depend upon the conceptual level at which standardization is contemplated.

The experts interviewed as part of this project and peer review group members were uniformly negative toward the idea of standardizing procedure classes at the plant level. In fact, the experts and peer review group members emphatically stated that a significant degree of standardization could not be readily obtained, and that any attempt to standardize procedure classes would be substantially more costly to implement than the benefits could justify.

The major barrier to standardization at the plant level identified by the experts and peer review group members is the variability in plant design and equipment noted in Section 3.2.2. The vendor representatives and the license examiners both pointed out that major differences between vendors in reactor designs create major differences in how operators perform their tasks. The experts also pointed out that even plants of the same reactor type often are fitted with different types of pumps, valves, and other components that are operated differently. Therefore, the procedures required to operate one plant will vary significantly from those required to operate another.

The vendor representatives, federal trainers, and peer review group members were similarly negative toward a wholesale change from a plant status-based approach to another classification scheme such as the evolution-based or system-based schemes. These individuals stated that although no deliberate decision to adopt a plant status approach based on either technical or human factors considerations appears to have been made by any of those involved in the nuclear industry, the plant status approach provides a framework for procedure classifications across the industry and seems to work "well enough" to retain. In the experts' opinions, the costs of rewriting, validating, and verifying many plant procedures, reorganizing plant classification schemes, and retraining operators cannot be justified, given the absence of substantial evidence that the current approach is inadequate.

The vendor representatives were open, however, toward the idea of attempting to increase the consistency of procedures within Owners' Groups. As noted in Section 3.3.1, all vendor representatives interviewed perceive disadvantages in the lack of standardization and believe that increased standardization would improve the communication of operating experiences between plants and increase the ease of transferring personnel between plants. Further, the development of each Owners' Group's set of technical guidelines for emergency operating procedures was described as a rewarding experience within the industry because of the research generated, the exchange of information between plants and vendors, the pre-planning that has gone into the process, and the quality of the new procedures. Although the vendor representatives saw substantial problems in attempting to standardize normal and alarm response procedures because of the differences in plants' equipment, they reported that there has already been some discussion within the Owners' Groups of attempting to upgrade and standardize abnormal operating procedures and to better integrate them with emergency procedures.

One vendor representative pointed out an additional advantage of reducing the variability of procedures within Owners' Groups. He noted that although the vendors are responsible for providing the technical guidelines for developing plant emergency operating procedures, they are not always involved in the translation of those guidelines into plant procedures because each plant is unique and because utilities are not always willing to pay for vendor involvement. Consequently, it has been his experience that technical guidelines often are incorrectly interpreted and that, as a result, plant emergency operating procedures often are technically incorrect. Further, he noted that many deviations from the technical guidelines are not picked up during the NRC's review of each plant's Procedures Generation Package (PGP), because of the translation of Owners' Group technical guidelines into plant-specific procedures requires detailed knowledge of the plant's design and of the intent of the guidelines, which NRC reviewers may lack. He noted that if plant procedures and classification schemes were standardized within NSSS vendor type, the likelihood of technically incorrect procedures would probably be decreased. This representative stated that involvement of vendors in the PGP process would accomplish the same end, but also might entail legal responsibilities for the vendors and disrupt their service relationships with utilities by placing them in the role of regulators.

Although the vendors interviewed saw advantages to standardization at the Owners' Group level, peer review group members did not. As previously noted, the majority of the peer review group members did not view the current inconsistencies between plants as potentially resulting in significant harm to the public. Although the issue of the lack of usability of some normal and abnormal operating procedures was seen as important to safety, the majority of the peer review group members concluded that standardization of procedure classification schemes is not the appropriate solution to the usability problems in these classes, as discussed in Section 3.3.3. Because there is little evidence that inconsistencies in classification schemes present a threat to public health and safety, most peer review group members did not believe that the costs of standardization at any level in the industry could be justified.

In conclusion, it does not appear that attempts to standardize the scope of procedure classes or to mandate a change in classification schemes at plants are likely to be successful. Because of greater, although still limited, consistency in plant equipment within Owners' Groups, there may be some benefit to standardizing procedure classes by NSSS vendor type. The lack of evidence to show that current inconsistencies between plants are safety-significant, however, suggests that NRC action to standardize classification schemes is unwarranted.

3.6 Summary of Findings and Implications Regarding Procedure Classifications

In response to the five major classification questions posed at the outset of this project, our findings from this portion of the project can be briefly summarized as follows:

- The current scope of and delineation between operating procedure classes across the industry cannot be determined because of the large inconsistencies in how procedures are classified across plants. The only consistencies found across plants are that procedure schemes comply with the guidance of ANSI/ANS-3.2 and are generally based upon plant status. Inconsistencies in plant procedures are due to major differences in vendor technical guidelines and in plant equipment.

- The current plant status-based classification scheme could be improved by ensuring that all procedures likely to be used in emergency conditions, including normal and abnormal procedures, are technically accurate, usable, and do not differ significantly in format.

- Standardizing the scope of procedure classes across plants is not feasible because of the large differences in plants' equipment that determine how they must be operated. Further, because inconsistencies in classification schemes do not appear to impact public health and safety, NRC action to standardize procedure classes is not justified.

- Classification practices could be improved by ensuring that procedure classes are meaningfully organized, are subdivided if large, do not require many transitions to procedures of another format during a plant evolution, and can be used in operator training. Each of these improvements would assist operators in accessing desired information.

- Because current procedure classification/indexing practices interfere with operators' abilities to access quickly the information they need, classification practices can delay operators' responses to emergencies, discourage them from trying to find and use procedures, and promote errors by confusing them. Each of these consequences of a poorly designed classification scheme can impair safe plant operations.

Conclusions and recommendations based on these findings and on the findings derived from our study of procedure interface issues are integrated and presented in Section 5.0.

4.0 PROCEDURE INTERFACES

As defined in Section 1.0, the term "procedure interface" refers to how operators are informed that they should move from one procedure to another or to another section of the same procedure. A procedure step that instructs an operator to leave the procedure he has been following and to begin following another procedure (i.e., to transition from one procedure to another) is an example of a "procedure interface."

Problems associated with procedure interfaces arise from absent or inadequate information provided to operators in the procedure steps and from the complexity of the transitions themselves (e.g., the need to follow several procedures simultaneously). A number of previous investigations have indicated that interfaces in nuclear power plant operating procedures are deficient (Fuchs, Engelschall, and Imlay, 1981; Cauley and Schroeder, 1985; Appendix A), and that the deficiencies contribute to errors in operators' task performance. The objectives of this portion of the project, therefore, were to identify the nature and extent of the deficiencies, their significance for the industry, and to explore potential methods of managing transitions within and between procedures more effectively.

4.1 Current Interface Problems

In this section, we describe the interface problems found in the course of prior projects and discuss their impact on plant operations. In addition, we also present the findings of secondary analyses of the human factors characteristics of procedure interfaces in a sample of normal and abnormal operating procedures collected from plants belonging to different Owners' Groups.

4.1.1 Findings of Prior Projects

Procedure interface problems have been noted in the course of several studies conducted for the NRC (e.g., the Review of Emergency Operating Procedures for Near-Term Operating Licensees; Safety System Status Verification). More recently, however, the results of four projects have pointed out the importance of procedure interfaces for plant safety and the availability of plant equipment.

Findings from a preliminary assessment of interface problems, conducted as part of the Operating Procedures project, indicated that procedure interfaces present significant difficulties for operators in task performance (Appendix A). For example, during site visits to nuclear plants, operators reported that plant procedures are designed so that operators are frequently required to follow two or more procedures simultaneously. In attempting to use multiple procedures, the operators reported (1) problems in determining how to coordinate steps in the different procedures, (2) difficulties in placekeeping in the procedures, and (3) problems with physically handling more than one procedure manual at a time. The operators stated that these problems had, at times, left them lost among the procedures and confused, and that the press of events sometimes required them to abandon efforts to use the procedures and to conduct their tasks on the basis of training and experience alone. Clearly, the inability to rely on procedures may seriously hamper the performance of inexperienced operators.

Three additional procedure interface problems were identified in the course of the preliminary assessment. These include (1) inconsistencies in the level of detail with which procedures are written, (2) interfaces that are inappropriate for use by operators who have different levels of experience, and (3) master indexing systems that do not aid the user in locating the desired procedure, as was also noted in Section 3.3.2 of this report. Plant training personnel stated that these deficiencies often delayed task performance for inexperienced operators because the operators had to spend time searching for reference material to understand a procedure or an interface written in too little detail and in scanning through procedures or the index to find referenced procedures. Under normal plant conditions, such time delays are unlikely to affect plant safety. Delays may negatively impact safety, however, during a developing emergency.

A study conducted by Cauley and Schroeder (1985) underscores the safety significance of such problems. In an empirical investigation of how operators manage procedure transitions in emergency operating procedures, these researchers identified ten interface problem areas from observing videotapes of operators responding to simulated plant emergencies and described the errors committed by operators. Among the actions that could lead to safety-significant errors were: (1) operators missing a required transition and continuing to follow an incorrect procedure, (2) operators becoming lost and confused when an interface was presented in a caution rather than in an action step, and (3) operators entering an incorrect procedure when given an incomplete procedure reference.

Extensive research conducted by the French to identify the causes of human errors that have led to safety-significant incidents in nuclear power plant operations also demonstrated the threat to public health and safety posed by procedure interface problems (Griffon-Fouco and Gomolinski, 1982). Among nine categories of possible causes for the operating incidents analyzed by the French researchers (e.g., work organization, ergonomic design of the control room, social environment, education and training of the personnel, etc.), procedure design was cited most often as leading to errors. In particular, cross-references among procedures and transitions between them were found to promote operator error that challenged safety systems.

In addition to the safety implications of procedure interface problems, poorly managed procedure transitions also have been linked to the potential for significant damage to plant equipment. For example, the Pressurized Thermal Shock project (NUREG/CR-2837, PNL Thermal Review of Pressurized Thermal Shock Issues, 1982) was conducted to verify the accuracy of industry claims that operators could operate the unit during a trip so as to cool the reactor and reduce pressure in the vessel without risk of pressurized thermal shock (i.e., the consequences of introducing large quantities of relatively cold water into hot reactor pressure vessels with welds embrittled by neutron bombardment). It was claimed that these operations could be safely accomplished through appropriate training and use of procedures. Project findings based on simulator exercises indicated, however, that operators would have serious difficulties in this situation, particularly in transitioning between procedures and in using two or more procedures simultaneously. These impediments to operator performance were expected to be particularly pronounced under the highly stressful conditions associated with a risk to reactor integrity.

4.1.2 Human Factors of Procedure Interfaces

The findings cited above suggest that procedure interface problems can significantly affect the safety of plant operations and the availability of costly plant equipment, although those data do not address the extent of the problems throughout the industry. An evaluation of the human factors characteristics of interfaces in normal and abnormal plant operating procedures, however, indicates that a substantial proportion of procedures currently in use across the industry present procedure transitions poorly and so contribute to interface problems. Further, as will be discussed in the sections to follow, many of these human factors deficiencies in the procedures appear to be linked to challenges to plant safety systems.

4.1.2.1 Interface Deficiencies

As reported in NUREG/CR-3968 (Study of Operating Procedures in Nuclear Power Plants: Practices and Problems) results of the procedure evaluation conducted as part of the Operating Procedures project showed four specific interface deficiencies. The evaluation indicated (1) that operating procedures frequently refer the operator to other procedures, (2) that the referenced procedures often are described incompletely, (3) that entry and exit conditions for the procedures are unclear or incomplete, and (4) that procedures frequently do not include placekeeping aids. In fact, an overall evaluation of the procedures indicated that close to one-half (48%) were less than acceptable on the basis of their human factors characteristics, and that abnormal operating procedures, in particular, were deficient (72%).

As suggested by the interview data regarding procedure classification issues, the human factors characteristics of interfaces in the procedures of plants belonging to the four Owners' Groups contacted for this project were found to differ significantly. The discussion to follow presents the ratings of human factors elements with specific impact on interface issues for the procedures of plants belonging to the four different Owners' Groups. Because of the relatively small sample sizes for some vendors, these data should be viewed as illustrative rather than as definitive.

Although the majority of the normal and abnormal operating procedures reviewed included a set of entry conditions for use of the procedures (i.e., this information was present in 95% of the procedures, 98% of abnormal procedures), the clarity of the specified conditions was rated as unacceptable in a relatively large proportion of the procedures evaluated (19% of the total, 26% of the abnormal procedures). Table 4.1 shows the ratings given for clarity of entry conditions by vendor and suggests that operators at both Westinghouse and General Electric plants may experience interface problems due to vague entry conditions for their procedures.

Exit conditions were included in 77% of all procedures reviewed, but clarity was again lacking in their presentation (i.e., 30% of the procedures were rated as less than minimally acceptable, 40% of the abnormal procedures). Table 4.2 shows that plants belonging to the Westinghouse Owner's Group had procedures with the most deficient exit conditions, and that nearly 40% of these plants' procedures were rated as unacceptable.

Ratings of the completeness of references to other procedures show that more than one-third of the procedures reviewed were unacceptable (34% of the total, 36% of the abnormal procedures). In fact, only 13% of the procedure references were rated as good, while the rest were rated as merely acceptable. Again, plants belonging to the Westinghouse and General Electric Owners' Groups showed the greatest number of deficient procedures (Table 4.3).

The procedures rated also were deficient in terms of whether or not the user is referred to a specific section or step of the procedure when sent from one procedure to another. Seventy-one percent of all procedures (85% of the abnormal procedures) rated on this dimension were considered unacceptable, as Table 4.4 shows. These data provide some insight into why inexperienced operators have difficulties with procedure interfaces, since inexperienced operators require clearer, more detailed information in procedures to understand them.

Ratings of the usability of placekeeping aids in the procedures indicated that nearly one-third (27%) of the procedures provided operators with inadequate assistance in keeping track of their progress through the procedures. As can be seen in Table 4.5, procedures from Westinghouse plants again received the largest proportion (35%) of unacceptable ratings among the vendor types. Poor quality of placekeeping aids has been cited as contributing to operators' difficulties in following more than one procedure at a time.

Finally, the extent to which subsequent actions following completion of a procedure are clearly identified in the procedure is an important element in managing transitions within and between procedures. Although the majority of the procedures did identify subsequent actions (71% of the total, 74% of the abnormal procedures), 20% of those actions were rated as unacceptably vague. As Table 4.6 shows, normal and abnormal operating procedures from Westinghouse plants lacked a clear description of subsequent actions most often, compared to the other vendors.

Based on this sample of procedures, it is evident that current practices in the industry do not take advantage of existing human factors knowledge

Table 4.1. Clarity of Entry Conditions by Vendor (N=142)

	Number of Procedures Given Each Rating*		
Vendor	Poor	Minimally Acceptable	Good
General Electric N=45 (32%)	9 (20%)	20 (44%)	16 (36%)
Westinghouse N=68 (48%)	15 (22%)	39 (57%)	14 (21%)
Combustion Engineering N=13 (9%)	2 (15%)	7 (54%)	4 (31%)
Babcock & Wilcox N=16 (11%)	1 (6%)	9 (56%)	6 (38%)
Total	19%	53%	28%

* These data are based on the combined samples of normal and abnormal operating procedures.

Table 4.2. Clarity of Exit Conditions by Vendor (N=117

Vendor	Number of Procedures Given Each Rating*		
	Poor	Minimally Acceptable	Good
General Electric N=40 (34%)	11 (28%)	17 (42%)	12 (30%)
Westinghouse N=50 (43%)	19 (38%)	24 (48%)	7 (14%)
Combustion Engineering N=12 (10%)	1 (8%)	9 (75%)	2 (17%)
Babcock & Wilcox N=15 (13%)	4 (27%)	8 (53%)	3 (20%)
Total	30%	50%	21%

* These data are based on the combined samples of normal and abnormal operating procedures.

Table 4.3. Completeness of References to Other Procedures by Vendor (N=142)

Vendor	Number of Procedures Given Each Rating*		
	Poor	Minimally Acceptable	Good
General Electric N=46 (32%)	18 (39%)	22 (48%)	6 (13%)
Westinghouse N=67 (47%)	25 (37%)	36 (54%)	6 (9%)
Combustion Engineering N=13 (9%)	3 (23%)	9 (69%)	1 (8%)
Babcock & Wilcox N=16 (11%)	2 (13%)	9 (56%)	5 (31%)
Total	34%	54%	13%

* These data are based on the combined samples of normal and abnormal operating procedures.

Table 4.4. References to Other Procedures Which Include Specific Section or Step by Vendor (N=141)

Vendor	Number of Procedures Given Each Rating*		
	Poor	Minimally Acceptable	Good
General Electric N=46 (33%)	34 (74%)	9 (20%)	3 (6%)
Westinghouse N=65 (46%)	47 (72%)	11 (17%)	7 (11%)
Combustion Engineering N=12 (9%)	10 (83%)	2 (17%)	0 (0%)
Babcock & Wilcox N=16 (11%)	9 (56%)	2 (13%)	5 (31%)
Total	71%	17%	11%

* These data are based on the combined samples of normal and abnormal operating procedures.

Table 4.5. Usability of Placekeeping Aids by Vendor (N=97)

Vendor	Number of Procedures Given Each Rating*		
	Poor	Minimally Acceptable	Good
General Electric N=26 (27%)	7 (27%)	7 (27%)	12 (46%)
Westinghouse N=52 (54%)	18 (35%)	25 (48%)	9 (17%)
Combustion Engineering N=8 (8%)	0 (0%)	4 (50%)	4 (50%)
Babcock & Wilcox N=11 (11%)	1 (9%)	6 (55%)	4 (36%)
Total	27%	43%	30%

* These data are based on the combined samples of normal and abnormal operating procedures.

Table 4.6. Clarity of Subsequent Actions by Vendor (N=106)

Vendor	Number of Procedures Given Each Rating*		
	Poor	Minimally Acceptable	Good
General Electric N=33 (31%)	4 (12%)	15 (46%)	14 (42%)
Westinghouse N=48 (45%)	14 (29%)	26 (54%)	8 (17%)
Combustion Engineering N=12 (11%)	1 (8%)	8 (67%)	3 (25%)
Babcock & Wilcox N=13 (12%)	2 (15%)	5 (39%)	6 (46%)
Total	20%	51%	29%

* These data are based on the combined samples of normal and abnormal operating procedures.

for developing procedure interfaces. In general, entry conditions for procedures were presented, but were unclear. Exit conditions also were presented, but were vague in many cases. Further, references to other procedures were consistently incomplete and subsequent actions were presented unacceptably in a substantial proportion of the procedures. Placekeeping assistance to operators also was inadequate. Finally, it seems that procedures from plants belonging to the Westinghouse Owners' Group, the largest in the industry, and to a lesser degree to General Electric's, account for a substantial portion of the deficient ratings. However, evaluating larger samples of procedures from plants belonging to the Babcok & Wilcox and Combustion Engineering Owners' Groups may have shown that procedures from these plants are similarly deficient.

4.1.2.2 Interface Deficiencies and Forced Outages

The consequences of these deficiencies in the human factors characteristics of normal and abnormal operating procedures were indicated by statistical analyses of the relationships between the overall usability of the procedures, specific interface deficiencies, and the number of forced outages in 1984 (NUREG-0200, Licensed Operating Reactors: Status Summary Report, 1984) experienced by the plants from which procedures were obtained for the Operating Procedures project.[2] A forced outage is defined in NUREG-0200 as an outage that must be initiated no later than the weekend following the discovery of an off-normal condition. Although there are many different causes for forced outages (e.g., equipment failures attributable to inadequate maintenance or to other types of human error), the number of forced outages a plant undergoes in a year can be interpreted as a general measure of plant performance and, hence, as one aspect of plant safety. The discovery of statistical relationships between forced outages and the human factors characteristics of procedure interfaces suggests that the usability of operating procedure interfaces affects plant operations, and so may impact plant safety.

The relationship between the human factors characteristics of normal and abnormal operating procedures and plant performance is demonstrated by the information summarized in Table 4.7. Table 4.7 shows the relationship between global ratings of the usability of the procedures evaluated for the Operating Procedures project and the number of forced outages experienced in 1984 by the plants from which the procedures were obtained. Reference to the table indicates that procedures that were rated as being better than acceptable and of good usability came from plants that had fewer forced outages in 1984 than procedures that were rated as acceptable or of poor usability. In fact, the plants with procedures rated as the most usable experienced only 2% of the forced outages in 1984.

Specific characteristics of procedure interfaces also were found to be related to the number of forced outages at the plants sampled. As was

[2] More detailed descriptions of the statistical tests performed and of the results of these tests are presented in Appendix C.

Table 4.7. Relationship of Procedure Usability to Forced Outages (N=135)

Number of Forced Outages in 1984	Overall Procedure Usability					
	Poor		Minimally Acceptable		Good	
	1	2	3	4	5	Total
0-1	3	3	4	0	0	10 (7%)
2-5	14	18	20	9	3	64 (47%)
6-9	5	10	11	6	0	32 (24%)
10-13	6	2	6	2	0	16 (12%)
14-17	0	5	4	4	0	13 (10%)
Total	28 (21%)	38 (28%)	45 (33%)	21 (16%)	3 (2%)	135

found with the global rating of usability, the plants with procedures that provide specific entry (Table 4.8) and exit (Table 4.9) conditions and usable placekeeping aids (Table 4.10) experienced fewer forced outages in 1984 than plants with procedures that were rated as deficient in these areas. Ratings of the completeness (Table 4.11) and specificity (Table 4.12) of references to other procedures and of the completeness of descriptions of follow-on actions (Table 4.13) also were related to the number of forced outages in the expected manner, but these relationships did not reach statistical significance (see Appendix C).

Although these data cannot be used to establish a causal relationship between overall procedure and interface usability and plant safety because they are not experimentally derived, the results do suggest that the human factors characteristics of normal and abnormal operating procedures and plant operations are linked. The results of these analyses are consistent with the findings of the studies discussed in Section 4.1.1 of the role of procedural inadequacy in operator error, and point to the impact of human error on plant safety and reliability.

4.1.3 Summary of Current Interface Problems

In summary, it appears that problems caused by inadequate interfacing among procedures are widespread throughout the industry and can potentially affect both plant safety and plant availability. Poorly designed interfaces can cause delays and errors in the performance of experienced operators and can cause even greater difficulties for inexperienced operators. As workforce composition in the control room changes (a trend that many plant managers have noted as new, inexperienced operators take over for retiring operators), it is essential that the problems resulting from deficient procedure interfaces be addressed and overcome.

4.2 Management of Interface Problems

In this section we discuss four classes of techniques for managing procedure interface problems. These solutions to interface problems were identified in the literature survey and in discussions with peer review group members, vendor representatives, and the federal trainers interviewed for the present project. The four types of solutions to interface problems include improving operator training, improving the human factors characteristics of procedure interfaces, aiding transitions within and between procedures with flowcharts, and computerizing procedure indexes and interfaces.

4.2.1 Training and Procedure Transitions

In agreement with the findings cited above and in the available literature (Finnegan, Rettig, and Rau, 1979; Griffon-Fouco and Gomolinski, 1982), the federal trainers, vendor representatives, and peer review group members emphasized the importance of operator training in overcoming difficulties in using procedures. The vendor representatives and federal trainers indicated that inexperienced operators suffer most from interface problems, although even experienced operators have difficulty with the procedures that they perform infrequently. The following types of

Table 4.8. Relationship of Entry Conditions to Forced Outages (N=135)

Number of Forced Outages in 1984	Clarity of Entry Conditions		
	Poor	Minimally Acceptable	Good
0-1	3	6	1
2-5	15	38	11
6-9	4	15	13
10-13	6	7	3
14-17	4	6	3
Total	32	72	31

Table 4.9. Relationship of Exit Conditions to Forced Outages (N=135)

Number of Forced Outages in 1984	Clarity of Exit Conditions		
	Poor	Minimally Acceptable	Good
0-1	3	7	0
2-5	34	24	6
6-9	14	12	6
10-13	10	6	0
14-17	2	8	3
Total	63	57	15

Table 4.10. Relationship of Placekeeping Aids to Forced Outages (N=135)

Number of Forced Outages in 1984	Usability of Placekeeping Aids		
	Poor	Minimally Acceptable	Good
0-1	4	2	4
2-5	36	19	9
6-9	19	5	8
10-13	7	8	1
14-17	5	6	2
Total	71	40	24

Table 4.11. Relationship of Procedure References to Forced Outages (N=135)

Number of Forced Outages in 1984	Completeness of References to Other Procedures		
	Poor	Minimally Acceptable	Good
0-1	4	5	1
2-5	21	33	10
6-9	14	16	2
10-13	8	8	0
14-17	6	6	1
Total	53	68	14

Table 4.12. Relationship of Section/Step References to Forced Outages (N=135)

Number of Forced Outages in 1984	References to Other Procedures Which Include Specific Section or Step by Vendor		
	Poor	Minimally Acceptable	Good
0-1	7	3	0
2-5	41	12	11
6-9	28	2	2
10-13	14	2	0
14-17	9	3	1
Total	99	22	14

Table 4.13. Relationship of Subsequent Actions to Forced Outages (N=135)

Number of Forced Outages in 1984	Clarity of Subsequent Actions		
	Poor	Minimally Acceptable	Good
0-1	2	6	2
2-5	35	18	10
6-9	14	14	4
10-13	7	7	2
14-17	2	4	7
Total	60	49	25

training to address the specific kinds of problems faced by inexperienced operators were proposed.

First, the federal trainers suggested that operators need to acquire the basic skill of using procedures. They reported observing that new operators who had previous military experience using procedures were better able to follow training procedures than those who had never before worked with procedures. The trainers proposed that knowledge of a plants' procedure classification system, procedure format and organization, special conventions, and so on would substantially assist new operators who have not previously worked with procedures. As noted in Section 3.3.2, operators do not currently receive such training from either vendor or plant training personnel.

The trainers also indicated that operators should be trained in the specific interfacing techniques used in their plant's procedures. For example, if the instruction "GO TO . . ." is used in a procedure interface tc mean "leave this procedure and go to another one," then operators should be informed during training of the meaning of the "GO TO . . ." convention. Further, the "GO TO . . ." convention should then be used consistently throughout the plant's operating procedures to signal a transition to another procedure.

Peer review group members also pointed out that training to manage procedure transitions should be repeated, as operators tend to forget what they have learned between training sessions at the simulator. Obviously, repetition is particularly necessary for those tasks that are performed infrequently at the plant (e.g., emergency response actions). Peer review group members reported that practice in control room mock-ups or with computer simulations (similar to video games) can keep skills fresh between training periods. Nuclear navy drills were cited as examples of how operators' skills can be maintained at high levels.

Providing operators with a greater knowledge of plant operations was an additional recommendation. Representatives from two of the vendors and all of the trainers indicated that operators must have detailed knowledge of plant operations to make judgments when they get into a blind alley with a procedure or if procedures do not cover an emerging situation. They recommended that training be directed toward giving operators a picture of the total plant so that they can effectively manage difficult procedure transitions and understand the implications of their actions. The interviewees emphasized that an in-depth understanding of plant processes is particularly important during transitions between abnormal and emergency procedures, for example, because of stress and time pressures, but indicated that current plant training programs do not sufficiently prepare operators to manage interfaces under these conditions.

Vendor training personnel proposed a slightly different role for training in the management of interfaces. As was reported by trainers at the plant level interviewed during the Operating Procedures project, the vendor trainers noted that they often observe the difficulties that operators experience with procedure interfaces during operator training for licensing and for requalification in the simulators. They reported that their feedback to procedure writers is often ignored, however, because of (1) the absence of official administrative channels for providing such information, (2) generally poor communications between training and operations departments at plants, and (3) a resistance to revising procedures because of overburdened procedure management and review systems in plants. The trainers recommended that they be included in plant procedure review processes and that systems be developed to ensure that their feedback on procedure usability leads to procedure revisions.

Peer review group members also endorsed the need for communication between trainers and procedure-writers to correct the deficiencies in procedure interfaces that become apparent during training. In addition to the disincentive to revising procedures of cumbersome plant procedures management systems, peer review group members also noted that pride of authorship often makes procedure-writers reluctant to accept feedback and to revise their procedures. Utility management commitment to high-quality procedures and policies that emphasize their importance to plant safety and availability were cited as the most effective means of ensuring that lines of communication between trainers and procedure-writers are established and that procedures are improved.

4.2.2 Usability Improvements to Procedure Interfaces

The license examiners, federal trainers, and representatives from three of the four vendor groups commented that how transitions are presented in procedure interfaces can substantially affect the difficulty or ease with which operators make transitions between procedures. The interviewees offered a number of suggestions for improving the human factors characteristics of procedures.

All vendor representatives agreed that simplifying transition requirements can reduce interface problems, as is also suggested in NUREG-0899. The vendors proposed that plant procedure writers attempt to reduce the number of procedure transitions, and representatives from two of the four vendors also suggested reducing the number of procedures to be performed concurrently. One strategy for reducing the number of interfaces in procedures that is recommended in NUREG-0899 is to include the relevant steps from referenced procedures in the text of the source procedure whenever possible. Several vendor representatives noted that this technique is particularly appropriate when alarm response procedures are referenced, as they are characteristically very short.

Representatives from two of the four vendors and federal training personnel agreed that transition activities, especially those that are time sensitive, require that operators be able to access procedures easily. Use of a clear, meaningful procedure classification system to index procedures was recommended, as noted in Section 3.3.2.

Another method for improving interfaces was suggested by the federal trainers, representatives of two of the four vendors, and was endorsed by the peer review group. It was proposed that if users must be referred to another procedure, referencing information included in the interface should include, at a minimum, the procedure title, its number, and the type of the procedure to which the user is being sent (e.g., normal, abnormal, emergency). Peer review group members pointed out the importance of providing this information to operators not only to assist them in locating the procedure, but also to inform or remind them of the plant conditions under which they are operating.

As noted above, however, representatives of only three of the four vendors indicated that such human factors techniques are useful for improving interfaces. In light of the procedure evaluation data presented in Section 4.1.2.1, it perhaps should not be surprising that the vendor representatives who downplayed the importance of human factors for managing transitions were from Westinghouse. Yet, of all vendors, Westinghouse emergency response technical guidelines have been identified as requiring operators to make the most transitions among procedures during an emergency situation and as creating the most interface difficulties for operators (Cauley and Schroeder, 1985). Further, personnel at the federal training center commented on the problems experienced by their students in attempting to follow emergency procedures derived from Westinghouse guidelines, especially when compared to the ease with which others are used (e.g., Babcock & Wilcox's ATOGS). Attention to the human factors characteristics of interfaces at the level of generic technical guidelines, then, may lead to substantially improved interfaces at plants.

4.2.3 Flowcharting Techniques

The use of flowcharts and related methods of condensing information and presenting it visually were recommended as an effective method for managing certain aspects of interface problems by all of the project participants. The experts and peer review group members differed, however, in their views of the limitations in applying flowcharting to interfaces, as did the available literature that discusses flowcharting techniques.

Three of the four groups of vendor representatives interviewed indicated that flowcharts are very useful. They suggested that flowcharts can best assist operators to manage interfaces when designed as visual aids for the activities and decisions described in written procedures. The vendor representatives also noted that flowcharts are useful as training aids for inexperienced operators, and could substitute for written procedures for highly experienced operators.

These vendor representatives also described several limitations to the use of flowcharts. One vendor representative pointed out that control room activities during large plant evolutions, such as start-up and some emergencies, are too complex to be captured in flowcharts. He noted that following several paths in a flowchart simultaneously is as difficult a task as following more than one procedure simultaneously. Further, representatives of two of the four vendors pointed out that complex, multiple path activities are difficult to present in a usable manner on one page or a single chart, and that the need to turn pages while following a flowchart disrupts the flow of information to the user.

Other limitations mentioned pertained to the costs associated with flowcharts. For example, peer review group members indicated that the cost of developing high-quality flowcharts and of keeping them up to date to reflect procedure changes are likely to be greater for flowcharts than for written procedures. Interviewees at the federal training center also indicated that the use of flowcharts could increase training costs, because it would be necessary to train operators to use flowcharts in addition to using written procedures. Such costs may be worth the investment, however, if the use of flowcharts can significantly reduce human error and so increase plant safety and availability.

Representatives from one vendor were quite favorable toward the use of flowcharts. This Owners' Group was considering abandoning the use of written procedures for their emergency technical guidelines and relying solely on flowcharts to communicate technical information. It was their belief that flowcharts can present a great deal of information simply, can better show relationships between actions, and can present key cautions better than written procedures.

Experimental studies of flowcharts as procedures also have resulted in divided evaluations of their usability. Some studies have found flowcharting to be a superior method of presenting information, while others have found that it makes little or no difference in task performance (Brooke and Duncan, 1980; Schneiderman, Mayer, McKay, and Heller, 1977; Ramsey, Atwood, and Van Doren, 1978). Flowcharts, as defined here and by industry practices, include what would typically be thought of as flowcharts (i.e., diagrams of task steps and decisions), in addition to action trees, decision trees, and decision tables.

The key advantage of flowcharting identified in the literature is that it conveys information more quickly and typically more accurately than prose (Kammann, 1975). This advantage may be particularly important for managing procedure transitions under abnormal and emergency conditions, because, as has been noted earlier, transitions within and between procedures are more difficult for operators to manage when under time pressure. Vendor representatives interviewed indicated that they have successfully used flowcharts in emergency conditions for highly experienced personnel and found that flowcharts significantly aided the senior operators' ability to understand and track the "big picture."

In general, it appears that flowcharting techniques can be used to reduce linguistic memory load, particularly for easier problems (Wright and Reid, 1973; Blaiwes, 1974; Kammann, 1975). Flowcharting helps the user to sort relevant from irrelevant information, it moves the major decision criteria forward in the information sequence when action steps require a decision, it decreases the demand on reading skill and concentration, and, finally, the sequencing of information in flowcharts parallels the sequence of actions required (Kammann, 1975).

Several disadvantages to flowcharting have been identified in the literature, however. In particular, flowcharts do not appear to facilitate the retrieval of information from memory when problems are complex or activities are interdependent (Wright and Reid, 1973).

In addition, the construction of flowcharts is a complex task in itself. It requires a clear understanding of the logic involved in the task being charted, and an understanding of the cues that humans rely on in information processing (Goodstein, 1981). It also requires an understanding of the interaction of these two factors, i.e., how presenting instructions for different types of tasks in different formats can affect the comprehensibility of the information. Unfortunately, writers of technical manuals, in general, and plant procedures personnel typically have little knowledge of this interaction (Booher, 1975; NUREG/CR-3817, Development, Use and Control of Maintenance Procedures in Nuclear Power Plants: Problems and Recommendations, 1985; NUREG/CR-3968, Study of Operating Procedures in Nuclear Power Plants: Practices and Problems.

Finally, because flowcharts reduce the amount of procedural information that is presented, they characteristically lack sufficient detail to support use by inexperienced operators. Because it is the inexperienced operator who encounters the most frequent and severe difficulty with procedure interfaces, the substitution of flowcharts for written procedures may be of limited value in the management of interfaces.

Flowcharting as an adjunct to written procedures, however, may be quite useful (Wickens, 1984). Given that some individuals better process spatial information than verbal, the use of flowcharts with written procedures may ensure that procedural information is available in a form that is easily used by all operators (Schneiderman, 1980; Yallow, 1980). Further, flowcharts can provide a context within which written procedures are more easily interpreted. In fact, the findings of several studies indicate that task performance is better when procedural information is presented both spatially and verbally than when it is presented in either form alone (Booher, 1975; Stone and Gluck, 1980).

4.2.4 Computerized Interfaces and Indexes

Over a decade ago it was anticipated that computer technology would significantly alter the design of control rooms and the information available to reactor operators (Seminara, Gonzalez, and Parsons, 1976). Although vendors were prepared to introduce these advances into control rooms in the '80s, many of the plants with such equipment were subsequently cancelled (Long, 1984). As a result, the current use of computers in the management of control room activities is extremely limited. This situation was verified by observations in the course of the site visits for a project conducted to evaluate plant maintenance procedures and the Operating Procedures project, as well as in the literature (Lay and Menke, 1983).

The usefulness of computer technology in control rooms to simplify problems in indexing procedures was emphasized by project participants. The experts interviewed and peer review group members were unanimous in recommending that procedure indexes be maintained on word processors to increase the ease with which they can be updated. Peer review group members also suggested that computer software be developed to assist operators in identifying the procedure they need to perform a particular task. A system that suggests procedure candidates to an operator based on keywords that the operator inputs was envisioned. Such a program would be similar to the bibliographic databases currently available in many libraries.

Project participants also recommended that lists of procedure interfaces be developed and maintained on computers. The need to update interfaces in normal and abnormal operating procedures that refer to outdated emergency procedures was emphasized by interviewees at two of the four vendors and by plant personnel interviewed for the Operating Procedures project. Computerized lists of interfaces that include (1) an entry for every plant procedure, (2) a list of the procedures that refer to it, and (3) a list of the other procedures to which it refers could be used to ensure that procedures are revised when changes to plant design or to other procedures that affect interfaces are made.

In light of the limited availability of computers in plants and limits in current computer technology, however, near-term applications are likely to be limited in scope. Representatives from one vendor very involved in the development of systems to utilize computers as operator decision aids indicated that there would be major usability problems with many such systems because they are not yet flexible enough to meet many user needs and skill levels.

Further, computers cannot be simply "plugged into" existing control rooms. They must be integrated by a systems engineering approach that considers operations requirements, reliability, and human factors considerations (Lay and Menke, 1983). Additionally, there may be extensive costs associated with efforts to integrate computerized operator aids with such existing plant systems as procedures, training simulators, and engineering and safety analysis codes (Long, 1984).

4.2.5 Summary of Interface Management Techniques

Four types of solutions to problems resulting from procedure interfaces were identified by the literature surveyed and by the individuals participating in the present project, including improved operator training, improved presentation of interfaces, flowcharting techniques, and computerized indexes and interfaces. It appears that the most powerful solutions to interface problems are offered by training and by improving the usability of plant procedures. Flowcharting is likely to be useful for senior, highly experienced operators to track control room activities and to manage interfaces, and helpful in combination with written procedures for inexperienced operators who encounter the most interface problems. Computerization of procedures indexes and the development of databases of interfaces among procedures may help resolve some interface problems, but computer technology is not yet sufficiently sophisticated or available across the industry to provide a major answer to interface problems.

4.3 Summary of Findings and Implications Regarding Procedure Interfaces

Ample evidence exists to suggest that problems with procedure interfaces are common in all types of operating procedures across the industry, and that the problems have significant consequences for the safety of plant operations and equipment availability. The present project, in addition to verifying that procedure interface problems are prevalent and serious, explored methods of addressing the problems. The remedies considered fall into the domains of training, human factors practices, flowcharting, and computer technology applications.

Because inexperienced personnel have the greatest difficulties with transitions in procedures, improved training was suggested as a technique for overcoming interface problems. Inexperienced operators are unfamiliar with using procedures to conduct their activities and need to be taught how to do so. Training in the use of procedure indexes also was recommended, given that inexperienced personnel have difficulty locating procedures, especially when faced with time pressures. More detailed training in plant operations was further suggested to assist inexperienced operators in overcoming procedural dead-ends.

Another technique for reducing problems associated with procedure interfaces is to improve the human factors characteristics of procedures. Existing data suggest that interfaces continue to present problems to operators in emergency procedures, despite recent efforts to upgrade emergency operating procedures. Evaluation of human factors practices in existing normal and abnormal operating procedures suggests that the design of interfaces in these procedures is deficient as well. Further, it appears that the manner in which interfaces are currently presented in procedures interferes with operator task performance, rather than supports it.

Flowcharting has received enthusiastic support from some vendors as a technique for decreasing interface problems. Flowcharts have been characterized as useful for training and for providing highly experienced personnel with the "big picture" when managing transitions or coordinating the activities of more than one operator. Flowcharts alone are of limited use, however, when activities are complex and interdependent or when used by inexperienced personnel who require detailed information. Flowcharts that accompany written procedures, and that present the same information visually but in less detail, appear to offer a better method of aiding operators to transition within and among the use of either flowcharts or written procedures alone.

The use of computers for interface management is limited by their lack of availability in the industry and by the lack of sophistication in current technology. One application of computers that would be relatively simple to implement, however, is the development and maintenance of computerized indexes of procedures and of the procedures that they reference to ensure that procedure indexes and interfaces are updated.

Conclusions and recommendations based on these findings are presented in Section 5.0.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the information gathered for this and prior projects regarding procedure classifications and interfaces, it appears that the task performance of operators, and hence the safe operation of plants, is potentially impaired by deficient procedure classification schemes and by the manner in which interfaces between procedures are presently managed across the industry. For example, some current procedure classification and indexing schemes hinder operators from easily identifying and locating the procedures they need to do their jobs, and vague, poorly-designed procedure interfaces cause operators to delay or to miss required transitions between procedures. These classification and interface problems not only increase the potential for safety-significant events where they occur, but they occur consistently throughout the industry.

The classification and interface problems identified in the course of this project, however, appear to be only one aspect of the larger problem of operating procedure usability in many plants across the U.S. and in all classes of operating procedures. As indicated by the findings of the Operating Procedures project, operating procedures for normal and abnormal plant conditions suffer many deficiencies that interfere with operator job performance, such as the presentation of information either in too little detail or in excessive, inappropriate detail for the experience levels of the users. In addition, the results of audits of plant emergency operating procedures (e.g., Clayton, 1985) and the findings of this project suggest that emergency operating procedures have yet to reach the level of usability and technical correctness that was expected to result from the NRC program for upgrading plant emergency operating procedures.

It appears, then, that further NRC and utility efforts and resources should be dedicated to addressing inadequacies in plant operating procedures. In the sections to follow, we discuss specific recommendations for improving procedure classification schemes and for addressing interface problems as well as methods for implementing the recommendations. Much of the information provided here was derived from discussion at the peer review meeting.

5.2 Recommendations

The findings of the present project suggest the following recommendations for actions to support operator task performance:

- The NRC, vendors, and utility representatives should form a working group to develop an integrated approach to upgrading operating procedures.

As noted above, the NRC program to improve emergency operating procedures does not appear to have engendered plant procedures that are highly usable. Therefore, it does not appear that simply applying the PGP approach to normal and abnormal operating procedures would result in substantial improvements to these procedures without other regulatory actions that would ensure industry compliance with NRC objectives.

Peer review group members suggested that, in addition to further NRC regulation, utility management must be willing to commit to upgrading procedures and to ensuring that the resources are available to plant personnel to implement high-quality procedures programs. Peer review group members also pointed out, however, that utility management must be more motivated than they are at present to improve operating procedures. Arguments regarding the savings resulting from increased plant availability and reduced maintenance costs or increased safety apparently are inadequate to elicit the necessary level of motivation. Peer review group members noted, though, that the threat of NRC regulation has increased utility motivation to address problems in the past and might have a similar effect in the present. In addition, peer review group members suggested that utility involvement in developing the NRC regulations may increase their willingness to comply with "the spirit" as well as "the letter" of any regulations that are implemented, as has been the case in other regulated industries (e.g., commercial airlines). Therefore, encouraging utilities to play significant role in designing NRC regulations regarding operating procedures by seeking their involvement in a working group to address upgrading operating procedures may lead to actual procedure improvements.

- All operating procedures that are significant to safety should be identified at each plant and NRC regulatory review and evaluation activities should be expanded to ensure the technical accuracy and usability of these procedures to prevent problems for operators when transitioning within and between procedures in different classes.

The current limitation in the scope of NRC activities to evaluate the usability of only emergency operating procedures does not provide assurance to the public that all procedures that are likely to be used in an emergency, or that have the potential to generate off-normal conditions, are of high quality. Because of wide variations between plants in equipment, however, it is not viable to standardize the scope of procedure classes to address this problem. Instead, peer review group members recommended that NRC and utility staff work together to identify operating procedures that are important to safety at each plant and that all of these procedures be required to be usable.

Finally, when discussing methods to improve safety-related operating procedures, procedure indexing schemes, and procedure interfaces, the NRC, vendor, and utility working group should consider the following specific recommendations:

- The human factors characteristics of procedure classification/ indexing schemes and of procedure interfaces for plant operating procedures should be improved and assistance offered to plant and NRC personnel in how to accomplish these ends.

- Operator training programs should be expanded to provide operators with information about how to use procedures, about specific plant interface conventions, and about how to use procedure indexes to locate procedures. In addition, input from plant and vendor training personnel for improving procedure interfaces should lead to timely procedure revisions.

- If flowcharts are used to manage interfaces, they should meet usability requirements, should be used primarily by experienced operators to track the "big picture," and should not be substituted for written procedures for inexperienced operators or for complex activities.

- Computerized systems for maintaining updated procedures indexes and lists of procedure interfaces should be implemented at plants.

The bases for these recommendations were extensively discussed in Sections 3.0 and 4.0, and information about how the recommendations could be implemented at plants are presented in Section 6.0. Peer review group members pointed out, however, that both plant personnel and NRC resident inspectors may be unsure about how to apply such written guidance to the tasks of (1) developing and evaluating procedure indexes and interfaces; (2) expanding operator training programs; (3) developing flowcharts; and (4) developing and implementing computerized systems. Therefore, peer review group members suggested that several alternative techniques be employed to disseminate this information, such as workshops for plant and NRC staff or the production of training videotapes that can be circulated throughout the industry. The peer review group members suggested that one barrier to the application of much of the knowledge available for upgrading operating procedures (e.g., human factors principles, flowchart design standards) may be the form in which the information currently is available (i.e., written guidance). Presentation of the information with different media may increase the likelihood that the information is used at plants to improve procedure classification schemes and procedure interfaces.

6.0 TECHNIQUES FOR IMPROVING PROCEDURE INTERFACES

In this section we present specific techniques for use by plant personnel to improve both procedure indexing schemes and procedure interfaces for all types of operating procedures and, therefore, to improve the safety and reliability of plant operations. The information used to develop the techniques is derived from expert input and from existing human factors literature. The techniques are presented in four sections pertaining to (1) procedure indexing schemes, (2) improving vendor and plant training programs, (3) constructing procedure interfaces, and (4) flowcharting techniques.

6.1 Procedure Indexing Schemes

The key purpose of a procedures indexing system is to organize the large number of procedures in existence in most plants so that procedure users can know what information is available to them and can locate it easily. Poorly designed indexing schemes contribute to operators' difficulties with procedure interfaces and can delay and degrade task performance. The following principles should be considered in constructing indexing systems that improve the accessibility of procedures to operators.

> Procedures should be classified and the procedure classification scheme selected also should be used for indexing procedures

In attempting to identify a procedure that contains necessary information from a procedures index, operators are performing a recognition task (Sternberg, 1966, 1969, 1975). That is, they are likely to have some idea of the type of information that they require or even of the specific procedure they are seeking, derived from their training or prior experience, and are faced with the task of identifying that piece of information or procedure from among many such data points. Obviously, the larger the set of elements that they must scan in an index, the longer the time required to find the desired procedure (Cavanaugh, 1972). If procedures are organized into classes (e.g., normal, abnormal, alarm response, emergency), however, and the classes are used as the basis of a plant's indexing system, operators are not required to scan every procedure in the index to find the one they need.

> Category labels should be meaningful and should correspond to operators' conceptions of plant operations

To assist operators in locating a desired procedure, the labels used for procedure classes should that communicate information about the procedures in each class (Bailey, 1982). For the class labels to be meaningful to operators, they should relate to the operators' understanding of plant operations, as developed through training and experience (Durding, Becker and Gould, 1977). If, for example, an operator has been trained to respond to annunciator alarms as abnormal events, then alarm response procedures should be classified and labeled as abnormal operating procedures.

Although procedure numbering schemes often are used to differentiate between classes of procedures (e.g., all procedures numbered in the 1300's are emergency procedures), procedure numbers are not a sufficient code for indicating procedure class because it is unlikely that operators conceptualize their activities and plant conditions in numerical terms. Short phrases (e.g., alarm response), single words (e.g., emergency), or acronyms (e.g., NOP for normal operating procedures) that are descriptive of how each procedure in a class is similar to the others in that class are preferred.

Large classes of procedures should be subdivided into smaller classes that also are meaningful

The requirement to scan a large number of procedures in one class to find a particular procedure delays operator task performance. Classes containing more than 30 procedures may be too large to allow quick location of a procedure and should be subdivided into smaller groups. For example, it may be necessary to subdivide the large class of all normal operating procedures at a plant into smaller sub-classes such as "Start-Up Procedures" and "Equipment Operating Procedures" for particular plant components or to develop sub-classes of procedures based on the operations of different plant systems. Further, subdividing large classes of procedures into smaller groups can substantially increase operators' abilities to remember where specific procedures are likely to be found in a procedure index (Bower, Clark, Leogold, and Winzenz, 1969).

Procedures should be ordered within classes

Techniques for ordering procedures within classes also will speed the process of locating a desired procedure. As suggested above, the organizing principle selected for ordering procedures within classes also should be consistent with the operators' cognitive models of plant operations, as developed through training. Thus, because operators are taught to conceptualize normal operations in terms of plant systems, the class of normal operating procedures could be ordered in terms of plant systems. Alternatively, the time sequence in which procedures in a particular class are commonly used also may be a helpful ordering technique. For example, in the class of normal operating procedures, a procedure describing operator actions in bringing the reactor from cold shutdown to 15% power should precede procedures describing operations to go to 45% power and then to full power operations.

Index manuals should depict the procedure classification scheme pictorially as well as verbally

Redundant presentation of information about how the procedures are classified will improve operator understanding of the indexing scheme (Durding, et al., 1977). Supplementing written procedure lists with visual aids that show the hierarchical structure of the indexing scheme will increase the ease with which operators use the indexing system. Figure 6.1 provides an example of a visual aid for a hypothetical plant operating procedures indexing system.

Indexing schemes should reflect both expert and novice operators' understanding of plant operations

Because the manner in which individuals organize information changes as their knowledge in a domain increases (Chase and Simon, 1973; Glaser, 1984), expert and novice operators are likely to differ in terms of how they conceptualize plant operations. Consequently, an indexing scheme that is useful for an experienced operator may not give enough information for an inexperienced operator. Therefore, both experienced and inexperienced operators should be involved in developing the indexing scheme at a new plant or in revising it at an operating plant. But, because novice operators encounter a greater number of interface problems when using procedure indexes than expert operators, if expert and novice operators cannot agree, then the system should be designed to meet the needs of the inexperienced operator. For example, if a combination of abbreviations and numbers is used to indicate procedure classes and inexperienced operators are concerned that they will not remember the meaning of the abbreviation/number codes under time pressure, then adding a legend that explains the codes to the first page of the index can aid the novice operators to use the index without cluttering it with information unnecessary for experienced operators.

Procedure indexes should be maintained on computers

To facilitate the updating of procedure indexes when new procedures are written or existing procedures are revised, procedure indexes should be maintained on computers and made available to operators in the control room. In addition to identifying the procedures in each class by title and number, computerized indexes can be used to provide operators with information about where printed copies of each procedure are located (e.g., the volume number in which the procedure can be found, if procedures are kept in notebooks in the control room or the specific

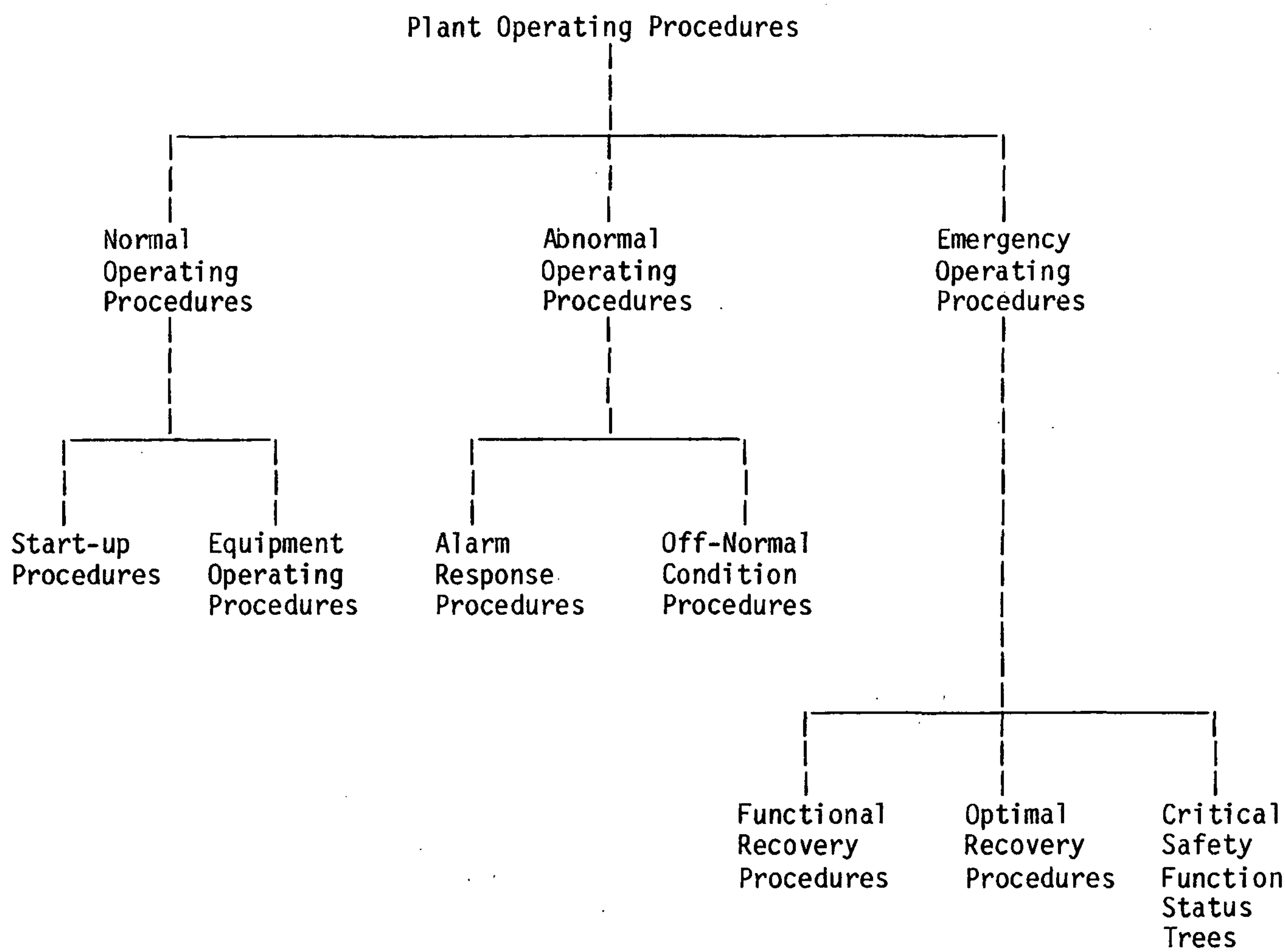

Figure 6.1. Pictorial Representation of a Hierarchical Procedure Indexing Scheme

drawer in a file cabinet), and the revision number and date that operators should look for on the procedure to be sure they have the most recent version. For document control purposes, computerized indexes also can be used (1) to indicate if the procedures cover safety-related activities; (2) to flag procedures for a periodic review of their currentness; and (3) to track procedures as they pass from person to person during revision or review.

Whether operators are given hard copies of the procedure index or have access to the index from a video-display terminal (VDT) or a microcomputer in the control room should depend on several factors. The disadvantage of hard-copy indexes is that some time is likely to elapse between when an index is revised and when the revised version is printed out and made available to operators. With a computerized index directly accessible to operators in the control room, delays for printing can be avoided. However, operators have to be trained to use the computer system and space in the control room must be allocated to the VDT or microcomputer if operators are to interact directly with the indexing system. Developing a user training program for operators, overcoming any resistance to a new technology, and finding space in the control room for the hardware are likely to be more difficult than is warranted by the benefits of having completely current indexes. As additional uses for computers in control rooms are found, such as for training or for aiding operator decisions, the use of computerized procedure indexes in the control room will become even more cost effective.

6.2 Training

Training is a particularly effective means of minimizing interface issues because the operators who experience the greatest difficulty with procedure interfaces are usually the less experienced operators. Good training provides operators with the internal, cognitive model of plant operations that is necessary for them to understand relationships among their plant's procedures, the plant procedure classification system, and the actions that must be taken if they reach a procedural dead-end (Bransford and Johnson, 1972; Rumelhart, 1980). To improve operators' abilities to manage procedure interfaces, operator training programs provided by vendors and at plants should take the following principles into consideration:

> Operators should be taught how their plant operating procedures are organized and how to use the plant procedures index to locate procedures

To ensure that inexperienced operators understand how the operating procedures at their plant are organized and that they are able to use the plant's procedure index to find procedures, operator training programs should address these issues. Trainers should use a pictorial description of how the procedures are organized, such as that shown in Figure 6.1, to introduce operators to the contents of the different classes of plant procedures and to how they are labeled in addition to introducing operators to the actual procedure index in use at the plant. Operators also should be given the opportunity to practice finding procedures in the control room or in a simulator using the procedure index. This type of training will assist operators in quickly locating the procedures they need.

Operators should be instructed in the use of their plant operating procedures with particular attention given to managing procedure interfaces

In addition to informing operators about how to access operating procedures, operators should be trained in how procedures are to be used. Classroom training should include information about:

- Any differences between classes in how the procedures are to be used (e.g., as a checklist after completing the task or verbatim compliance).

- What is contained in the different sections of the procedures.

- The definitions of the abbreviations and acronyms that are typically used.

- The definitions of the action verbs used (e.g., the difference, if any, between "verify" and "check").

- How to coordinate actions in more than one procedure at a time (e.g., whether they are to complete the procedures serially or to alternate steps).

- What particular conventions are used in the procedures to refer to other procedures (e.g., use of the "GO TO" convention).

- What the different formats of different classes of procedures are and how to use them (e.g., use of a dual column format)

Classroom training in the topics listed above should be supplemented with opportunities for operators to practice using procedures and transitioning between them in simulators or control room walk-throughs. Procedure practice should be based on scenarios that require (1) transitions between procedures in one class (e.g., between two emergency procedures); (2) transitions between procedures in different classes (e.g., from an abnormal into an emergency procedure); and (3) the use and coordination of multiple procedures (e.g., start-up procedures or emergency procedures). The combination of classroom training and hands-on experience can reduce the probability of operator errors when they are faced with the unfamiliar tasks of using procedures and transitioning between them.

Operators should be trained to use flowcharts

If flowcharts accompany plant procedures or replace written procedures for some tasks, operators also should be trained in their use. To avoid errors and confusion, operator flowchart training in the classroom should include (1) descriptions of the different types of flowcharts used in the plant, (2) information about the logic used in developing them, (3) definitions of the color codes and symbols used in the charts, and (4) the relationship of the flowchart to the written procedure that it accompanies and how they are to be used together. Simulator or control room walk-through training in the use of flowcharts also should be provided to operators.

Communication links between operator trainers and procedure-writers should be established

In addition to expanding the curricula of operator training programs conducted by plants and vendors, it should be recognized that trainers can serve a valuable role in identifying for procedure-writers problem areas with existing procedures. A communication link or administrative channel should be established to facilitate contacts between plant and vendor trainers and procedure-writers.

One way to improve trainer/procedure-writer communication is to assign a procedure-writer to observe simulator training exercises in which new or revised procedures are used, in addition to being present at procedure verification and validation exercises. Another method to improve communication is to require procedure-writers to respond to written suggestions from trainers within a specified time period, such as two weeks, although the requirement to document the suggestions and the responses may discourage plant personnel from making procedure revisions. Other, less formal techniques may better facilitate procedure revisions when interface problems are identified during training.

6.3 Constructing Usable Procedure Interfaces

Deficiencies in the human factors aspects of procedure interfaces for all types of operating procedures and the consequences of those deficiencies for operator task performance mandate that procedure interfaces be improved. The following human factors guidance should be considered in evaluating existing procedure interfaces and in constructing interfaces for new procedures.

The number of references to other procedures should be minimized

As suggested for emergency operating procedures in NUREG-0899 (Guidelines for the Preparation of Emergency Operating Procedures, 1982), interface problems can be decreased simply by reducing the number of interfaces with which an operator must contend. Rather than referring the operator to a second procedure, inclusion of the referenced procedure (especially alarm response procedures, as they are typically short) or the section referenced in the source procedure obviates the need for an interface. Application of this guidance to normal and abnormal operating procedures as well as to emergency operating procedures will reduce a substantial number of interface problems.

The number of transitions between procedure classes during complex plant evolutions should be reduced

Because procedures in different classes often are formatted differently and these differences in formats can cause operators to become confused, transitions between classes of procedures should be minimized during plant evolutions. The need to reduce class transitions is particularly important during stressful, time-limited events. To the extent possible, Owners' Groups and/or individual licensees may want to identify complex evolutions, such as plant start-up or shutdown, that require a substantial number of transitions and evaluate the possibility of incorporating all referenced procedures into the class of procedures that would typically govern the evolution.

The usability of all operating procedures should be improved

Improving the human factors characteristics of all operating procedures will ensure that references to other procedures do not send the operator from a usable, well-designed procedure to a procedure that is difficult to understand and to follow. Ensuring that all plant operating procedures are organized in accordance with the demands of the task, are legible, are written at an appropriate level of detail for the user, and so on, will substantially reduce interface problems. Extensive guidance for preparing usable procedures can be adapted from several sources, including NUREG-0899 (Guidelines for the Preparation of Emergency Operation Procedures, 1982), the Air Transport Association Specifications for Manufacturers' Technical Data (ATA 100, Rev. 21), and Military Specifications Technical Manual Writing Handbook (Military Specifications MIL-HDBK-63038-1).

Specificity in interfaces should be increased

The level of detail of the information presented to operators in procedure interfaces generally should be increased. Interfaces should (1) specify the title, number, and class of a referenced procedure; (2) specify page numbers and step numbers, if sections of long procedures are referenced (a practice to avoid); (3) specify if the operator is to return to the source procedure after completing the applicable portion of the referenced procedure; (4) specify if the operator is to go to another procedure after completing the steps in the source procedure; (5) specify the step number in the source procedure to which the operator is to return; or (6) indicate if the operator is to perform the two procedures concurrently. The interface also should indicate where in the control room the procedure can be located (e.g., which notebook, file drawer), if appropriate. Such clarity in procedure references will increase their understandability and ensure that even inexperienced operators know what actions they are to take. Examples of specific interfaces are presented below as action steps in a procedure in dual column format.

- To transfer control of a process from one procedure to another without returning to the first:

Action Step	Procedure Location
GO TO EOP-1, "Reactor Trip Recovery"	Emergency Operating Procedures, Volume 1

- To transfer control of a process from one procedure to a specific section of another without returning to the first:

Action Step	Procedure Location
GO TO EOP-1, "Reactor Trip Recovery," page 4, step 4.2	Emergency Operating Procedures, Volume 1

- To direct the performance of a second procedure concurrently with the first:

Action Step	Procedure Location
CONCURRENTLY PERFORM AOP-6, "Loss of Condenser Vacuum," while continuing in this procedure	Abnormal Operating Procedures, Volume II

- To incorporate a transition into a logic statement:

Action Step	Procedure Location
IF SI is required, THEN manually ACTIVATE both SI trains.	
IF NOT, THEN GO TO EOP-1, "Reactor Trip Recovery"	Emergency Operating Procedures, Volume I

> Interface conventions should be used uniquely and consistently throughout all plant procedures

To ensure that operators easily can identify transition points, the specific phrases and other techniques (e.g., the use of Notes) used to construct interfaces in procedures should not vary. If, for example, the phrase "GO TO" is used to transfer control of a process from one procedure to another, it should not be used to indicate parallel procedure use as well. The inclusion of a list of interface conventions and their definitions in procedure-writers' guides will assist procedure-writers to use the conventions uniquely and consistently.

> Placekeeping aids should be used for complex interfaces or the simultaneous use of two or more referenced procedures

The use of placekeeping aids, such as check-offs next to action steps and bookmarks (NUREG-0899; Cauley and Schroeder, 1985), can prevent operators from losing their places in procedures when they are temporarily referred to another procedure or must coordinate activities in more than one procedure.

Interfaces should be current

As procedure changes are made in response to equipment modifications or operating experience, the information contained in interfaces that refers to a revised procedure may become outdated. References to obsolete emergency procedures are a common problem among abnormal and alarm response procedures in many plants. A system for ensuring that interfaces are kept current should be developed and implemented in every plant.

One method for tracking procedure interfaces is maintaining a computerized database of them. Such a database should include (1) an entry for every plant procedure, (2) a list of the procedures that refer to it, and (3) a list of the other procedures to which it refers. The lists also should include the step numbers in which the references are made. Whenever procedures are revised, the interface database can be used to identify procedures that are affected by the change so that those procedures can be revised as well. Of course, new interfaces created by a revision or a newly written procedure must be added to the database.

Procedure interfaces should be validated with inexperienced operators

Because inexperienced operators find interfaces more difficult than do experienced operators, it is important to ensure that newly written or revised interfaces are usable by inexperienced operators. Conducting simulator exercises or control room walk-throughs of interfaces with inexperienced operators and then revising the procedures based on what is learned will ensure that the interfaces are as manageable as possible.

6.4 Flowcharting

Flowcharts can be effectively applied in managing interfaces in several ways. First, flowcharts used as training aids can simplify the presentation of plant procedures to inexperienced operators. As noted above, they also can be useful as a visual aid to describe procedure indexing schemes. The use of flowcharts to present procedural information is not always advisable as a technique to overcome procedure interface problems, however.

The best uses of flowcharts are: (1) to assist shift supervisors or shift technical advisors (STAs) in tracking "the big picture" during complex events, and (2) as an adjunct to written procedures (Schneiderman, 1980; Yallow, 1980). Because shift supervisors and STAs are highly knowledgeable about plant operations, they can "fill in" for themselves the detailed procedural information that is lacking in flowcharts and can benefit from the absence of detail as they assess the overall progress of activities during complicated evolutions. Similarly, flowcharts can be helpful to less experienced operators as an adjunct to written procedures to provide them with general information about the purposes and effects of the actions described in written procedures.

Flowcharts should not be used as substitutes for written procedures, however. They lack sufficient information allow inexperienced operators to rely on flowcharts alone for most activities, and even experienced operators are likely to require more detailed information for complex activities and for infrequently performed tasks than flowcharts can provide.

The usability of flowcharting for operators at all experience levels depends heavily on how well-designed the flowcharts are, however. Factors to consider in producing usable flowcharts to manage procedure interfaces include:

The size of the flowcharts and of the letters, numbers, and symbols used should be legible from the distance at which operators are expected to read them

Clearly, if a flowchart is to be presented as a wall chart, then the size of the flowchart as well as the size of the information it presents should be much larger than if the flowchart is to be used in a notebook on a countertop. At whatever distance the chart is to be presented, research has consistently shown that letters and numbers should subtend a visual angle of 15 to 20 minutes of arc to ensure readability (Cakir, Hart, and Stewart, 1980; Giddings, 1972; Smith, 1979). For a given distance, visual angle (minutes of arc) is calculated by the equation:

$$\text{Visual Angle} = \frac{3439(L)}{D}$$

where L = the size (in inches) of the object measured perpendicular to the line of sight and D = the distance (in inches) from the front of the eye to the object (Bailey, 1982).

Letters in sentences should be presented in mixed case and lines of text should be double-spaced

To ensure the readability and understandability of the information presented in a flowchart, a mixture of upper and lower case letters should be used (Engel and Granda, 1975; Kinney and Showman, 1967; Mehlman, 1981; Poulton and Brown, 1968). Further, the results of several studies have shown that double-spacing between lines of text also improves readability (Kolers, Duchnicky, and Ferguson, 1981; Ringel and Hammer, 1965; Tullis, 1983).

Any use of symbols should be consistent throughout all flowcharts and procedures used by operators at the plant and consistent with symbols that are familiar to operators

The use of symbols in flowcharts that are the same as the symbols used on logic charts for trips and alarms or in plant drawings, for example, improves the understandability of the charts to operators and increases the speed with which operators will learn to use the charts, as they will not be required to learn new symbols. Consistency in the use of symbols prevents confusion. Common practices in using symbols are described in Drefuss (1972). Common practices within the nuclear industry also have been described (EPRI, 1984; ANSI 3.5), and should be followed.

Unnecessary information should be eliminated from flowcharts and spacing between items should be sufficient to ensure readability

The major advantage that flowcharts offer over written procedures is that they assist the rapid and accurate comprehension of essential information. To ensure that flowcharts maintain this advantage, it is important that the amount of information presented is kept to the essential (Fecht, Rideout, Rankin, Barnes, Saari, Triggs, DeSteese, 1985). Explanatory information, notes, and some graphs and figures should not be included.

In addition, it is important that the information shown on flowcharts be presented distinctly (Fecht, et al., 1985). For example, flowpath lines connecting action and decision boxes should cross other lines as infrequently as possible and where lines must run parallel to one another, sufficient space should be left between them so that the operator's eye can easily follow the line of interest at the distance from which he is viewing the chart.

The presentation of a flowchart on more than one page should be avoided

Because the sequence of actions and information in procedures characteristically branches, the presentation of flowcharts on more than one page may require the operator to skip pages or to return to pages already passed. These transitions may confuse operators and prevent them from maintaining a sense of how far they have progressed in the task described by the flowchart. Given that the purpose of flowcharting is to better manage interfaces between and within procedures, the requirement that operators repeatedly move from page to page within the flowchart defeats the purpose of flowcharting and should be avoided.

> If it is necessary to use more than one page to present a flowchart, then:

- Each page should carry the title of the flowchart in a consistent location on the page;
- The page number in the series of flowchart pages should be noted in a consistent location on each page (e.g., Page X of Y).
- Each page should carry information about how to progress to the next page in the sequence of actions.
- A reduced, but legible copy of the entire flowchart should be presented before the flowchart pages are presented.
- Operators should be provided with placekeeping aids.

Although it is not at all desirable to present a flowchart on more than one page, the practices described above can ameliorate some of the problems presented by multi-page charts. The practices are taken from reviews of guidelines for grouping and organizing displays in other settings (Bailey, 1982; Cakir, et al., 1980; Smith and Aucella, 1983).

> Any coding schemes used (e.g., color, letter size) should be unique and used consistently throughout all flowcharts with which operators interact and operators should be provided with keys to the coding schemes on the flowchart, if possible

Research in a number of areas indicates that the usefulness of a code (e.g., color, letter size, type, underlining) as a means of communicating information decreases to the degree that it is used to communicate more than one set of meanings (Cakir, et al., 1980; Engel and Granda, 1975). Maintaining consistency in coding schemes assists operators in remembering what the code means and prevents confusion. For infrequently used codes, providing a code key on the flowchart can improve the understandability of the chart.

The number of codes used should be kept to a minimum as should the number of levels of the code

The purpose of using codes to communicate information is to emphasize important aspects of that information. The use of a large number of different codes (e.g., color, letter size, type, underlining) will decrease the emphasis that any one code can bring to a piece of information and may confuse operators who do not remember the meanings of the different codes. In addition, codes with too many levels (e.g., for color codes, the levels would be the specific colors used--such as red to indicate highest priority, yellow for next highest, and so on) also place an unnecessary burden on operator memory. Three to four levels of a code have been identified as optimal (Cakir, et al., 1980; Department of Defense, 1981; Smith and Aucella, 1983).

Flowcharts should be kept up to date

Just as it is necessary to revise written procedures when plant equipment is modified or other changes are made that affect procedures, it is important to keep flowcharts current to ensure that they provide accurate information to operators. Including flowcharts in plant administrative document control systems is one technique for maintaining their currentness. The use of computers to generate and revise flowcharts also can make their updating more convenient and less expensive.

Flowcharts should be verified and validated

To ensure that a flowchart is technically accurate and can be used by the individuals for whom it is designed, it should be verified and validated before it is disseminated for use. Because inexperienced operators have the most difficulties with procedure interfaces and require the most detail in procedures to be able to perform tasks, validation of flowcharts that will be used by novice operators should be performed by them.

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APPENDIX A

PRELIMINARY ASSESSMENT OF INTERFACE PROBLEMS

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March 1, 1985

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Subject: Preliminary Assessment of Interface Problems

Dear Mike:

The purpose of this draft letter report is to apprise you of the results of our preliminary assessment of interface problems among the procedures of operating nuclear power plants (NPPs) in the U.S. The preliminary assessment was undertaken as part of Project P-2: Program Plan for Assessing and Upgrading Operating Procedures for Nuclear Power Plants, Task 3: Define Current Industry Practices and Problems.

This letter report draws upon four sources of information: (1) the findings of several NRC-sponsored projects previously completed by Battelle; (2) initial Project P-2 scoping efforts in which procedure interface problems were identified; (3) information obtained in P-2 site visits to nine operating nuclear power plants (NPPs); and (4) comments of the P-2 Peer Review Group during the second review group meeting discussion of interfaces (Seattle, 4 December 1984) and their responses to the first draft of this letter report. Each of these information sources is discussed separately below, and several types of procedure interface problems are identified. Finally, this report offers several conclusions and recommendations for further action to assess the nature, scope, and safety significance of procedure interface problems.

As you know, the primary purpose of this letter report is to describe the types of interface problems found among NPP procedures to date. We are looking forward to beginning the new project on procedure interfaces so that we can build upon this preliminary assessment and increase our understanding of problems in this area.

Findings of Prior Projects

Problems resulting from interfaces between NPP procedures were first identified in three previous projects conducted by Battelle for the NRC. Project-related activities and findings showed that users of procedures experience problems when they have to go from one type of procedure (e.g., emergency operating procedures) to another (e.g., an abnormal procedure). They also experience difficulties when they have to move from one procedure to another even when these procedures are of the same type. The three prior projects are described below, but only those portions of the projects pertinent to interface problems are reported here.

The Review of Emergency Operating Procedures (EOPs) for Near-Term Operating Licensees project was undertaken to assess the adequacy of plant EOPs from both a technical and human factors point of view. EOPs from a number of plants were given desk-top reviews (to verify that the EOPs were consistent with owner's group and plant technical guidelines and were consistent with good human factors writing practices) and simulator reviews (to verify that the operators could actually perform the EOPs as written and that the EOPs would actually mitigate the emergency event). The desk-top reviews revealed that transitions between EOPs and other procedures governing abnormal and normal operations were neither clearly marked nor clearly described in the procedures. Also, other procedures often were referenced without specification of which steps were to be followed in the referent procedures.

During simulator exercises, it became apparent that the interface deficiencies identified in the desk-top reviews made the procedures difficult for operators to use under changing plant conditions. The operators often had difficulty deciding what procedures they should be following at a particular point in time, and the operators' responses to events were delayed as they sought out the other procedures or parts of other procedures referenced in the EOPs. In addition, operators experienced difficulty in finding the correct place to enter a referenced procedure and in deciding whether or not steps in a referenced procedure were to be followed concurrently with the EOPs.

The Safety System Status Verification project addressed the question of whether or not operating crews in NPPs had the information available to verify the status of plant safety systems in all phases of operations. Of particular interest in this project were interfaces among administrative, surveillance and operating procedures when 1) removing or disabling a piece of safety-related equipment for maintenance or to perform surveillance tests, 2) returning that equipment to service, and 3) verifying that these tasks were performed correctly. One of the significant findings of this project was that the procedures which supposedly "interfaced" with other procedures were often vague and incomplete, sometimes contradicted the related procedures, and, in some cases, were unnecessarily lengthy and complex. The consequences of these interface deficiencies were that operators and other users were at times unable to verify the availability of safety systems and so were in danger of violating the plants' technical specifications.

The Pressurized Thermal Shock (PTS) project was concerned with the consequences of introducing large quantities of relatively cold water into a hot reactor pressure vessel (RPV), the welds of which had been embrittled because of neutron bombardment. One of the claims made by the industry was that operators could handle the situation by cooling down the plant at a rate that would not endanger the integrity of the RPV. The operators could perform this very difficult task, it was claimed, because they would be properly trained and would use the proper procedures. The procedures involved were several abnormal and normal operating procedures that had to be used simultaneously.

Following extensive study of the PTS situation and evaluation of the industry's claims, project personnel concluded that operators would have serious difficulties in transitioning between the procedures involved, particularly during a highly stressful situation. It was suggested that the operators' difficulties would be essentially the same as those encountered during emergency conditions where the controlling procedures were EOPs.

The findings of these three projects suggest that procedure interfaces present problems to users of NPP procedures that can lead to degraded and delayed task performance, and to the possible violation of plant technical specifications. Further, these projects' findings indicate that interface problems exist among NPP normal, abnormal, and emergency operating procedures as well as between surveillance and administrative procedures.

Initial P-2 Scoping and Problem Identification

The results of our scoping efforts for project P-2 provided additional evidence that procedure interfaces present difficulties to operators when using normal and abnormal operating procedures. These findings were reported in detail in our Summary Letter Report of 31 January 1984, and are briefly summarized here.

Fourteen license examiners and staff at the NRC Reactor Training Center in Chattanooga, Tennessee stated in telephone interviews with P-2 project staff that they had noted procedure interface problems of varying degrees of seriousness in all of the NPP procedures with which they had worked. The interface problems they reported included the following.

Interfaces Between Types of Procedures. The license examiners stated that interfaces between abnormal operating procedures (AOPs) and the new

EOPs are particularly difficult for operators to manage because of the different orientations of the two types of procedures in most plants (i.e., event vs. symptom-based or function-based). Differences in the formats used and the level of detail with which the procedures are written, as well as a lack of specific exit and entry information in both types of procedures contribute to operator confusion in identifying the steps they are to follow when moving between procedures.

The training people at the Federal Training Center made a similar point regarding transitions from AOPs or EOPs to normal operating procedures (NOPs). They noted that the exit instructions for EOPs and AOPs often state, "once you regain ..., revert to normal operating instructions." However, an NOP often cannot appropriately be used to guide the operator's next actions because system functioning has been degraded. As a result, the operator is left to improvise.

References to Other Procedures. The license examiners also stated that all three types of operating procedures (i.e., EOPs, AOPs and NOPs) often require the operators to use more than one procedure concurrently or serially to accomplish a given task. In particular, NOPs frequently refer the operator to other NOPs, which govern tasks they are to perform before continuing on in the first procedure. The worst case mentioned by the examiners was an NOP that required the user to track activities governed by three procedures simultaneously. The operators experienced great difficulty in coordinating the activities described in the procedures.

In addition, the license examiners noted that interfaces between procedures are made even more difficult for operators because different procedures (even within the same class of procedures) often are written at varying levels of detail. They suggested that safety may be degraded as the operator searches for the relevant information in a lengthy and complex procedure when a task must be performed within a time limit.

As was indicated by the findings of the three prior procedure-related projects, the results of the interviews with the federal trainers and license examiners suggest that interfaces between NPP procedures cause problems for procedure users. More detailed information about different types of interface problems was gathered in P-2 site visits to operating NPPs across the U.S.

Site Visits to Nuclear Power Plants

The purpose of the site visits was to gather information regarding current practices and problems with NOPs and AOPs across the commercial nuclear power industry. Table 1 shows that the sites visited varied widely in terms of years of operating experience, size, vendors and architect-engineers. At all sites, project staff interviewed plant managers

TABLE 1

SUMMARY OF SITES VISITED
N = 9

TYPE OF PLANT:	BWR	1
	PWR	8
NUMBER OF UNITS:	1	5
	2	3
	3	1
YEARS IN OPERATION:	2	2
	7-8	3
	10-11	3
	17	1
NSSS VENDOR:	WESTINGHOUSE	4
	GENERAL ELECTRIC	1
	BABCOCK & WILCOX	3
	COMBUSTION ENGINEERING	1
ARCHITECT-ENGINEER:	BECHTEL	3
	FLUOR	1
	STONE & WEBSTER	1
	UNITED ENGINEERS & CONSTRUCTORS	1
	BURNS & ROE	1
	GILBERT	1
	UTILITY	1

or other supervisory personnel, individuals responsible for the development of procedures, operator training personnel (at most sites), and operators on duty in the control room.

An interview protocol was developed to guide interviews with these individuals. The protocol included the following questions concerning procedure interfaces:

1. Following the completion of all the steps in a procedure, is the user referred to another procedure that governs his or her subsequent actions?

   If yes, does the reference typically direct the user to a procedure by title, section, page and/or step number?

   If no, how does the operator know what further actions are required?

2. When a procedure refers the user to a second procedure, does the second procedure reference the first as an entry condition for use of the second?

3. If the user is referred to a second procedure while in the middle of the first, does the first procedure indicate at what step in the second procedure the user is to begin?

   Does the second procedure tell the user when (i.e., under what conditions) to return to the use of the first, and at what step to begin again following the first procedure?

4. Is a user ever referred to more than one other procedure or document to complete a task governed by any of the plant's operating procedures?

   If yes, what is your estimate of the percentage of AOPs that require more than one interface with another procedure or document? The percentage of NOPs?

5. To what extent do procedure interfaces cause problems for operators when performing a given task?

The interviewees differed in whether or not they perceived procedure interfaces as creating task performance problems for operators at their plants. In general, the users of procedures--operators and trainers--reported problems from procedure interfaces more frequently than procedure preparers or personnel at higher levels in the plants' management hierarchies. The supervisory personnel and procedure preparers indicated that procedure interfaces had led to some problems in the past, but that they believed that effective solutions to these problems had been devised. In contrast, the individuals who use the procedures most often, i.e., operators and trainers, reported that interface problems continue to exist. The most significant problems are use of multiple procedures and the transition between procedures. These are discussed below.

Use of Multiple Procedures to Perform a Task. At six of the nine plants visited, operators reported problems caused by the requirement to refer to and follow more than one procedure to perform a task. References to other procedures were described as most common in EOPs, where the operators are referred to AOPs, and in the NOPs governing plant start-up activities, where the operators are referred to other NOPs.

The most frequently cited problem resulted from references to other procedures while in the body of a first (source) procedure. The problem is that of knowing when to do what in the source procedure, including keeping your place in that procedure, while following the steps in one or more additional procedures. Operators at five of the plants reported that it is difficult to remember what steps in a source procedure have been completed when returning to that procedure from a referent procedure.

At two plants visited, operators reported that placekeeping is made even more difficult by multiple tiers of references to other procedures. At these plants, some of the NOPs and EOPs refer the users to a second procedure, that procedure then refers them to a third, and so on. The worst case described by the operators at one plant is an EOP that requires them to track and to coordinate activities in five referent procedures simultaneously.

At another plant, placekeeping difficulties had arisen when the activities governed by a referent procedure had not led to the expected outcomes. To obtain the desired plant conditions, the operator found it necessary to use a different procedure from the procedure specified by the source procedure. However, the different procedure that was used included some steps like those in the source procedure, so it was unclear to the operator where to re-enter the source procedure.

In addition to placekeeping difficulties, operators at three plants reported that references to other procedures from a source procedure delay task performance while the operators attempt to locate the referent procedures. The operators stated that locating one AOP referenced in a source procedure is not a significant problem for them, because there are relatively few of this type of procedure and they are bound together in notebooks kept within easy reach in the control rooms. However, locating an NOP among the hundreds of NOPs listed in the plants' master procedures indices was described as time-consuming and a disincentive to use the NOP by the operators. Locating more than one AOP or EOP to complete a particular task also was cited as leading to delays in task performance.

Operators who had been involved in simulator validations of one plant's new symptom-based EOPs were especially concerned with the reference issue. At this plant, both EOPs and AOPs have been rewritten in the same format so differences in the formats of the two types of procedures are not a problem to the operators. Rather, the problem identified by the operators was that nearly all (90%) of the new EOPs require the operators to refer to one and usually more EOPs and/or AOPs while following the source EOP.

In addition to placekeeping problems caused by these multiple references, the operators reported difficulty in finding the referent procedures quickly and in having enough tabletop or counter space in the control room to lay out all of the referent procedures. The operators stated that in some simulator exercises, neither they nor the supervisory personnel observing the exercises had been able to follow the procedures. To control the simulated emergency plant conditions, the operators found it necessary to abandon use of the procedures altogether and instead to rely on their experience and training. The operators at this plant believed that the new EOPs and AOPs are poorly designed and are the cause of their difficulties. The procedure preparers, plant manager and operations superintendent, however, attribute the operators' difficulties to lack of familiarity with the procedures and to the operators' resistance to change.

The training personnel with whom we spoke at four of the plants also reported that references to other procedures interfere with or delay operator task performance. They noted that managing references to other procedures is significantly more difficult for inexperienced operators than for experienced operators. They also indicated that both placekeeping and locating referent procedures cause problems for inexperienced operators in simulator exercises. At none of the plants visited, however, are operators trained to locate the procedures required for a given task. We also did not see effective master indexing systems and/or procedures that were specifically designed to aid the user in finding the right procedure(s) and the right steps within the procedure(s).

As previously noted, the license examiners we interviewed believed that references to other procedures from the main body of a source procedure present significant problems to operators in task performance. The operators and trainers interviewed in the site visits suggested further that the severity of the problems depends upon the number of references to other procedures from a source procedure and upon the operator's degree of experience in working with the procedures.

Transitions Between Procedures. None of the operators interviewed indicated that transitions between classes of procedures (i.e., moving from an EOP to an AOP) present them with substantial problems. The operators stated that they know which class of procedures to enter for the various plant conditions and that exit or entry conditions included in procedures neither interfere with nor aid their abilities to transition between procedures.

In contrast, the training personnel interviewed at plants indicated that transitions between types of procedures create significant problems for inexperienced operators. The trainers suggested that lack of specific exit information in procedures and the novice operators' unfamiliarity with the content of many procedures make it difficult for them to select appropriate procedures for all plant conditions.

Further, the trainers reported that transitions between types of procedures, where the procedures are written at different levels of detail, confuse inexperienced operators. In particular, transitions to procedures written without extensive explanatory material were reported to lead to operator difficulties because inexperienced operators may not be able to find necessary information in a less detailed procedure or know at which point to begin following the procedure. The trainers also indicated that problems due to transitions between procedures are exacerbated for inexperienced operators when the operators are required to act under time pressure.

Solutions to Interface Problems. The techniques used to ameliorate problems from procedure interfaces varied at the NPPs visited. At all of the plants, however, individuals responsible for writing NOPs reported that they attempt to limit the number of references to other procedures from source procedures when developing new procedures or revising existing ones. Personnel at one plant indicated that they had reduced the percentage of their NOPs that refer the user to another procedure to no more than 10 percent.

Operations supervisors and procedure writers at two plants stated that they rely upon training and operator experience to deal with procedure deficiencies, including interface problems. At one of these plants, the plant manager reported that many of the plants' separate, shorter procedures are being incorporated into longer procedures to reduce the overall number of procedure interfaces. Although the supervisory personnel at these two plants were satisfied with their solutions to interface problems, operators and trainers still reported that the lack of clear exit and entry instructions in the procedures make them difficult for inexperienced operators to use. Further, locating procedures and the use of procedures are not emphasized in these plants' training programs, so it did not appear to the interviewers that training is provided to inexperienced operators that would help them in using multiple procedures.

At one plant, all personnel interviewed reported that references to other procedures from source procedures, as well as transitions between types of procedures, had created significant problems for operators. To minimize interface problems, the operations superintendent and procedure writers developed flow charts to assist the operators in tracking activities governed by complex procedures or by procedures that reference other procedures. Clear exit instructions that include direction to the next applicable procedure also were added to each of the plant's NOPs to improve transitions between procedures. Personnel at this plant generally were satisfied with the results of these modifications, although the operations superintendent reported that operators occasionally come to a "dead-end" when transitioning between procedures because not all possible plant conditions have been identified and addressed in the procedures.

At another plant, interface difficulties have been addressed in three ways. First, when procedure writers find it necessary to refer the user to another procedure from the main body of a source procedure, the reference in the source procedure is specific (i.e., by title and procedure number), clearly marked, and the user is referred to a particular section or to certain steps in the referent procedure, rather than to an entire procedure. Second, the prerequisite section of every NOP itemizes the action steps that must be completed before beginning the referent procedure. This section also provides a description of the plant conditions necessary for the procedure to be used. Third, the exit instructions for each procedure specifically reference the procedures to be followed next. Both experienced and inexperienced operators reported that they do not find procedure interfaces difficult to manage at this plant.

Summary. The results of the site visits indicated that references to other procedures and transitions between types of procedures can interfere with operators' task performance, particularly if the operators are unfamiliar with the procedures to be used or are inexperienced. Well-constructed entry and exit instructions for each procedure, reductions in the number of references to other procedures, flow charts to track activities, procedures written at a consistent level of detail, and assistance to operators in locating procedures are ways currently used to decrease problems arising from procedure interfaces in NPPs.

Peer Review Group Input

The findings of the prior Battelle projects, P-2 scoping activities and the NPP site visits described above were presented to the members of the P-2 Peer Review Group at the second Review Group meeting held on 4 December 1984. Review Group members, in general, agreed that procedure interface problems can impair the safety of NPP operations. Their specific comments on the site visit findings are presented next, as are their comments on an earlier draft of this letter report.

Review group members suggested that operators' difficulties in quickly locating necessary procedures represent a significant safety issue. While the group members agreed that training in locating procedures could be helpful to solve this problem, they indicated that training may not be the best solution. One group member perceived the location issue as a problem of procedure control, rather than a training problem, and suggested that improvements to the indexing systems used at plants could increase the accessibility of procedures. Another group member stated that training should not be ignored in addressing the location problem, because he believes that no matter how well an indexing system is designed, operators must be somewhat familiar with it to use it effectively, especially under time pressure. A third group member reported that the ease with which operators locate alarm response procedures at his plant has been increased by marking annunciators with the numbers of the relevant procedures.

Review group members also agreed that references to other procedures from the main body of a source procedure could cause difficulties for operators. Group members pointed out, however, that references to other procedures from plant start-up procedures may not impact safe operations because plant conditions at start-up are neither unstable nor potentially dangerous. There was no disagreement within the group on this point. In an abnormal or emergency situation where prompt action is necessary, however, review group members indicated that the number of references to other procedures should be minimized. When prompt action is required, the action steps should be included in the basic procedure.

One peer review group member discussed an interface problem not identified during the site visits. This individual stated that procedure writers at his plant sometimes lose track of some of the other procedures affected by changes to one particular procedure. As a result, references in a source procedure might refer the user to a procedure that is no longer available or to a section of a procedure by an incorrect number. He noted that currently there is no system at his plant, or at any others of which he is aware, to record the relationships among the plants' procedures. In commenting on the previous draft of this letter report, one group member again pointed out this possible consequence of detailed references to other procedures. He noted:

> There is an interesting "Catch 22" in the interface issue. According to your site visits, transitions between procedures may be best handled by specific references to particular sections or certain steps of the referent procedures. This high level of detail in procedure references is exactly what makes a system of procedures difficult to maintain. A change to one procedure may affect many others. Without careful attention to the interface, erroneous references will occur.

Review group members did not support the position of some operations managers that operator experience can be relied upon to ameliorate interface problems. They pointed out that the composition of the operations workforce at most NPPs is constantly changing. Therefore, procedure interfaces designed for experienced operators become less usable when experienced staff leave or when new employees are hired. For example, one group member reported that the retirement of several senior operators at his plant had created the necessity to re-write a number of procedures, because the new operators had difficulties with the procedure interfaces that the more experienced operators had not encountered. To circumvent this problem, procedures at another group member's plant are written on the assumption of no operator experience, and so careful attention is given to the interfaces among procedures.

In comments on an earlier draft of this letter report, one group member pointed out that there are a number of ways to address the problem of changing staff composition, in addition to writing procedures for the least experienced operator. Procedures written in dual-column format, with action steps located in one column and detailed explanatory information and additional guidance provided in the other, can ease interface problems for novice operators. Alternatively, procedure interfaces can be designed for a particular level of operator experience and then novice operators can be given the training necessary for them to use the procedures effectively. This review group member noted that the NPPs with which he is familiar address the issue of operator experience/interface design differently, and he stated that he is not sure that any one solution is superior to the others.

Review group members stated that they possessed minimal information about problems arising from transitions between types of procedures. However, one group member reported that procedure writers at his plant anticipated transition difficulties for operators between the new style EOPs and the plant's existing AOPs, so they have re-written the AOPs and changed the AOP format to make it consistent with their new dual-column, symptom-based EOP format. The two group members currently working at nuclear power plants volunteered to investigate the transition issue in greater depth when they returned to their plants and to convey the information they gathered to project staff.

These two group members reported that they presented the interface discussion topics included in the P-2 site visit protocol to senior operations personnel at their plants. The senior staff indicated that transitions between different types of procedures do not seem to present operators with any greater difficulties than references between procedures of the same type. Other interface problems reported by the senior staff at these plants did not differ from those identified in our site visits to other NPPs.

Finally, the Review Group members suggested that the procedure interface issues identified in the preliminary assessment are worthy of further study. It was the opinion of the group members who have personal experience in plant operations that task performance problems for operators caused by procedure interfaces have not been previously addressed in many NPPs. It was the consensus of the group that any future review groups formed to study and comment on interface issues should have some members who have experience with the actual development, evaluation and use of operating procedures in NPPs.

Conclusions and Recommendations

The purpose of this report is to summarize our preliminary assessment of the extent of the interface problems affecting the user of normal, abnormal and emergency operating procedures. Our assessment is based upon what we have learned during the course of several previous projects conducted by Battelle for the NRC as part of the Division of Human Factors Safety Technology Program, in addition to the P-2 project activities reported here. Clearly, we have gathered information that represents actual experience in the use of procedures at operating plants.

In reviewing the information we have obtained, it is apparent that procedure interface problems exist and that these problems are serious enough to warrant further investigation. Our activities to the present, however, have not identified the causal mechanisms that lead to the interface problems.

Our experience in those areas of human factors that deal with procedure-type issues, in addition to our knowledge of the procedures literature, does allow us to hypothesize about some of the causes of interface problems. The basic issue is one of information flow from the procedures to the procedure user and factors which appear to degrade that process. Some of these degrading factors seen at operating plants are:

1. The requirement to follow several procedures concurrently to complete a task.

2. Inconsistent levels of detail among procedures.

3. Construction of interfaces that are inappropriate for use by operators at different levels of experience.

4. Master indexing systems that do not aid the user in locating the desired procedure.

It is our recommendation that the primary thrust of the new project on interface issues be to understand as many as possible of the key causal

Project to Examine Interfaces Among
Nuclear Plant Operating Procedures

Project Questions
September 25, 1985

1.0 Frequency of Transitions (or Interfaces) among Operating Procedures

1.1 In general, how often do procedures require operators to transition from one procedure to another?

1.2 What types of procedures most often require transitions/interfaces?

1.3 In what circumstances are transitions among procedures most common?

2.0 Problems Associated with Transitions among Procedures

2.1 Do references from one to other procedures cause problems for operators? What type of problem(s)?

2.2 Does the need to follow more than one procedure at a time create problems? What type of problem(s)?

2.3 Are particular problems associated with any of the following:

- Transitions among different media (e.g., flowcharts, VDTs, narrative in hard copy)?
- Transitions among different types of procedures (normal, abnormal, emergency)?
- Transitions among different formats of procedures (within medium)?
- Transitions among procedures written at different levels of complexity?
- Logistics involved in accessing procedures?
- Logisitics involved in handling multiple procedures?

3.0 Causes/Solutions to Problems with Transitions among Procedures

3.1 What are the underlying causes of interface-related problems?

3.2 What steps could be taken to reduce or eliminate those problems?

4.0 Current Classification Schemes for Normal, Abnormal, Emergency, and Alarm Response Procedures

4.1 In what ways are procedure classification schemes consistent across plants?

4.2 In what ways do procedure classification schemes differ from plant to plant?

5.0 Appropriate (or Optimal) Classification Schemes for Operating Procedures

5.1 Could current classifications be improved by changes?

5.2 Are there benefits (or disadvantages) to standardizing the scope of operating procedures across plants?

5.3 In general, what changes, if any, should be made to procedure classification practices?

APPENDIX C

REANALYSIS OF PROCEDURE EVALUATION AND FORCED OUTAGE DATA: METHODOLOGY AND RESULTS

APPENDIX C

Reanalysis of Procedure Evaluation and Forced Outage Data: Methodology and Results

The purposes of this appendix are: (1) to describe the methods used to gather and evaluate the sample of normal and abnormal operating procedures that were reanalyzed for this project, and (2) to present the results of that reanalysis in greater detail than presented in Section 2.3.

Methods

As described in NUREG/CR-3968, Study of Operating Procedures in Nuclear Power Plants: Practices and Problems, the methods used to gather and evaluate normal and abnormal operating procedures involved five steps. The steps included: (1) developing rating forms to record reviewers' judgments and comments on the procedures; (2) identifying a sample of procedures for review; (3) contacting all sites with operating nuclear power plants and requesting copies of six of their procedures; (4) reviewing the procedures; and (5) analyzing the results of the review. Each of these is discussed in greater detail below.

A. Developing the Procedure Evaluation Rating Forms

Two rating forms were developed in order to guide and structure the review of operating procedures. The first form, the "Procedure Rating Form" contained a total of 34 items concerning the format, style, and content of the operating procedure being reviewed. Items in the form were adapted from several sources, including NUREG/CR-1977, Guidelines for Preparing Emergency Procedures for Nuclear Power Plants; NUREG/CR-0799, Draft Criteria for Preparation of Emergency Operating Procedures; and writer's guides provided by staff at plants visited as part of the Operating Procedures project. These items were selected and adapted for inclusion on the rating form to focus the review on the usability of the procedures.

In addition, a brief rating form, the "Plant Procedure Rating Form," was developed to record the total number and type of procedures reviewed for each site and the consistency of the format between different procedures from the same site.

The first draft of the rating forms was reviewed by the NRC technical monitor for the Operating Procedures project and pilot-tested by project team members who served as reviewers. On the basis of the reviews and pilot testing, several modifications were made to the forms. Copies of the final versions of the forms are found on pages C-5 to C-7 of this appendix. Items 11, 26 to 30, and 34 evaluated the interfaces in the procedures and so were of interest for this project.

B. Identifying a Sample of Procedures for Review

In identifying a sample of procedures for review, two criteria were considered very important. First, the procedures selected were intended to be typical of plant operating procedures in general. Second, the procedures were expected to be utilized, to the greatest extent possible, at both boiling and pressurized water reactors in order to minimize the difficulty of drawing comparisons across plants.

Working closely with the Operating Procedures project peer review group and the NRC technical monitor for that project, six procedures were identified as meeting the criteria. The procedures were intended to be representative of three different classes of operating procedures which were within the scope of that project: normal operating procedures, normal operating procedures governing calculations, and abnormal operating procedures. The procedures are as follows:

Normal operating procedures

- Plant start-up to 15% power
- Start-up of the condensate and feedwater system(s)

Normal operating calculation procedures

- Reactivity balance
- Reactor coolant leak rate

Abnormal operating procedures

- Loss of condenser vacuum
- Loss of component cooling

C. Collecting the Procedures

All NRC licensees with at least one commercially operating plant at the time the data were collected were asked to provide current copies of the six procedures listed above. Plant managers were sent a letter requesting their assistance, a description of the Operating Procedures project and planned review of procedures, and a postage-paid return envelope. In response to this one-time mailing to 56 sites (83 plants), a total of 154 procedures were returned by 31 sites (representing 46 plants).

D. Reviewing the Procedures

Five members of the Operating Procedures project team, including the two authors of this report, conducted the review and evaluation of the procedures. All reviewers had prior experience in drafting procedure preparation guidelines, reviewing procedures, and/or developing the evaluation checklist. The reviewers pilot-tested the rating forms individually on a small sample of procedures, and then discussed the ratings, the evaluation criteria, and the rating forms (1) to ensure a common basis of evaluation and (2) to revise the rating forms as needed. Throughout the evaluation process, individual reviewers collaborated on questionable items or procedures.

As procedures were received from plants, all identifiers (e.g., plant name, utility name, etc.) were removed from the procedures. This minimized the effects of possible evaluator bias and assured the anonymity of the plants participating in the review. Reviewers were assigned procedures to review on the basis of the reviewer's availability. Each reviewer reviewed between 9 and 49 procedures. Each rated all of the procedures provided by a particular plant in order to facilitate overall judgments about the consistency in format across different types of procedures from a given plant.

E. Analyzing the Results of the Review

For the Operating Procedures project, analyses of the results of the review were designed to permit a summary description of the results and to draw conclusions about the usability of normal and abnormal operating procedures. For the present project, the analyses were intended (1) to assess differences in the usability of the interfaces in procedures from plants of different vendors and (2) to assess whether or not the number of forced outages in 1984 experienced by plants participating in the project was independent of the usability of the interfaces in the plants' procedures.

The appropriate statistical test to address these two questions is the Chi-Square test of the independence of categorical variables (Runyon & Haber, 1971). However, because too few procedures were obtained from Combustion Engineering and Babcock & Wilcox plants for reliability in the first assessment, Chi-Square tests were not calculated to assess differences in the procedures from plants belonging to different Owners' Groups.

For the Forced Outage X Interface Characteristic (e.g., placekeeping aids, entry and exit conditions, etc.) analyses, procedures fell into one of four quality categories and one of eighteen outage categories. The four quality categories defined by the evaluation form were Absent, Poor, Minimally Acceptable, and Good. The eighteen outage categories represented the range of the number of outages for 1984 (0 to a possible 17 outages during the year). For the Forced Outage X Overall Usability analysis, the procedures were divided into five quality categories, also ranging from Poor to Good. All analyses were conducted using a Corona personal computer with an Omega cartridge disk subsystem and Statistical Package for the Social Sciences software (Norusis, 1984).

Results

Table C-1 shows the values of Chi-Square, the degrees of freedom, and the significance levels for each analysis performed. The summary tables in Section 2.3 of the report show how the procedures were distributed within the overall usability, interface characteristic, and forced outage categories. For the interface characteristic tables, the categories of Absent and Poor were collapsed as were the forced outage categories for ease of presentation.

Table C.1. Results of Chi-Square Analyses of Procedure Evaluation and Forced Outage Data

Interface Characteristic	Chi-Square	Degrees of Freedom	Significance Level
Overall Usability	88.94	48	.0003
Placekeeping Aids	54.68	36	.0237
Entry Conditions	62.70	36	.0038
Exit Conditions	56.65	36	.0155
References Complete	39.39	36	.3207
References Specific	40.94	36	.2626
Subsequent Actions	42.47	36	.2122

OPERATING PROCEDURE RATING FORM

PROCEDURE NAME ________________ REVISION NO. ______ TOTAL NO. OF PAGES ______ PROCEDURE TYPE [ ] Normal [ ] Abnormal [ ] Emergency [ ] Don't Know

PLANT NUMBER ____________ NRC REGION ____________ PLANT TYPE [ ] BWR [ ] PWR [ ] Other RATER ID __________

Note: Blank = Not Applicable

	Present 1	Absent 0	Quality -	Quality 0	Quality +
FORMAT					
1. Table of Contents included	[ ]	[ ]	[ ]	[ ]	[ ]
2. Objectives clearly defined	[ ]	[ ]	[ ]	[ ]	[ ]
3. Page layout (format) consistent (easy to follow)	[ ]	[ ]	[ ]	[ ]	[ ]
4. Sign-off present	[ ]	[ ]			
5. Procedure name on every page	[ ]	[ ]			
6. Procedure number on every page	[ ]	[ ]			
7. Revision number appears on each page	[ ]	[ ]			
8. Date appears on each page	[ ]	[ ]			
9. "Page ____ of ____" on every page	[ ]	[ ]			
10. Most recent revisions are marked	[ ]	[ ]			
11. Placekeeping aids (e.g., checklist) appear useful			[ ]	[ ]	[ ]
12. Warnings and Cautions properly placed			[ ]	[ ]	[ ]
13. Warnings and Cautions clearly identified			[ ]	[ ]	[ ]
14. Figures, Tables, and Graphs appear usable			[ ]	[ ]	[ ]
STYLE OF EXPRESSION AND PRESENTATION					
15. Action instructions in procedure contain only one action (verb) per step			[ ]	[ ]	[ ]
16. Instructions are written in short, concise, identifiable steps (as opposed to multi-step paragraphs)			[ ]	[ ]	[ ]
17. Steps specifically identify the action to be taken			[ ]	[ ]	[ ]

PROCEDURE NAME ________________ PLANT NUMBER ______ RATER ID ______

STYLE OF EXPRESSION AND PRESENTATION (cont.)	Present 1	Absent 0	Quality -	0	+
18. Steps express limits quantitatively (e.g., "2 turns," "100 psig," etc.)					
19. Units consistent within procedure (steps, graphs, etc., consistent with text)					
20. Indicators, controls, and/or equipment identified completely					
21. Nomenclature within the procedures is consistent . . .					
22. Logic statements used properly (see CR 1977)					
23. Procedures are written at two levels, for experienced and inexperienced operations personnel					
CONTENT					
24. Single indicators of achieved objectives included . .					
25. Multiple indicators of achieved objectives included .					
26. Criteria for using this procedure are clearly specified (Entry Conditions)					
27. Criteria for going to another procedure are clearly specified (Exit Conditions).					
28. Instructions contain complete reference(s) to other procedures					
29. References to other procedures specify specific section or step of referenced procedure					
30. Subsequent actions clearly identified (e.g., specify follow-on procedure, identify person to be notified, etc.)					
31. Procedure clearly indicates when it is complete . . .					
32. Source documents, tech specs, etc., used as background for procedure are referenced					
33. Source documents, tech specs, etc., for action instructions are referenced in the procedure					

34. Rater's overall judgment of procedure: 1=very poor; 2=poor; 3=minimally acceptable; 4=good; 5=very good . __________

PLANT PROCEDURE RATING FORM

PLANT NUMBER ________ RATER ID ________ NUMBER OF PROCEDURES REVIEWED ________

Procedures Reviewed (circle one for each procedure):

Yes	No	PLANT START
Yes	No	COND & FEED
Yes	No	R BAL
Yes	No	RC LEAK
Yes	No	L/COND VAC
Yes	No	L/COMP COOL

Format Is Consistent (check one):

|__|1 a. across procedures

|__|2 b. within abnormal procedures only

|__|3 c. within normal procedures only

|__|4 d. within both (but not across normal and abnormal) procedures

|__|5 e. not at all/very little

APPENDIX D

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PEER REVIEW GROUP MEMBERS
February 26-27, 1986

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12 SUPPLEMENTARY NOTES

13 ABSTRACT (200 words or less)

This report presents activities and findings of a project designed to evaluate current practices and problems related to procedure classification schemes and procedure interfaces in commercial nuclear power plants. The phrase "procedure classification scheme" refers to how plant operating procedures are categorized and indexed (e.g., normal, abnormal, emergency operating procedures). The term "procedure interface" refers to how reactor operators are instructed to transition within and between procedures.

The project consisted of four key tasks, including (1) a survey of literature regarding problems associated with procedure classifications and interfaces within and between procedures, as well as techniques for overcoming them; (2) interviews with experts in the nuclear industry to discuss the appropriate scope of different classes of reanalysis of data gathered about nuclear power plant normal operating and off-normal operating procedures in a related project, "Program Plan for Assessing and Upgrading Operating Procedures for Nuclear Power Plants"; and (4) solicitation of the comments and expert opinions of a peer review group on the draft project report and on proposed techniques for resolving classification and interface issues. In addition to describing these activities and their results, recommendations for the NRC and utility actions to address procedure classification and interface problems are offered.

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