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HUMAN FACTORS REVIEW PLAN

Barbara Paramore
L. Rolf Peterson
Editors

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The logo for Lawrence Livermore National Laboratory, featuring a stylized 'U' symbol above the text 'Lawrence Livermore National Laboratory' which is arranged in a curved, V-shape.

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HUMAN FACTORS REVIEW PLAN

December 1985

Barbara Paramore
L. Rolf Peterson
Editors

Prepared for:
U.S. Department of Energy
Office of Nuclear Safety

by
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Livermore, California 94550

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EXECUTIVE SUMMARY

"Human Factors" is concerned with the incorporation of human user considerations into a system in order to maximize human reliability and reduce errors. This Review Plan is intended to assist in the assessment of human factors conditions in existing DOE facilities. In addition to specifying assessment methodologies, the Plan describes techniques for improving conditions which are found to not adequately support reliable human performance.

The Introduction provides an overview of human factors as a discipline, describes DOE initiatives to improve human factors at DOE nuclear facilities, and describes the objectives and scope of the Review Plan. Section 2.0, Managing a Review, provides guidance to management on structuring and tailoring a human factors review based on the specific characteristics of a particular facility.

The remaining five sections address the following topics:

- o Selection of Areas for Review — describes techniques for needs assessment to assist in selecting and prioritizing areas for review
- o Human Factors Engineering Review — is concerned with optimizing the interfaces between people and equipment and people and their work environment
- o Procedures Review — evaluates completeness and accuracy of procedures, as well as their usability and management
- o Organizational Interface Review — is concerned with communication and coordination between all levels of an organization
- o Training Review — evaluates training program criteria such as those involving: trainee selection, qualification of training staff, content and conduct of training, requalification training, and program management.

Each of the above sections discuss personnel requirements for the review, presents evaluation criteria and methods, and gives options for problem resolution.

The Appendix, at the end of the Review Plan, has been designed to facilitate access to review aids and references for each of the five review sections. Tables, Figures, and

Exhibits that are not essential to text comprehension, along with references, have been placed in the associated section of the Appendix, thereby streamlining the text and making reference materials readily available.

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1.0 INTRODUCTION

1.1 Overview of Human Factors Goals, Issues, and Applications

The explosive growth of sophisticated technological systems over the last decades has produced enormous benefits for every aspect of society. Increasing machine power has enabled man to engage in processes and operate on a scale that, until recently, were barely imaginable. Technological advancement has, however, brought its own set of problems. Human endeavors involve hazards of a far greater magnitude than in the past. In many settings it is being realized that the most remarkable technology will be of limited value when it is implemented without proper consideration of its suitability for people — its users, controllers, and maintainers. Accidents, injury, systems with high failure rates, and even abandoned systems attest to the problems. So does the growth of related legislation, regulation, and litigation.

Many problems can be traced to the interfaces between technology and the people who operate and maintain a system. People make errors: errors of omission, commission, precision, timing and sequencing, as they perform the tasks associated with system operations and maintenance. Few of these errors, however, are random. Humans are remarkably reliable in appropriate conditions. Most human error is associated with situational factors that can be removed either during system design or, later, in an operational system, by retrofits of one form or another. Little can be done to eliminate random human error. Much can be done to eliminate conditions that promote human error and to provide adequate margins of safety where neither human error nor equipment malfunctions can be tolerated.

The branch of technology that is concerned with the reduction of human error in system operations and maintenance is called "human factors." Human factors uses the principles, methods, and data of engineering and behavioral science to design systems that maximize human reliability. Human reliability is a function of:

- o The physical interface between people and equipment
- o The environments in which people work

- o The type and amount of training they receive
- o The accuracy and ease of use of the procedures they are given for guidance
- o The effectiveness of the organization in which they work.

A human-machine interface that impairs the flow of information between instruments and a person or that impedes control actions can induce error. A work environment that is noisy, poorly illuminated, or improperly ventilated can induce human error. Training that does not provide all necessary skills and knowledge and does not provide opportunity to learn and practice job tasks can induce error. Procedures that are incomplete, poorly formatted, and difficult to use can induce error. When more than one of these conditions exist, the combination has a compounding effect that further increases the probability of human error.

1.2 Initiatives to Improve Human Factors at Department of Energy Nuclear Facilities

The Department of Energy (DOE) is committed to the goal of maintaining at each DOE nuclear facility a level of safety assurance that is adequate to protect the public and facility personnel. This goal necessitates consideration of human factors. It does not, however, require that all facilities adhere to a single set of requirements for human factors applications. The diversity of DOE facilities missions, activities, sizes, and resources must be taken into account in deciding how the safety goal can best be accomplished at each facility. Each facility should evaluate its own human factors problems to determine where improvements may be needed and how they can best be made.

DOE's Office of Nuclear Safety has established a Human Factors Application Program to assist DOE nuclear facilities in efforts to enhance human factors. Four program elements have been defined:

1. Provide guidance for facility initiatives to assess human factors applications.

2. Provide guidance concerning human factors engineering criteria applicable in the design of human-machine systems for new facilities, and in the design of new systems or system modifications at existing facilities.
3. Promote coordination of activities related to human factors engineering, procedures, training, and other factors in personnel performance and safety, to achieve an integrated application of good human factors and facility design, operations, maintenance, and safety.
4. Promote exchange of human factors information throughout DOE headquarters, field offices, and contractor organizations.

Several steps have already been taken toward meeting these objectives:

- o Workshops to develop awareness of human factors technology have been conducted in regional locations. The workshops, attended by both contractor facility personnel and DOE field office personnel, provide an orientation to human factors concerns, principles, methods and criteria.
- o Guidance for training program development and evaluation has been issued.
- o An annotated bibliography of human factors literature has been developed as an information resource for DOE and contractor personnel.
- o Human factors engineering design guidelines for system and equipment maintainability have been prepared. The maintainability guidelines are applicable to the design of new systems and equipment and also may be used for review and enhancement of the maintainability of existing systems and equipment.

This Human Factors Review Plan provides guidance for a range of human factors application areas. It is offered to assist in the assessment of human factors conditions at existing facilities. The Review Plan describes criteria and methods that may be selectively used to improve human factors as determined to be appropriate at a particular facility. Other sources of criteria and methodological guidance are referenced. The objectives and scope of the Review Plan are discussed in more detail below.

1.3 Objectives and Scope of the Review Plan

Nuclear facilities, like other complex systems, have many interfaces with human beings. These interfaces consist of:

- o The human-machine interface
- o The human-environment interface
- o The human-procedures interface
- o The human-organizational interface
- o The human training interface.

The principal objective of this Review Plan is to identify practical methods that may be used to evaluate the adequacy of each of these interfaces in existing DOE facilities. The Plan also identifies techniques that can be employed to improve interfaces that have been found to be less than adequate supports for reliable human performance.

1.3.1 Applicability

Given the large number of DOE nuclear facilities already in operation compared with the number being designed, the methods presented here were designed mainly to be applicable to existing facilities. Approaches for use in facility design are not presented here.

An effort has been made to provide guidance that will be applicable across the different types of DOE facilities. Thus it can be expected that this Plan may not precisely fit a particular facility. Rather, its goal is to provide a framework within which a facility can plan a human factors improvement program to meet its unique needs.

1.3.2 Selection Among Review Options

Since it may not be economically feasible to review all interfaces in detail, this plan provides guidance for selecting the types of interfaces that should be reviewed. Moreover, within individual areas of review, alternative review methods are described and compared so that choices among them may be made.

Finally, this plan provides guidance in deciding which of the human factors problems identified during a review should be corrected, and in deciding the priority among those to be corrected.

1.4 Organization of the Review Plan

Section 2.0 of this Review Plan provides guidance to management on structuring a human factors review program for a facility. The focus is on ensuring that the scope of the review is tailored to the particular needs of the individual facility, that appropriate personnel resources are identified, and that the program is conducted in an integrated manner. The remainder of the Review Plan is organized on the basis of application areas.

First, techniques for needs assessment are described, to assist in the selection and prioritization of areas for review. This material is presented in Section 3.0.

Then methods of conducting a review in each area are described in the following sections:

- o 4.0 Human Factors Engineering Review
- o 5.0 Procedures Review
- o 6.0 Organizational Interface Review
- o 7.0 Training Review.

Reference lists and examples of review aids for each application area are provided in the Appendix.

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2.0 MANAGING A HUMAN FACTORS REVIEW

Potential benefits to be derived from effective implementation of a human factors review program at a DOE facility include improved safety for facility employees and the public, improved operational and maintenance efficiency and effectiveness, reductions in outages and process upsets due to human error, and reduced costs. The extent to which these benefits accrue as a result of a particular facility's implementation of a human factors review plan will depend on the initial structuring and staffing of the program and on the resources committed to it by management.

The emphasis in this section is on providing management with suggestions and guidance to help ensure the success of the program. The key point to be made is that human error of commission or omission only manifests itself in the activities of maintainers and operators; the key to reducing the incidence of human error is identifying the underlying systematic causes that "set up" the hands-on operator or maintainer to make the error.

2.1 Program Management Structure

The organizational structure for management of a human factors review program should be tailored to the organizational structure of the particular DOE facility. It should, however, be designed to ensure that the following are addressed:

- o Management representatives of operations, maintenance, engineering, training, and other relevant functional units should be involved as a steering committee. They should ensure that an appropriate review plan scope is defined and that the results of the review are directed at improving overall facility operations.
- o The Human Factors Review Program Director should have management experience appropriate for management of a program of this scope. He should have objectivity with respect to any individual functional group within the facility organizational structure, and should have an understanding of the overall facility operation.

- o Appropriate involvement of personnel from the various functional units within the facility organization should be available.
- o Provisions should be made to ensure that the appropriate technical disciplines are available for necessary analyses.
- o Representatives of operations, maintenance, engineering, training, and other relevant disciplines should be involved in the assessment process and in the selection of retrofits to the existing systems, procedures, training program, or other areas to ensure that the most cost-effective solutions are chosen.

2.2 Steering Committee Composition

Potential benefits from a properly implemented human factors review will accrue because people will be able to do their jobs more effectively with less error. The data collection methodologies described in this guidebook are designed to identify situations where human factors problems exist and to provide management with sufficient information to identify the appropriate "fix" to improve the situation. Human error can occur because of inadequacies in system design, training, procedures, or organizational communication. Since potential solutions to the identified human factors problems can also fall in each of these areas, the Steering Committee should include representatives of appropriate functional units as well as the line organizations being reviewed.

The Steering Committee should be given a charter defining its role and its responsibility for conduct of the human factors review. This charter should be approved by facility management at the appropriate level with responsibility for the systems and functions being reviewed, and with authority for implementing identified improvements.

The primary role of the Steering Committee should be to approve the scope of the review, approve the plan for the review, ensure that their respective organizational elements provide the necessary personnel and resources to support the review, and review any recommended changes and improvements recommended by the Assessment Team as a result of the review.

2.3 Human Factors Review Program Director

A Human Factors Review Program Director (Program Director) should be designated to provide overall coordination of the review and to provide continuity in management of the day to day activities. The Program Director's responsibilities should include coordination with the Steering Committee and with other personnel involved in the review. In addition, the Program Director should provide management direction to Review Team members and serve as Chairman of the Assessment Team.

2.4 Review Program Participants

The Review Team, under the direction of the Program Director, actually performs the review. The review team should therefore include representatives of the organizational elements being reviewed, and should be made up of people with the appropriate technical qualifications.

The Review Team should have a core group of specialists in the fields of human factors, operations, training, organizational communications, and instrument and control engineering. The core team may be supplemented by individuals in other specific technical disciplines as necessary depending on the nature of the organizational function.

Recommended qualifications for the human factors specialist include a degree, preferably at the graduate level, in human factors engineering or engineering psychology. However, qualified human factors specialists may have received their formal academic training in other disciplines ranging from behavioral sciences to engineering. Therefore, the pertinent formal training requirements for human factors specialists on the Review Team should include course work in at least some of the following areas: human factors engineering, ergonomics, human performance theory, sensory/perceptual processes, experimental design, quantitative methods/statistics, anthropometry, survey design, and industrial engineering/design.

Since there is no single academic route, certification, or licensing requirement for qualifying as a human factors specialist, professional experience of prospective human factors specialists should be taken into account. As a guideline, five or more years experience is preferred for at least one human factors specialist on the Review Team. Less experienced human factors personnel may effectively conduct review activities under the direction of the senior human factors specialist.

For operations and maintenance personnel, a minimum of two years experience is recommended with the equipment and systems used by the organizations being reviewed. Engineering personnel and other disciplines should have a bachelor's degree or equivalent in a course of study relevant to the specific discipline, plus three years experience with the systems and equipments being used.

2.5 Assessment Team Participants

The Assessment Team is the group which reviews the findings of the review team, determines the significance of the findings, and recommends improvements to the Steering Committee for implementation. The Program Director should serve as the Chairman of the Assessment Team. Other members should include the human factors specialist, the lead individual for each of the individual data collection tasks, and appropriate operations and other representatives from the organizational units being reviewed. Specific methodologies for assessment are described in the appropriate sections of this guidebook.

2.6 Management of the Program

The initial step in management of the review is to develop a Program Plan. The Program Plan should define the scope of the review and specify the authority of the review team to carry out its work. The Program Plan should also specify the participants and their roles,

3.0 SELECTION OF AREAS FOR REVIEW

Most facilities will not be able to undertake a complete human factors review at any given time, but will choose instead to select the most important issues. Naturally, high priority areas should be addressed first, with areas of less concern being reviewed later as resources permit. This section describes a means of conducting a needs assessment to help establish priorities.

3.1 Needs Assessment

A needs assessment questionnaire survey is the easiest and most thorough way to prioritize areas for review. The questionnaire may be self-administered or administered in an interview.

3.1.1 Needs Assessment Personnel

A manager should be assigned responsibility for coordinating the needs assessment. This coordinator should be knowledgeable about the facility's organizational structure and have the authority to schedule activities and obtain cooperation from the necessary personnel. To achieve objectivity in the analysis of the survey results, it is desirable for the coordinator to be from outside those departments or functional areas represented in the respondent sample.

Ideally, someone experienced in performing questionnaire surveys and in human factors analysis should prepare the questionnaire, assist in defining the respondent sample, and perform or direct the interviews and the analysis of responses. This person also should be from outside the functional areas represented in the respondent sample.

It is desirable for "outsiders" to perform the data analysis, in which individual responses are combined into a results profile. If there are only a few respondents in each department and if background information is collected, then the identities of respondents

are likely to be obvious to co-workers if they review the individual questionnaires, and objectivity may be compromised.

If interviews are conducted, one or two additional personnel should be trained to assist in the interviewing. Interviewers should be from outside the respondents' departments, to assure respondents of anonymity, if that is possible.

The steps in conducting a questionnaire survey for needs assessment are listed and discussed below:

- o Develop questionnaire
- o Select respondents
- o Distribute and collect questionnaires
- o Analyze and interpret questionnaire data
- o Establish assessment criteria
- o Perform the assessment.

3.1.2 Questionnaire Development

The key to good questionnaire development for the needs assessment is the definition of questions that probe for problems in each human factors application area. Topic areas for the questionnaire should include questions on the adequacy of:

- o Workspace Layout and Environment
- o Panel Design
- o Annunciator Warning Systems
- o Computer-Based Systems
- o Corrective Maintenance
- o Preventive Maintenance, Testing, and Calibration
- o Communication
- o Organizational Interfaces
- o Procedures
- o Training.

Two types of questionnaire items are recommended to assess needs in these areas: "critical incident" items and scalar items.

Critical Incident Items. "Critical incidents" are specific behavioral examples in which the safety or effectiveness of performance was in jeopardy or was actually impaired. To develop relevant critical incident questionnaire items both the human factors area of interest and the potential outcomes of problems must be considered. Questions should cue the respondents about the types of situations that should be described, for example, "Describe any incident in which your procedures were of insufficient detail or were unclear and resulted in ineffective or erroneous performance."

Scalar Items. In addition to critical incident items, scalar items (five-point scale) rating the respondents' perceived satisfaction with each human factors area should be included in the needs assessment questionnaire. Scalar items are easiest to score and provide a convenient way to compare the relative importance of the human factors areas.

Examples of Needs Assessment Questionnaire Items. Exhibits 3-1 and 3-2 in the Appendix at the end of this report show a set of questions that might be used in a needs assessment survey. Many of the questions were adapted from the interview protocol found in NUREG-0700.

Respondent Information. It is helpful in the analysis of questionnaire data to have certain information about the respondents. Section 4.4.1.2 lists the most useful items to be included (page 31).

Respondent's names should not be written on the questionnaires. Instead, each respondent should be assigned an identification code number. This should be recorded before questionnaire distribution. Letter prefixes to the identification numbers may be used to indicate department/functional area.

Questionnaire Pretest. It is desirable to pretest the questionnaire to ensure that question wording is unambiguous and that questions elicit the kinds of information that are needed. A pretest also allows a more accurate estimate of the time required to complete the questionnaire. It is recommended that questionnaire completion time should not exceed two hours whether the questionnaire is self-administered or administered in an interview.

Two or three people should be chosen as pretest respondents from among the departments/functional areas to be included in the survey. They should complete the

questionnaire or be interviewed and asked to comment on the questions. Their comments will provide a basis for improving the questionnaire.

3.1.3 Selection of Needs Assessment Questionnaire Respondents

The objective in respondent selection is to get a range of input across departments/functional areas and also to obtain perspectives from different levels within the organization. A cross section of the major organizational units involved in safety-related activities is recommended.

The number of respondents in the survey sample will depend on the number of staff within the applicable functional areas. As a rule of thumb, four to five people from each area should be sufficient. For departments/functional areas with a large staff, a 30% sample should be considered. For areas with a small staff, everyone may be included. Operators, technicians, and craftsmen, and line supervisors should be drawn from at least the following areas: Operations, Maintenance, Instrumentation and Control (I&C), Health and Safety, Quality Control/Quality Assurance, Training, and Technical Documentation and Procedures. Managers should also be included. Table 3-1 in the Appendix illustrates the type of vertical and horizontal representation that is needed.

3.1.4 Questionnaire Distribution and Response

Before questionnaires are distributed, cognizant managers should be briefed about the needs assessment process. They should be told what will be asked of them and their personnel, and the time frame in which the needs assessment will be conducted. It is also recommended that each manager inform his/her personnel that they may be asked to participate as respondents in a needs assessment survey and to explain its purpose.

The following materials will be needed in addition to the questionnaires:

- o List of respondents with name, functional area/department, location code/mail stop, and telephone number. A code number should be assigned to each respondent. This list should be kept confidential.
- o A memo to be distributed with the questionnaire which explains the objective of the needs assessment and encourages candid, thoughtful responses. Anonymity of responses should be guaranteed. This memo should be signed by an appropriate top-level manager.
- o Copy of questionnaire for each respondent with instructions for completing it, including due date, where to return it, and the name and telephone number of a point of contact to call in case of any

questions. An addressed return envelope should be provided with the questionnaire.

One to two weeks should be allowed for completion of questionnaires. After that time, the needs assessment coordinator should follow up by memo or telephone call, allowing an additional week if necessary for completion of the questionnaire.

3.1.5 Interviews

Preparation for interviews is similar to the preparation for a self-administered questionnaire survey. Managers and other personnel who may be involved should be briefed as described at the beginning of Section 3.1.3, above. A list of respondents as described in that section should be prepared. A memo to respondents should be prepared and given to the respondent at the beginning of each interview. This ensures that the needs assessment is explained to each respondent in the same way.

In addition, other steps will be necessary if the needs assessment survey is to be conducted by means of interviews:

- o If item explanations and probes are to be allowed, a written instruction that defines acceptable statements for these purposes should be prepared. ("Probes" are sometimes used to draw out more complete responses or to redirect a respondent whose answer is not well targeted on the question asked.) As an alternative, interviewers may be instructed to read the questionnaire items as written, and offer no further explanation or encouragement to respondents.
- o Train and/or instruct the interviewer(s), depending on their experience.
- o Arrange for private space in which to conduct interviews.
- o Contact respondents to schedule their interviews. The schedule should be planned to allow interviewers time after each interview to review their recording of responses and ensure that it is clear and complete.

3.1.6 Analysis and Interpretation of Questionnaire Data

After collection of completed questionnaires, they should be reviewed to ensure that they were properly completed. After the initial review, two types of analysis will be needed. One type will be directed at the qualitative critical incident questionnaire items. The other type will focus on the quantitative scalar items. Each type of analysis is described below.

Critical Incident Items. Responses to each critical incident question should be categorized and separate tallies made for each functional area (e.g., Operations, Maintenance). Because these questions are open-ended, there may be many multiple responses. Each type of response should be treated equally in the data reduction process.

Once response tallies for each item have been obtained, the number of responses per category should be converted into a percentage of total responses for each item. Percentages make it easier to interpret what the data suggest in terms of identifying specific problems areas for a given group of respondents (e.g., functional area, job level, experience level), or response patterns across all groups. It should be recognized, however that individual responses may be most useful, even if unique. A particular respondent may have more in-depth knowledge of a topic than other respondents.

Scalar Items. Frequency data for each item should be computed. Measures of central tendency (e.g., mean and mode), and variability (e.g., standard deviation), should be calculated for the total group and for subgroups of respondents (e.g., functional area or job level groups). The response distributions, measures of central tendency, and variability may then be compared for groups of respondents (e.g., by functional area, job level, experience level). Comparisons between the total set of responses and those made by particular groups may also be of interest.

Once the response categories and calculations have been made, the needs assessment team should be augmented by one or two individuals who are knowledgeable about the overall work and organization of the facility and about the specific functional areas that were included in the questionnaire survey. This expanded team should review and interpret the results to identify those human factors areas regarded as most important by the facility's personnel. A prioritized list of problem areas should be prepared based on the questionnaire response data.

3.1.7 Establishment of Assessment Criteria

After identification and prioritization of the human factors problem areas, the nature and scope of the formalized human factors review can be decided. To assist in this process, a set of assessment criteria can be used to determine the suitability of each potential human factors review area. Assessment criteria include: relevance to organizational

issues, payoff to facility, safety considerations, and ease of implementation. Each criterion is briefly described below.

- o Relevance to Organizational Issues. This criterion estimates the degree to which the candidate human factors review area addresses the improvement of real organizational issues. High relevance ratings are preferred.
- o Payoff to Facility. This criterion estimates the relative benefits of the candidate review areas in terms of improving cost efficiency or productivity. High potential payoffs are preferred.
- o Safety Considerations. This criterion estimates the extent to which safety, either to facility personnel or the public, plays a role in defining the issues related to the candidate human factors review area. High safety consideration ratings warrant most immediate attention.
- o Ease and Cost of Implementation. This criterion assesses the level of required involvement on the part of the facility's management and technical personnel necessary to ensure an objective in-depth evaluation of the candidate human factors area. Reviews requiring a large allocation of resources would receive a low ease-of-implementation rating. High ratings are preferred.

3.1.8 Assessment Procedure

The definitions provided above provide a basis for selecting among candidate review areas. A five-point scale (1=low; 5=high) can be used by each member of the needs assessment team to rate the areas on each criterion. Once individual ratings have been obtained, mean ratings for the group can be calculated to determine the best estimate of the desirability of each option. These ratings should be included in recommendations to the facility's management as part of the rationale for selecting specific areas for the human factors review over other options. Trade-offs will have to be made based on the relevance of the candidate review areas to the most important issues facing a facility, the potential gains to be made in each area, and the personnel and financial resources required to support each review.

3.2 Preparation of an Action Plan

3.2.1 Objective

Based on the assessment criteria ratings, the final selection of the human factor areas to be reviewed should be made, and a plan should be prepared to guide the performance of these reviews.

3.2.2 Personnel

It is desirable to establish a steering committee to prepare the action plan. This committee should include key managers and resource personnel as appropriate. The needs assessment team may be involved in this committee. The steering committee should serve throughout the review to help resolve any issues that may arise, periodically assess progress, and make decisions about implementing recommendations that result from the reviews.

3.2.3 Scope

The action plan should be the working-level document that defines the "what, where, when, who, why, and how" of the human factors reviews to be conducted. For each review area, a set of technical and personnel requirements should be generated from the guidance provided by Sections 4 through 7 of this Review Plan. This should include the definition of skill and knowledge requirements necessary to perform each type of review. In some cases the same individuals may be suitable for several review areas; in other review areas individuals who have specialized skills will be required.

4.0 HUMAN FACTORS ENGINEERING REVIEW

Human factors engineering is concerned with optimizing the interfaces between people and equipment and between people and their work environment. Equipment that is not compatible with human capabilities and limitations may contribute to human error. These errors may be due to poorly designed displays, controls, or equipment groupings and labelling. Equipment refers to tools as well as to control panels. Environmental conditions may also contribute to human error. Excessive noise, heat, poor illumination and glare are examples.

The purpose of a Human Factors Engineering (HFE) Review is to evaluate the human-equipment and human-environment interfaces at a facility, to identify features of these interfaces that may contribute to human error, and to develop cost-effective solutions for these human factors engineering problems. An HFE Review may address the human factors engineering design of an operational control room, an experiment station, or another facility area such as design for maintainability.

An HFE review has three phases: (1) planning; (2) performance of the review; and (3) assessment and resolution of findings. These phases are summarized below and discussed in detail in Sections 4.3-4.5.

The planning phase is important to ensure proper consideration of requirements, personnel acceptance and support, and efficient performance. Knowledge of facility operations and knowledge of HFE review methodology is needed for planning.

Performance of the review involves comparing the characteristics of work areas and equipment to human engineering design criteria. Some HFE criteria are applicable regardless of a specific task. Other HFE criteria refer to the suitability of the work area and equipment for specific tasks. These criteria are concerned not only with individual components but also with the relationships and layout of components to support the integrated flow of tasks. To apply criteria of this kind it is necessary to have knowledge of a system's operating characteristics and of the specific tasks required of personnel. Examples of both types of criteria are to be found in the Appendix (Exhibits 4-1 and 4-2).

In the course of an HFE Review, any equipment design characteristics or environmental conditions that are inconsistent with one or more HFE criteria is called a "Human Engineering Discrepancy" or HED. Some, but not all, HEDs have the potential to degrade human performance and to cause human error. Some HEDs may not have any significant effect on performance or contribute to error. Therefore, once identified, each HED should be assessed for its significance: that is, for its potential to degrade performance and cause error. When an HED has been assessed and found to have the potential to contribute to human error it may be called a Human Engineering Deficiency rather than discrepancy or HED. This is why the assessment and resolution of HEDs is an important part of an HFE Review.

Assessment involves identifying the possible effects of discrepancies on performance (e.g., delay, misinterpretation of information, ignorance of a critical condition, incorrect control action) and the possible system consequences. Then ways of correcting significant discrepancies may be defined, and the costs of correction may be compared to the costs of performance degradation. This provides a basis for deciding on the resolution of discrepancies — i.e., it provides a basis for selecting and prioritizing corrective actions.

4.1 Review Objectives

A thorough HFE review should accomplish the following objectives:

1. Evaluate environmental conditions that may affect human performance (e.g., HVAC, lighting, noise)
2. Evaluate workspace layout and arrangement of instrumentation, controls, and other equipment, tools, and materials
3. Evaluate the characteristics of instrumentation, controls, annunciators, communications equipment, and other equipment
4. Determine if adequate system status and advisory/warning information is provided
5. Determine if adequate control capabilities exist
6. Determine the availability of necessary feedback and analytic aids
7. Determine if adequate communication capabilities exist
8. Evaluate panel arrangements to verify appropriate integration of components

9. Evaluate design adequacy with respect to how well it facilitates the work to be done in a performance context.

The applicability of these objectives depends on the depth of review that is desired. The first three objectives address characteristics that can be evaluated without in-depth knowledge of task performance requirements. Objectives 4-9 require consideration of the use of the equipment in performing tasks. This distinction will be discussed in more detail in Section 4.4, Review Methods.

4.2 Review Criteria

The human factors engineering literature provides sources of criteria applicable to HFE reviews at DOE nuclear facilities. Some of the most widely used sources are listed below. Additional sources are referenced at the end of this chapter.

- o Bongarra, J.P., Jr. (1983). Human factors design guidelines for maintainability of Department of Energy (DOE) nuclear facilities (draft). Livermore, California: Lawrence Livermore National Laboratory, Nuclear Systems Safety Program.
- o Department of the Army. (1975). Human factors engineering design for Army materiel (MIL-HDBK-759). Washington, DC: Author.
- o Department of Defense. (1981). Human engineering design criteria for military systems, equipment, and facilities (MIL-STD 1472-C). Washington, DC: Author.
- o Department of Defense. (1966). Maintainability program requirements (MIL-STD-470). Washington, DC: Author.
- o Kinkade, R.G. & Anderson, J. (Eds.). (1984). Human factors guide for nuclear power plant control room development (EPRI-NP-3659). Palo Alto, CA: Electric Power Research Institute.
- o McCormick, E.J. & Sanders, M.S. (Eds.). (1982). Human factors engineering and design (5th edition). New York: McGraw-Hill.
- o Seminara, J.L., Gonzalez, W.R., & Parsons, S.O. (1981). Human factors review of nuclear power plant maintainability (EPRI-NP-1567). Palo Alto, CA: Electric Power Research Institute.
- o U.S. Nuclear Regulatory Commission. (1981). Guidelines for control room design reviews (NUREG-0700). Washington, DC: Author.

- o Van Cott, H.P. & Kinkade, R.G. (Eds.). (1972). Human engineering guide to equipment design. Washington, DC: U.S. Government Printing Office.
- o Woodson, W.E. (1981). Human factors design handbook. New York: McGraw-Hill.

Industry and facility-specific standards and conventions may also be a source of criteria. In addition, the expert judgment of HFE specialists may be drawn upon, especially in interpreting the applicability of criteria.

4.3 Planning for an HFE Review

The planning phase should include:

- o Selection of methods
- o Selection of personnel
- o Scheduling
- o Preparation of a facility-specific review plan
- o Preparation of review aids such as criterion checklists, data forms, and an HFE review questionnaire.
- o Briefing of participants and others affected by the review.

4.3.1 Selection of Methods

HFE review methods differ in the types and completeness of information they generate and in the resources they require (e.g., personnel mix time, and funding). These methods are described in Section 4.4. At the end of that section, trade-offs in the selection of methods are discussed.

4.3.2 Personnel Requirements for an HFE Review

Personnel requirements for an HFE review will vary, depending on the methods selected. In most reviews a combination of people will be needed with expertise in:

- o Human factors engineering and analysis
- o System/equipment design engineering

- o Facility operations, maintenance, or other functional areas.

Management responsibility for the review should be specified. It is recommended that a single individual be assigned to serve as the HFE review coordinator. The coordinator should be very familiar with the facility organizational structure and the work done by the functional areas or departments considered in the review. The coordinator should have management skills and the authority to secure personnel participation and maintain the schedule.

The coordinator should thoroughly understand the objectives and tasks of the HFE review and be willing to take on the responsibilities of the coordinator role. It is recommended that the coordinator be assisted by a human factors specialist. An assistant should also be provided to maintain review documentation and provide clerical support.

More detailed recommendations concerning personnel requirements for specific review tasks are made in the discussion of each method (Section 4.4).

4.3.3 Scheduling

A schedule of review tasks should be prepared. The schedule for other review activities (e.g., a procedures review) should also be considered. It may be possible for some tasks to contribute to more than one review.

The schedule should include all phases of the review, from planning through assessment and resolution of findings.

4.3.4 Preparation of a Facility-Specific Review Plan

It is usually desirable to prepare a written HFE review plan tailored to the review objectives of a particular facility. Such a plan will serve as guidance for all persons involved in a review.

4.3.5 Preparation of Review Aids

Review aids should be selected or prepared in advance, according to the methods chosen by a facility. Other review aids are discussed in more detail in the descriptions of methods in Section 4.4. An HED report form should be prepared for use in documenting

discrepancies found by any of the review methods used. (See Exhibits 4-3 and 4-4, in the Appendix, for examples of HED report formats.)

4.3.6 Personnel Briefings

It is important to acquaint participants, and others who may be affected by the review, with its objectives, schedule and the tasks to be performed. This is necessary to establish acceptance and support for the effort. It is recommended that a general briefing be provided during the planning phase. Other briefings should be given to the appropriate personnel at the beginning of each specific task. Management should be apprised of the progress of the review as it proceeds.

4.4 Review Methods

Three basic methods are typically used in performing HFE reviews:

- o Operating experience review
- o Observation checklist surveys
- o Systems analysis approach.

An operating experience review will provide information applicable to all of the objectives of an HFE Review. It may include an analysis of historical records (e.g., Unusual Occurrence Reports) and/or an HFE questionnaire or interview survey. Although an operating experience review will provide useful information, it will not provide all of the information needed for a thorough HFE Review. Its principal value is to identify design characteristics that have contributed to human error in the past or that are perceived as human engineering discrepancies, deficiencies, or problems by personnel.

An observation checklist survey may be used to meet the first three objectives listed in Section 4.1. Those objectives address directly observable or measurable characteristics of the workspace and equipment such as desk/console height, spacing requirements between rows or items of equipment, illumination levels, labeling, control coding, scale divisions on displays, etc. Characteristics of these kinds can be evaluated on the basis of generically

applicable human engineering criteria, without in-depth knowledge of the specific work performed.

The systems analysis approach can be used to meet Objectives 4-9 in Section 4.1. These objectives address the adequacy of workspace and equipment design to enable personnel to perform their required tasks effectively. The systems approach involves system function and task analysis to specify the human performance requirements and the equipment characteristics required to support them. Actual equipment characteristics are compared to these data to identify design discrepancies. The systems approach may identify discrepancies such as lack of displayed information about a parameter, poor location of a source of information so that it cannot be accessed when needed, and insufficient means of communication with others who must be involved in performing an activity.

These methods of HFE review are described in more detail in the following sections.

4.4.1 Operating Experience Review

An HFE review of operating experience may include a review of a facility's documentation, a personnel questionnaire/interview survey, or both.

4.4.1.1 Documentation Review

This review method may be used to identify equipment design characteristics that have had a negative effect on facility personnel performance in the past. If a documentation review is also performed for other areas of review (e.g., procedures review) it should not be done more than once. This requires that the data collected include items pertinent to all human factors applications areas to be addressed by the documentation review.

Selection of Records. Probable sources of useful information include:

- o Facility performance records
- o Unusual Occurrence Reports (UORs)
- o Unusual Incident Reports (UIRs)
- o Operating and maintenance logs
- o Triennial Management Review (per DOE Order 5480.1A, Ch. 6)
- o QA/QC data and audits.

It is recommended that reports going back one to five years be reviewed, depending on the volume of records per year. Different approaches to report sampling may be used. For example, all UORs and UIRs from a 3 to 5 year period might be reviewed, while operating and maintenance logs over a 1 or 2 year period might be sampled (e.g., 1 week per month, rotating the week drawn each month).

Personnel Requirements. Documentation reviewers must be able to interpret the reports and relate apparent problems to specific human engineering criteria. Therefore, expertise in facility functions and expertise in HFE evaluation will be needed. It may be necessary to involve more than one facility expert if the review addresses the human engineering design of more than one functional area. Technical specialists (e.g., I&C or system engineers, radiation protection technicians) may also be needed to answer particular questions.

Preparation of a Data Form. A data form should be prepared so that the data are collected in a consistent manner and can be easily collated to develop a profile of HFE problem areas. A two-part form (or two separate forms) will be needed: one for initial screening of the reports and one for detailed analysis of the reports identified as pertinent to the HFE review. An example of a documentation review data form is included in the Appendix (Exhibit 4-5).

Performance of the Documentation Review. The first step is to examine report files to select those to be analyzed. Reports of equipment failures resulting from material defects/stress, or from improper design, fabrication, or installation of equipment, may be ruled out immediately. Human errors may have contributed to such failures but they are assumed not to be operating facility errors.

Ideally, all documents involving reports of human error should be analyzed for their HFE implications and classified as to type of error and the consequence of error.

The screening documents should be based on the functional areas to be addressed in the HFE review. For example, a review may be limited to documents related to operations or to maintenance. However, care must be taken not to eliminate cases where error in a functional area not under review contributed to error in the target functional area.

The following types of information should be searched for in the analysis of facility documents:

- o The work area/unit involved
- o The results of the error (effect on the facility, equipment, personnel)
- o The type of error
- o The HFE discrepancies that appear to have contributed to the error
- o Immediate actions and follow-up corrective actions
- o The effectiveness of the immediate and corrective actions

Descriptions of discrepancies should (1) explain the equipment/environmental characteristics that are not in accordance with good HFE practice and (2) specify equipment or components involved by function, identification number, and location. An entire category of equipment or components may be involved or only an individual component. In the former case it is not necessary to identify each item in the class, but any exceptions from the discrepancy should be noted.

4.4.1.2 HFE Questionnaires/Interviews

HFE questionnaires/interviews can provide both quantitative and qualitative data based on personnel experience in interfacing with the design. Different questionnaires may be needed if more than one functional area is being addressed in the review (e.g., chemical processing operations and corrective maintenance).

Either a self-administered questionnaire or an interview approach may be used. If the former is chosen, it is desirable to plan on follow-up interviews with selected personnel to answer questions concerning their written responses and to obtain additional information about key areas of concern.

Personnel Requirements. Respondents should be selected from each functional area being reviewed (e.g., operations or subdivisions of operations, preventive and corrective maintenance). The most useful information will be provided by those who do the actual work and by their line supervisors.

The sample size will depend on the number of staff in the applicable functional areas. As a rule of thumb, four to five respondents from each area may be sufficient. For areas

with a large staff, a 30% sample should be considered. For areas with a very small staff, all may be included.

Personnel will also be needed to develop or select the HFE questionnaire, administer it, and analyze responses. At least one individual who is experienced in work of this kind will be needed. One or more others as needed may be trained and supervised by the specialist to assist in conducting interviews, analyzing data, and performing other tasks. Ideally, any personnel involved in interviewing or in questionnaire response analysis should be from outside the functional areas being addressed in the review to ensure objectivity and preserve respondent anonymity.

The HFE review coordinator will be needed to facilitate selection of respondents and scheduling.

Preparation of a Questionnaire. In designing questionnaires, a number of steps are necessary:

1. Decide on the topics to be covered in the questionnaire.
2. Develop a preliminary pool of questions for each topic.
3. Decide on the format(s) appropriate for the questions.
4. Write and edit the questionnaire items.
5. Group and sequence the items.
6. Prepare instructions for self-administration and instructions for the conduct of interviews.
7. Test the questionnaire on a small number of respondents (2 to 3), evaluate, and revise as necessary to clarify questions and ensure responses will be on target.

The way questions and instructions are stated can affect the quality of data obtained. References on questionnaire/interview design may be consulted for discussion of issues such as item wording and sequencing, question ambiguity and bias, instructions for responding to questions, and instructions for interviews.

To develop an item pool, HFE criterion topics should be identified that are applicable to the functional areas being addressed in the review. Examples of topics are listed below:

- o Work station dimensions (i.e., anthropometrics)

- o Workspace and equipment design/arrangement
 - accessibility
 - test and service points
 - tool interfaces
 - safety provisions
- o Controls
- o Displays (meters, recorders, etc.)
- o CRT displays
- o Warning and annunciator systems
- o Labels and location aids
- o Panel layout, control-display relationships
- o Communication systems/equipment
- o Protective clothing
- o Tools and instruments.

When relevant topics have been identified, specific criteria to be covered by questions should be selected from the criterion source documents identified in Section 4.2 and in the reference list at the end of this chapter. Criteria that require personnel input should be selected. Criteria that can be applied by direct observation, without familiarity with the work performed, may be omitted if an observation checklist survey is to be used as an additional method of HFE review.

It is not appropriate to include criteria in a questionnaire or interview that require measurements to be made or the detailed comparisons of equipment characteristics to specifications. However, the principles underlying such criteria may be addressed in a general way. For example, it would not be appropriate to ask if all displays are located within the recommended upper and lower limits for display height. However, personnel might be asked if all displays are located at a height that makes them easy to read.

An HFE questionnaire may be complete in its coverage of HFE criteria. This is particularly appropriate when it is the only method selected for use in the HFE review. However, it is recommended that a questionnaire require no more than 2 hours to complete, whether it is self-administered or administered in an interview. Completion time can be determined in the pretest. If observation checklist surveys will also be used, then the questionnaire may be less detailed and questions may be written in more general terms to address major criterion topic areas.

A YES/NO questionnaire response format is recommended. There are two approaches to writing this kind of item. One approach is to write all items so that a YES response or a NO response always indicates that the criterion is met (there is no HED related to the criterion). Exhibit 4-6 (in the Appendix) shows example items written in this way. This approach simplifies questionnaire analysis. A drawback is that it invites respondents not to read and answer questions carefully. A second approach is to vary item wording so that response choices are sometimes YES (no discrepancy) and sometimes NO (discrepancy). This approach increases analysis time but demands careful reading of each question.

Space in the questionnaire should be provided for including an explanation when a response indicates a discrepancy, and a "not applicable" response may also be allowed for.

Criterion references should be included after each item of a questionnaire. This facilitates the analysis and grouping of responses by the criteria to which they are related.

Other types of item formats may also be used. The following format was used in a survey of communications systems in nuclear power plants:

"Rate on a scale of 1-7 the effectiveness of the emergency alert or warning system(s) in your plant (1 = never works, 7 = system perfect)."

System: _____
1 2 3 4 5 6 7

One or more open-ended items should be included to allow respondents to identify any discrepancies not brought out by structured items. An open-ended item might be written for each criterion topic, or a single, general request for any additional remarks can be put at the end of the questionnaire.

It is often helpful in the analysis of questionnaire/interview data to have information about the background of respondents. The following types of information are pertinent:

- o Department/functional area
- o Typical duties
- o Years of experience performing that type of work at the facility
- o Related experience.

Examples of HFE questionnaires are provided in the review aids in the Appendix (Exhibits 4-7 and 4-8).

Questionnaire Distribution and Collection. Before questionnaires are distributed, managers, supervisors, and staff in the functional areas addressed by the review should be briefed about the objectives of the HFE questionnaire/interview. Personnel should be informed that they may be asked to participate. They should be assured of the anonymity of their responses and encouraged to answer thoughtfully and candidly. Examples of the types of questions asked should be reviewed.

The following materials will be needed in addition to the questionnaires:

- o A list of respondents with name, functional area/department, location code/mail stop, and telephone number. A code number should be assigned to each respondent. This list should be kept confidential.
- o A memo to be distributed with the questionnaire which explains the objective of the needs assessment and encourages candid, thoughtful response. Anonymity of responses should be guaranteed. This memo should be signed by an appropriate top-level manager.
- o A copy of the questionnaire for each respondent with instructions for completing it. Include due date, where to return it, and the name and telephone number of a point of contact to call in case of any questions. An addressed return envelope should be provided with the questionnaire.

One to two weeks should be allowed for completion of questionnaires. After that time, the HFE review coordinator should follow up by memo or telephone call, allowing an additional week if necessary for completion of the questionnaire.

Interviews. Administration of interviews is discussed in Section 3.6. The information given there is also applicable if an HFE questionnaire is to be administered in interviews. See, specifically, Section 3.1.4.

Analysis of Questionnaire Responses. The following steps are recommended:

1. Inspect each questionnaire to ensure completeness and clarity of responses. It may be necessary to follow up with a respondent or an interviewer concerning certain items.

2. Prepare a table showing the frequency and percentage distribution of responses to each item (see Exhibit 4-9, in the Appendix).
3. Review all responses that indicate a discrepancy for each item. Prepare an HED report for each item. Identify the item, state the number and percentage of respondents who indicated a discrepancy in relation to the item, and summarize the discrepancy information given by all respondents. Be sure to provide clear identification of equipment, components, or environmental characteristics involved, including their location. (See Exhibits 4-3 and 4-4, in the Appendix for examples of HED report formats.)

4.4.2 Observation Checklist Survey

An observation checklist survey is performed by systematically comparing workspace, equipment, and environmental characteristics to HFE criteria. Direct observations and measurements of specific characteristics will be required. In some cases it may be necessary to look at documentation such as equipment/system specifications or administrative procedures to determine whether criteria are met.

An observation checklist survey may be performed in the actual work setting, in a simulator, or from photomosaic mockups. If the survey is done in a simulator, it is necessary to identify any differences between the simulator and the actual work setting. If the survey is done from a mockup, it will be necessary to go to the work setting to evaluate environmental criteria and certain other criteria that cannot be evaluated with a mockup alone.

Personnel. Personnel requirements for conducting an observation checklist survey are suggested below:

- o An experienced human factors engineering specialist to prepare checklists, train other personnel in performing checklist surveys, direct mockup construction if applicable, and participate in and oversee the performance of the surveys
- o Two additional survey personnel. More may be desirable, depending on the time allotted to complete the surveys. Preferably, one will have expert knowledge of the equipment and the work performed, and the other will have HFE training and experience.

Preparation of Checklists. Since criteria for design for operability and design for maintainability are not the same, different checklists will be needed for each to be reviewed.

In addition, checklists should be divided according to HFE criterion topics. Examples of potential topics are:

- o Workspace (e.g., general layout, availability and accessibility of equipment, tools, and materials, feasibility of coordination between personnel as required, work station/panel anthropometrics)
- o Environmental factors (e.g., lighting adequacy, climate control, auditory environment)
- o Communications systems/equipment (e.g., access, susceptibility to interference, audibility at different locations, provision for communications when wearing protective clothing or breathing apparatus, operating condition of equipment)
- o Warning systems (e.g., audibility and discriminability of auditory alerts, readability/discriminability of visual alarms, prioritization of alarms, first-out information, personnel response subsystems)
- o Controls (e.g., position indication, activation feedback, protection, coding, design specifications for usability)
- o Displays (e.g., readability, printing, markings/scales, coding)
- o Computer-based systems (e.g., software security, command language usability, keyboard design, CRT display and printer formats)
- o Labels and location aids (e.g., label subordination, placement in relation to components, readability, needs for demarcation, use of color coding and mimics)
- o Panel layout (e.g., spacing and arrangement of components).

Criterion topics and criteria to be included under each topic should be selected on the basis of review of HFE guidelines in the literature. Then existing checklists may be modified as necessary or checklists may be prepared to cover the selected criteria.

Care should be taken to word checklist items clearly, so that they will be interpreted in the same way by all users. It is desirable for two or three personnel to review checklists before they are used so that ambiguous items can be detected and corrected.

Checklist items should be worded positively, so that items checked YES indicate that the criterion is met and items checked NO indicate that an HFE discrepancy exists. Provision should be made for indicating that a criterion is not applicable. A criterion reference should be given for each item. Space should also be provided for notes to identify the equipment/components and locations where discrepancies are found. Exhibit 4-10 (in the Appendix) is a typical format for an HFE observation checklist.

Major sources of HFE criteria are listed in Section 4.2. Additional sources are included in the list of references at the end of the chapter. Examples of observation checklists are included in the review aids in the Appendix (Exhibits 4-1 and 4-2).

Other Materials/Equipment Needed. Measurement equipment will be needed (e.g., tape measure, angle finder, push-pull gauge, torque gauge, caliper).

Specialized equipment and expertise are needed to measure and evaluate climate control, lighting adequacy, and sound. If problems in these areas are indicated by observations and personnel comments, it is recommended that the appropriate technical specialists be brought in to perform measurements.

Performance of Observation Checklist Surveys. To determine whether a work area is fully consistent with an HFE criterion, it is usually necessary to inspect a number of components or take a number of measurements. For example, a criterion for meter scales is that there should be no more than nine graduation marks between numerals. All meters should be checked to make sure the criterion is met.

In many cases, however, a criterion can be applied to only one of each different type of a component. For example, there may be three or four different types of meters, but meters of any given type may be identical.

Some observation checklist topics will require a panel-by-panel review (e.g., panel layout for control system operations, test, and calibration). Other topics address special equipment, such as operator consoles and CRT formats for graphic display systems. Still other topics should be reviewed from the perspective of the overall work area, such as workspace arrangement and communications.

Observation checklist survey team members should perform their assigned surveys, completing their checklists to indicate whether each criterion is met and, if not, to identify discrepancies. A discrepancy report should be written to describe and locate each discrepancy. This information should be given to the HFE review coordinator for consideration in the assessment and resolution of HFE review findings.

4.4.3 Systems Analysis Approach to HFE Review

The objective of the systems analysis approach to HFE review is (1) to establish the input and output requirements of personnel tasks, and (2) to evaluate the adequacy of the existing equipment design and configuration against those input and output requirements.

Personnel Requirements. To implement a systems analysis approach, a team is needed that has the following combination of capabilities:

- o Expertise in performing the work being analyzed
- o Expert knowledge of equipment design and operating characteristics
- o Human factors expertise — specifically, experience in performing function and task analyses for HFE applications.

A human factors specialist should develop the methodology to be used with input and concurrence from the review coordinator and other facility personnel, and should oversee its application.

Material Requirements. The following materials should be assembled or prepared in advance:

- o System/equipment documentation (e.g., system descriptions, panel front drawings, technical specifications, safety analyses, procedures)
- o A task-descriptive data collection form.

Summary of the Methodology. A systems analysis for HFE review is complex. While it is not possible to describe here the methodology in detail, four major steps in the systems analysis approach to HFE review include:

1. Review system functions.
2. Identify and analyze personnel tasks.
3. Verify that task input and output requirements are met by the design.
4. Validate the performance effectiveness of the integrated "man-machine system".

Definitions of key terms in these steps are given in Figure 4-1. The steps are described in the following paragraphs.

System Function Review. This effort begins with a review of the organizational context of which the system is a part. The output goals of the system are specified, including any criteria and constraints associated with them. The analysis then identifies the system functions necessary to accomplish these output goals. Functions may need to be subdivided depending on their complexity.

The next step is to review the engineering design to determine how equipment subsystems and major components are used to accomplish system functions. The analysis continues by describing the process of function implementation, including human and equipment roles, by reference to the system design. Specific criteria for function performance should be identified.

With the functions and function allocation established in general, the analysis proceeds to look at the performance sequences, or procedures, and the relationships of functions and human and equipment actions in time. The preliminary analysis of system functions provides a basis for selecting performance sequences or procedures to ensure that the full range of functional requirements is addressed, without necessarily analyzing all possible sequences or risking omission of a major aspect of performance. The analysis should address the requirements of procedures, but should not be derived from the procedures. That is, the analysis should look independently and objectively at the task input and output requirements represented by procedures, and should use other data sources in establishing or verifying those requirements.

Steps of performance sequence analysis are summarized below:

- o Develop a narrative description of the sequence, or a "scenario." This defines initiating and final conditions, the major events or phases, the functions invoked by the events or phases, and the major human and automatic actions. Exhibit 4-11 (in the Appendix) is an example of a scenario for control system operations (nuclear power).
- o Develop functional flow diagrams. These depict the interrelationships between functions and the sequencing of performance requirements. Such diagrams are developed at levels of increasing detail until a level suitable for identification of human behavioral functions and tasks is reached. Figure 4-2, in the Appendix, is an example diagram from a functional flow analysis of an aircraft system mission.
- o Develop action-decision diagrams. Diagrams of this kind may be prepared instead of or in addition to functional flows.

If used in conjunction with functional flows, action-decision diagrams may pick up where the former leave off. The functional flows would provide an overall integrated picture of operations over time. The action/decision diagrams would further break out the human action requirements and show the data which govern decisions and the points at which decisions must be made.

Figure 4-3, in the Appendix, illustrates the nature of a decision-action diagram.

At this point, a task list can be developed and task-descriptive information gathered to document the specifics of the input and output requirements for each task.

A Note About System Function Review for Maintenance, Test, and Calibration Activities and for Primarily Manual Operations. The preceding discussion of system function review is most applicable to complex control systems in which personnel interact with equipment and software to perform system functions. In other activities, the man-machine dynamics characteristic of control system operations are not present. The functions belong to personnel. In maintenance task analyses, for example, a system review is performed to identify and categorize the equipment to be maintained and the types of equipment and tools to be used. Behavioral functions are defined, which represent categories of human actions performed on the various types of equipment (e.g., checking, servicing, calibration, troubleshooting, etc.). Performance sequences and a task list may then be generated by integrating and further analyzing equipment types and behavioral functions.

Task Analysis. The first step recommended is to prepare a task list for each performance sequence from the results of the system function review. The task list indicates the scope and sequencing of the total array of human performance requirements in the sequence.

- o Sequence identification: an alphanumeric code and/or title.
- o System function identification: an alphanumeric code and/or title.
- o Behavioral function identification: an alphanumeric code and/or title.
- o Task sequence number, based on time of task initiation relative to initiation of other tasks. Task sequencing may not be absolute; an acceptable sequence should be established.
- o Task title: a summary statement of the human performance requirement.
- o Task purpose/objective: the immediate reason for performing the task, or the output expected from the task.

Each task may then be described in terms of a predetermined set of information items. The following is a list of items commonly included in task description for HFE applications:

- o Work-area location: where task is accomplished.
- o Task cue(s): What causes task to be initiated.
- o Task action description: detailed, sequential description of each task action element or step.
- o Display and control needs (for cue, task action input information, task action feedback information).
- o Needs for tools, equipment, materials, aids, protective gear, etc.
- o Frequency of performance: once, twice, etc., per shift, daily, weekly, monthly.
- o Performance time: estimated hours and minutes task will take/maximum permissible time.
- o Performance criteria/standards: criteria for successful task execution.
- o Hazards inherent in the task/environment.
- o Potential errors.
- o Error likelihood (usually a relative rating).
- o Potential consequences of error.
- o Error severity (usually a relative rating).
- o Task difficulty (usually a relative ranking).
- o Skills and knowledge: types of skills or knowledge pertinent to the selection and training of individuals for the job or tasks.
- o Physical characteristics: special physical requirements necessary for effective task performance (e.g., body size, strength, dexterity, coordination, physiological tolerance to stressors).

A variety of formats are used for recording task-descriptive data. Figures 4-8 and 4-9 (in the Appendix) are two examples.

Verification of Design Adequacy To Support Task Performance Requirements. The objective of verification is to ensure that personnel have ready access to all the information and controls and other tools, equipment, and materials they need to perform each task in accordance with the specified performance standards.

For instrumentation, this includes verification that all necessary parameters are displayed, in a suitable form (e.g., status indication, specific value or band, trend). It also includes verification of specific instrumentation characteristics, such as appropriate units, range and precision. Similarly, the suitability of control characteristics such as precision, range of control, and response time should be verified.

Verification may also address issues such as design safeguards against hazards in the use of tools and equipment, or design provisions to minimize the likelihood of error.

Verification may be partly performed by comparing design specifications to the task-descriptive data. It should also, however, include examination of equipment characteristics in the actual work location, with reference to the requirements identified in the task-descriptive data.

An HED report should be prepared for each case in which it appears that the design does not adequately meet task input and output requirements. This information should be submitted to the HFE review coordinator for consideration in the assessment and resolution of findings.

Validation of the Integrated "Man-Machine System" Design. The objective of validation is to ensure that the functions allocated to personnel can be performed effectively given the existing work area, equipment configuration, staffing, and procedures. The recommended approach to validation is to conduct performance exercises. Performance exercises allow design characteristics to be evaluated in the context of the performance of procedures. Experienced personnel are asked to perform procedures step by step. Normal staffing should be used to perform these exercises.

Exercises should be observed by a team consisting of an HFE specialist, an expert in the work being performed, and a systems/equipment technical expert. Preferably, the observers will have already participated in the system function review, task analysis, and verification.

Performance exercises may be conducted in the actual work location, in a simulator, or in mockup if available. A mockup used for this purpose should be a full-scale replica of the

panels and other equipment used. The work setting should be represented as realistically as possible.

Procedures should be selected for performance exercises to allow all major interfaces to be used and all key personnel performance requirements to be observed. All or parts of several different procedures may be selected to provide this coverage.

Scenarios are helpful to guide the performance exercises. Scenarios indicate the paths through procedures that personnel will take during performance exercises. This is essential in the case of multi-path or multi-contingency procedures. Scenarios developed in the system function review may be used (see Exhibit 4-11, in the Appendix, for an example) for this purpose.

If performance exercises will be conducted in a real-time simulator, it will be necessary to review the scenarios with a simulator operator to ensure that they are feasible and provide sufficient information to program the simulator.

A guideline or checklist for observers should be prepared. It should identify the base set of criteria to be applied in performance observation (although observations will not necessarily be limited to predefined criteria). Among the areas that may be addressed are equipment layout in relation to task action sequencing, feasibility of time-constrained actions, coordination of actions when more than one person is involved, communications, and effects on task performance of requirements to wear protective clothing and breathing apparatus. Performance observation checklists should be tailored to the type of work being observed.

The objectives and activities involved in performance exercises should be discussed with all participants before each exercise. The scenario and/or procedure should be reviewed with participants. Questions should be resolved and roles specified if more than one person is involved in performing a procedure. Observers should be assigned to observe individual personnel.

Personnel performing a procedure exercise should then conduct the procedure in real time including all necessary face-to-face and telecommunications. Observers should make notes about potential problem areas in accordance with the observer guidelines/checklist.

Performing personnel should repeat the procedure again, this time in a slow walk-through. They should point out and explain all of their actions. If a team is performing the procedure, this will require phasing of the actions of each participant. Observers should ask questions as they arise and make notes accordingly to their checklists. After its completion, participants should discuss the exercise to further define any problems. An HED report should be prepared to document each problem.

Performance exercises may be conducted for review of procedures as well as for review of design adequacy. If both areas are included in a facility review, it is desirable to conduct one set of exercises for both to save time.

4.4.4 Comparison of HFE Review Methods

The methods described in the preceding sections may be used together for a comprehensive review, or a more modest effort using selected methods may be sufficient. The advantages and limitations of each method are discussed below.

Documentation Review. Reviewing facility documentation enables reviewers to identify a sample of problems that have had a tangible, substantive effect on operations.

The merits of reviewing facility documentation to uncover human engineering problems depend on the clarity and completeness of the records. If records are not well kept and standardized in format, then interpretation may be difficult. Another drawback is that past experience cannot predict the future problems that may occur due to human engineering discrepancies. Therefore, a documentation review may reveal valuable information regarding actual problems and provide direction for future evaluations, but it should be performed in conjunction with one or more other methods for a more complete HFE review.

HFE Questionnaires/Interviews. This method provides the opportunity to obtain user input concerning the functional adequacy of the design. Questionnaire items can also be written to address the types of criteria covered in an observation checklist.

This method will identify design problems that are of the greatest concern to personnel. It will not, however, provide the best context for systematic identification of every type of discrepancy or every occurrence of a particular type of discrepancy.

The HFE questionnaire/interview method can be expected to yield incomplete data. However, it will provide more complete data than a documentation review.

Observation Checklist Survey. This method can provide a complete and detailed evaluation of the HFE acceptability of the face characteristics of components, of anthropometrics, labeling, and environmental conditions. It is not, however, a good way to evaluate design adequacy with respect to specific task performance requirements. It will, for example, identify display scales which are not well designed for readability. It will not indicate whether all necessary parameters are displayed in appropriate units over required ranges. Personnel questionnaire/interviews and the systems analysis approach are better methods for making these kinds of evaluation of the functional adequacy of the design.

Systems Analysis Approach. This is the best method to ensure the functional adequacy of a design. It also provides some opportunity in the verification step to identify discrepancies from generic criteria for characteristics of types of components. However, the systems approach is not as effective and complete for the latter purpose as an observation checklist survey.

The main drawback of the systems analysis approach is that it is time-consuming and conceptually demanding when used in the review of complex control system operations, and it may be unnecessary unless there is reason to question the functional effectiveness of the design. For example, if there is any question about whether all emergency response requirements can be met, the systems analysis approach should be applied to verify and validate the design for its emergency response capability.

Appropriate Combinations of Methods. If it is decided to use only selected methods, either of the following two combinations can provide a relatively thorough review. The first combination can be expected to require a lower level of effort, but will also yield less complete and in-depth information:

1. HFE questionnaires/interviews and observation checklist survey.
2. Observation checklist survey and systems analysis approach.

Documentation review may be added to either combination.

4.5 Assessment and Resolution of HFE Discrepancies

An organized method is needed in order to assess the safety significance of each discrepancy, for developing feasible solutions, and for estimating solution costs. This information may be used to decide which alternative solutions represent cost-effective improvements.

4.5.1 Assessment Team

An assessment team should include at least one individual representing each of the following specialties:

1. A qualified human factors specialist.
2. An individual trained and experienced in performing the work of functional area being addressed.
3. A technical specialist familiar with system/equipment engineering design.
4. Other design specialties, as appropriate, may be added. An instrumentation and controls engineer may be needed in some cases.

The assessment team should perform the assessment and resolution of discrepancies as a team, and not independently as individuals.

4.5.2 Assessment and Resolution Steps

1. Screen and organize discrepancy reports.
2. Assess the relative significance of discrepancies, identify those which will be analyzed for solutions.
3. Identify alternative solutions.
4. Evaluate alternative solution costs.
5. Decide on solutions to be implemented.

Screening and Organization of Discrepancy Reports. A preliminary screening and organization of discrepancy reports will increase the efficiency of the subsequent steps in the assessment and resolution process. Several screening and organizational issues should be considered. Examples are described below. The assessment team may identify other factors that provide a basis for sorting and organizing discrepancy reports before the assessment of safety significance and solution development is undertaken.

Some HFE discrepancies identified in the review may not represent true design deficiencies. This situation may arise when human engineering principles are inappropriately applied or when special circumstances are not taken into account. For example, there may be cases where a discrepancy represents a minor inconvenience but clearly would not impede personnel performance. These discrepancies may be eliminated from further consideration.

In other cases a discrepancy may call for increased personnel awareness through training, or through administrative procedures or other documentation. Discrepancies of this type should be handled separately with appropriate managers.

The assessment team should establish a consensus opinion regarding the question of design deficiency. If a discrepancy is judged not to represent a design deficiency, the reasons for this decision should be documented.

Screening can also be expected to identify duplicate discrepancy reports, especially if more than one review method is used. In addition, some discrepancy reports may describe a small part of a larger problem covered in another report. All information concerning a common problem should be grouped together.

It may also be desirable to group discrepancies for which a surface enhancement is the best solution. A surface enhancement uses paint, labels or tape to solve a problem, and requires no engineering change. It may be decided to correct such discrepancies without assessment of their significance. In any case, grouping them will help to ensure that all of them are treated in a consistent manner.

Remaining discrepancies should be grouped in ways that will facilitate integrated assessment and development of solutions. Appropriate groupings may be by panels, work areas or equipment systems under review. In the case of control systems, for example, grouping of discrepancies by panel is recommended.

Assessment of Discrepancy Significance. The significance of a discrepancy can be expressed as the ratio of the potential that it will induce human error to the potential for error detection and recovery, multiplied by the consequence (assuming that an error is made and not recovered). Expressed functionally:

$$\text{Significance} = \frac{\text{Potential for Error}}{\text{Potential for Recovery}} \times \text{Consequence of Error.}$$

The significance value derived from this assessment may be used as a measure of the relative benefit of correcting a discrepancy and thus as basis for prioritization. Although the potential error consequence associated with a given discrepancy must be undesirable, if the potential of making the error is low and/or potential for detection and restoration is high, the discrepancy will have a relatively low significance. Thus the benefit of correcting it may be relatively low.

The significance terms identified above may be rated on the basis of expert judgment using a scale of 1 to 5, low to high (e.g., 1 = lowest potential for error and 5 = highest potential for error).

Another approach is to define factors to be considered in arriving at ratings. For example, factors that affect potential for error inducement may include:

- o The time within which an action must be taken
- o Frequency of use of the equipment or component involved
- o Degree of skill/attention necessary for use of the component
- o Locatability of component (Is it in a logical, accessible place?)
- o Identifiability of component (Is it well labeled?).

Factors that may affect detection and recovery of an error may include:

- o Is the action in which the error may occur normally verified?
- o Is direct information available to verify whether an error condition exists, or must this be inferred from indirect information?
- o Is there a time limit for recovering the error (e.g., How fast will conditions degrade? Is there a point of no return?)
- o How difficult is it to recover from an error so that it has no consequence on safety?

Consequence assessments may be done in different ways. For complex control systems, an assessment may be based on weights assigned to the functions of the systems and subsystems that could be impaired. Exhibit 4-14 (in the Appendix) shows an example list of nuclear power systems grouped by function. The functions are prioritized (high to low)

on the basis of their importance to safety. Numerical weights may be assigned to each function.

Exhibit 4-15 (in the Appendix) illustrates a scheme that has been used for the assessment of error consequences in a decontamination and decommissioning operation of a DOE nuclear facility.

Identification of Solutions. Many human engineering problems can be improved relatively simply by surface enhancement techniques (e.g., changing control and display labels, changing recorder paper supplies, adding demarcation lines to enclose functionally-related controls and displays). Design of appropriate enhancement solutions should be performed by human factors engineers with input from plant personnel who have first-hand knowledge of the equipment and the associated human engineering problem(s). In identifying candidate solutions, the assessment team must consider whether the enhancement may conflict with other proposed changes or existing facility conditions and conventions.

If discrepancies cannot be corrected by surface enhancements, they may require design modifications. Design modifications may include the relocation of panel components, the addition or removal of panel components; system modifications (e.g., addition of limit switches, rerouting of sensing lines); rearrangement of a workspace; or modifications to the lighting or HVAC systems.

Design modifications should be developed by specialists with the required expertise. They should be informed about the problem to be solved. Potential solutions may be suggested. The design specialists should be asked to define alternatives and associated costs that will solve a problem.

It is important to cross check all proposed changes to ensure that no new problems are created in the process of correcting discrepancies.

Estimation of Solution Costs. The cost of implementing a solution to a discrepancy can be determined by estimating the resources required for each solution.

and the methodologies to be used. The Program Plan, following review and approval by the Steering Committee, should be the guiding document for the conduct of the review.

Once the Program Plan has been accepted and adopted by the Steering Committee, and the participants have been selected, it is recommended that an orientation for the participants in the review be conducted. This orientation should cover human factors engineering objectives and methodology, general plant design and operation, and the scope of work defined in the Program Plan. The purpose of this review is to provide all participants with a common framework and understanding of the scope and intent of the review and their respective roles in its successful completion.

Estimates should include engineering and construction labor and materials. In addition, procedures revision costs and training costs that may be associated with correcting discrepancies should be considered. Although generally less than physical change costs, these other costs can be significant. For example, recurrent training over the life of a facility as a solution can represent a substantial cost. If a solution requires significant procedure changes or additional training, an estimate of these costs should be made.

It may be desirable to devise an ordinal cost classification scheme so that the relative costs of different solutions can be more easily compared.

Decisions on Solutions to be Recommended for Implementation. The significance and cost information described above should be weighed to make final recommendations to facility management for the implementation of solutions. The assessment team should arrive at a consensus. If this cannot be reached, then the problem should be brought to management for a decision.

5.0 PROCEDURES REVIEW

In studies of safety-related incidents at commercial nuclear power plants it has been found that:

- o About 40% of incidents involving human error in operations were procedure-related.¹
- o About 75% of incidents involving human error in maintenance, test, and calibration activities were procedure-related.²

These were cases in which it could be determined that a procedure was available for the activity being performed, but was not used, was used improperly, or was incomplete, incorrect, out-of-date, or deficient in some other way. Exhibit 5-1, in the Appendix, gives some examples of procedure-related errors recently circulated by the U.S. Nuclear Regulatory Commission's Office of Inspection and Enforcement.

In a major project for the Air Force Systems Command a 92%-100% reduction in errors was found to occur with improved maintenance and troubleshooting procedures.³ These data suggest that review and improvement of procedures can significantly reduce the risks and costs of human error.

This chapter includes objectives, methods, and criteria for a complete review of procedures. It can represent a large scope of work depending on the number of functional areas (e.g., processing operations, maintenance) and procedures involved. Facilities may decide to select from the objectives, methods, and criteria presented here according to their particular needs and resources.

Both technical and operational issues are included in the scope of this chapter. That is, the procedures review addresses issues that require technical/operational data and knowledge to evaluate. They are nevertheless human factors issues. If, for example, procedures are incomplete, or contain incorrect or imprecise information, those are critical human factors concerns. With such deficiencies, procedures cannot be counted on to support reliable human performance, as they are intended to do.

Thus it was decided not to limit the guidance to matters of information presentation only. Guidance is offered for technical verification and for validation of the performance effectiveness of procedures as well.

5.1 Review Objectives

Five objectives of procedures review are treated in this chapter:

1. Verification of the technical accuracy and completeness of existing procedures.
2. Verification of the presentation design adequacy of existing procedures.
3. Validation of the performance effectiveness of existing procedures.
4. Evaluation of the procedures management system.
5. Assessment of the need for additional procedures.

5.2 Review Criteria

Detailed criteria under each of the potential review objectives are discussed in the individual sections on review methods (Sections 5.4.1 through 5.4.5). Criterion checklists are provided in the Appendix (Exhibits 5-2, 5-3, 5-4).

5.3 Trade-Offs in Determining the Scope and Costs of Procedures Review

The scope and costs of a procedures review depend on the review objectives to be addressed, the number and complexity of procedures to be reviewed, and the review methods selected. It may be decided, for example, to address only the first objective — to

verify the technical accuracy and completeness of existing procedures. Or it may be decided that procedures are technically accurate and complete, but there are questions about clarity of presentation. In that case, the review might be limited to the second objective — to verify the presentation design adequacy of existing procedures. If it is decided to address either of these objectives in the review and if problems are found, then it is advisable to conduct validation exercises (Objective 3) to further develop the findings or to validate revisions made on the basis of those findings. The latter is especially important. It is also advisable to look at the procedures management system (Objective 4) to identify underlying reasons for problems.

Another approach to limiting the review might be to begin with validation of performance effectiveness and conduct verification activities only to follow up on problems identified in the validation. This would be a less thorough strategy but should identify major problems.

The review may also be limited to procedures in one functional area (e.g., maintenance) or to a subset of procedures within one functional area. Many combinations are possible.

There may be no question about priorities for procedure review. If there are questions about where the needs are greatest, they may be resolved based on a preliminary needs assessment. Suggestions for conducting such an assessment are given in Section 3.0.

5.4 Review Methods

Methods that may be used to meet each of the three major review objectives are described in Sections 5.4.1 through 5.4.5. Before the specifics of the methods are described, general personnel requirements, applicable across all of the objectives and methods, will be identified.

A single individual should be assigned to coordinate all activities of the procedures review. The procedures review coordinator should:

- o Have thorough knowledge of facility organization, operations, and support functions

- o Have lines to facility management which provide him/her authority to involve personnel in review activities, control the review schedule, and otherwise meet review requirements
- o Have a commitment to the quality of procedures and an understanding of the objectives and criteria of procedures review
- o Have management skills and be willing to take on the responsibilities of the assignment.

The coordinator should monitor performance of review activities (this may be on a sampling basis) as well as interface with management, handle scheduling, ensure clear and complete documentation of findings, assist in resolution of questions, and perform other coordination functions as required.

The coordinator should be assisted by a human factors specialist or someone else who is experienced in the procedures design and review. The human factors specialist should select or prepare all review aids such as criterion checklists and forms for recording findings.

An individual should also be assigned to assist the coordinator in maintenance and control of review documentation. This individual should have appropriate administrative and clerical skills.

Additional personnel requirements specific to each method are identified in the methods sections. Often a combination of facility technical expertise and human factors expertise will be needed. To the extent possible, however, these requirements have been separated to allow the most efficient possible use of personnel time.

5.4.1 Verification of the Technical Accuracy and Completeness of Existing Procedures ("technical verification")

Technical verification is a "tabletop" activity in which procedures are systematically compared to technical documentation and expert knowledge of the bases for procedural requirements. This may be done to answer the following major questions about the technical adequacy of a procedure:

- o Are all action and information requirements covered without error?
- o Is the procedure written at an appropriate level of detail? (i.e., is the guidance complete enough for all users to perform the instructional steps, without cluttering the procedure with unnecessary detail?)

- o Are user checkoffs and independent verifications of correct performance specified at the proper points to guard against significant error?

Sources of Information. Listed below are examples of the types of documentation that may contribute to the technical bases for procedures:

- o System/equipment design specifications provided by vendors
- o Instructions for system/equipment operation, test, calibration, maintenance
- o Safety analyses and risk assessments
- o System function and task analyses
- o Technical Specifications, including Limiting Conditions of Operations and Safety Limits (for Category-A reactors)
- o Regulatory and facility specifications for radiological protection and contamination control
- o Procedures for equivalent activities at other facilities.

Documentation of the technical design bases for emergency response requirements has been prepared specifically for use in the development of emergency operating procedures at the commercial nuclear utilities. Generic technical guidelines were prepared by the nuclear steam supply system (NSSS) owner's groups and then made plant-specific and incorporated into Procedures Generation Packages by the individual facilities. This documentation incorporates and integrates data from sources of the kinds listed above. Analogous documentation has been prepared by a number of DOE nuclear facilities. Where available, it should provide the principal reference for the technical verification of procedures.

Where the documented technical design bases for procedural requirements are incomplete, technical experts will be needed to provide information. Depending on the activity addressed by the procedure, expertise may be needed in system/equipment engineering, instrumentation and control system engineering, radiological protection, industrial safety, system safety analysis, or other areas.

If the documented bases for procedural requirements are incomplete or not well integrated, it would be desirable to pull together the necessary information in the course of performing this review. This would provide a record which could be maintained as a reference for future use in procedures management.

Personnel Requirements. The core personnel who perform the technical verification should be thoroughly trained and experienced in performing the procedures under review. In addition to being master performers, they should have knowledge of the skill range of personnel who may use the procedures. They will be referred to as "technical evaluators." Preferably, a team of two technical evaluators will work together on each procedure. If procedures in more than one functional area are to be reviewed, then a different team of technical evaluators with different skills may be needed for each area.

Material Requirements. The following materials will be needed for technical verification:

- o A copy of each procedure to be reviewed
- o A copy of each procedure referred to in the procedures to be reviewed
- o Copies of technical documentation that provides the bases for the procedures to be reviewed
- o Copies of pertinent regulatory guidance/requirements
- o List of standard terminology, acronyms, and abbreviations if available
- o Schematic drawings as applicable (e.g., equipment/system diagrams, P&IDs, panel front drawings)
- o Review aids such as checklist and forms for recording findings and recommendations
- o Copies of schedule.

Preparation of Checklist. It is recommended that a criterion checklist be used to structure the evaluation. The following are examples of specific criteria that should be covered in the checklist. Some tailoring may be necessary for different types of procedures:

- o Descriptiveness of title and stated purpose of procedure
- o Accuracy and completeness of entry conditions or symptoms and prerequisites
- o Accuracy and completeness of procedure steps
- o Specification of required communications
- o Appropriateness of order of steps; correct identification of steps that must be performed in a particular order
- o Specification of time requirements where applicable
- o Correctness and sufficiency of component identification, including location when there could be uncertainty

- o Correctness and consistency of nomenclature, acronyms, and abbreviations
- o Correctness and completeness of parameter identification
- o Clear and accurate identification of values and conditions which represent operating or safety limits
- o Clear and accurate specification of values and trends which provide cues to step initiation, step completion, and decisions as to subsequent steps
- o Inclusion of all applicable cautions and warnings
- o Correctness of logic statements
- o Complete and clear identification of significant contingencies that could occur in procedure execution, and clear instructions as to how to proceed under contingency conditions
- o Correctness of "GO TO" instructions within a procedure and instructions to enter another procedure; provision of clear instructions about whether, when, and where to return
- o Need for aids such as flow diagrams and references; accuracy and clarity of aids provided
- o Sufficiency of procedural guidance for personnel who have completed training but do not have substantial experience in performing the activity.
- o Sufficiency of guidance in procedures that are not used often
- o Potential consequences of incorrect execution of a step; need for a formal checkoff or verification by the procedure user or by another person.

An example checklist for technical verification of procedures is included in the review aids in the Appendix (Exhibit 5-2).

Other Preparation Steps. The procedures review coordinator should also ensure that the following additional preparation steps are completed before the technical verification begins:

- o Schedule the verification; obtain agreement of managers/line supervisors whose staff may be involved, as well as participants themselves.
- o Assemble materials.
- o Assure availability of suitable workspace.
- o Brief participants on the objectives and steps of the technical verification, including criteria, aids, documentation of findings, and schedule. (It is also desirable to describe in this briefing the entire

scope of the procedures review, so that participants will have a clear understanding of the division of work.)

Performance of the Technical Verification. The technical evaluators should consider each criterion identified in the checklist, making comparisons to technical documentation and drawing information from their own knowledge to decide on the adequacy of the procedure with respect to the criterion. It may be necessary to draw upon the expertise of other personnel to resolve questions.

The disposition of checklist items should be noted on the checklist. Notes should also be made on a copy of the procedure itself to identify any problems in individual instructional steps and attachments. From these notes, an evaluation report should be prepared. Any problems should be defined clearly, keyed to the appropriate criteria, and keyed to the parts or steps of the procedure to which they apply. If additional inquiry/analysis is necessary to resolve a question or evaluate a potential problem, this should be stated. Recommendations for correcting problems may be included. They should be considered in the assessment and resolution of review findings when a plan for making improvements is established (see section 5.5). It is important, however, to ensure that considerations about the effort required to correct a problem are not allowed to bias assessment of the significance of the problem.

5.4.2 Verification of the Presentation Design Adequacy of Existing Procedures ("procedure design verification")

Procedure design verification, like the technical verification, is a tabletop activity. It is done by comparing procedure characteristics to human factors criteria and to facility guidelines/directives concerning the organization, format, style, and wording of procedures.

Personnel Requirements. The core personnel for this evaluation should include at least one human factors specialist or other person with applicable experience in procedure design/evaluation. (This person will be referred to as the "procedures design specialist.") Others may be involved as needed for the number of procedures to be reviewed. They should have above-average writing/editorial skills and ability to attend to detail. They should be familiarized with the criteria and supervised by the procedures design specialist.

Material Requirements. The following materials will be needed for the procedure design verification:

- o A copy of each procedure to be reviewed
- o A copy of each procedure referred to in the procedures to be reviewed
- o If technical verification has been performed (as described in Section 5.4.1), copies of the findings and recommendations
- o Facility administrative directives/guidelines pertinent to procedure design
- o A checklist of procedure design criteria representing principles in the literature and facility-specific directives and guidelines (an example checklist is provided in Exhibit 5-3 in the Appendix)
- o A data format for recording findings and recommendations
- o List of standard terminology, acronyms, and abbreviations, if available
- o Copies of schedule.

Preparation of Checklist. A checklist approach is recommended for this evaluation as for the tabletop technical evaluation. Listed below are examples of criteria that should be included in a procedure design evaluation checklist:

- o Completeness of procedure identification information (e.g., title, number, revision number, date of issue, number of pages in procedure)
- o Conformance to facility guidance concerning organization into sections (e.g., objective, initial conditions, immediate actions, subsequent actions, diagnostic aids)
- o Clarity of responsibilities and provisions for coordination when a procedure is performed by more than one person
- o Placement of Notes, Warnings, and Cautions
- o Discriminability of Notes, Warnings, and Cautions from Instructional Steps
- o Complete separation of action instructions from information that belongs in Notes, Warnings, and Cautions (e.g., action instructions should not be imbedded in Warnings, and vice versa)
- o Clarity of instructional steps
- o Conciseness and clarity of wording; readability
- o Conformance to facility standard nomenclature, acronyms, and abbreviations
- o Correct spelling, grammar, and punctuation

- o Correct use of capitalization
- o Consistency and clarity of logic statements
- o Clarity and completeness of internal branching instructions and instructions for branching to other procedures
- o Need for internal or external branching to other procedures (could the relevant instructions more effectively be incorporated in the step series under review?)
- o Readability/clarity of aids such as graphs, flow diagrams, tables
- o Provision for required calculations (e.g, for recording input data, calculations, and results).

An example checklist for verification of procedure design is included in the review aids in the Appendix (Exhibit 5-3). If the facility has a procedure writers guide, it should be the primary source of checklist items. Items suggested herein that are not addressed in the writers guide might be added. If the facility does not have a procedure writers guide, it would be highly desirable to prepare one as part of this effort.

Other Preparation Steps. These are as stated for the technical verification (see Section 5.3).

Performance of the Procedure Design Verification. The design evaluators should consider each criterion in the checklist. If the facility has a procedure writers guide, the evaluators should refer to it as necessary to ensure that the procedure conforms to its specifications.

The disposition of each checklist item should be noted on the checklist. Notes should also be made on a copy of the procedure itself to identify any problems in individual instructional steps and attachments. From these notes, an evaluation report should be prepared. Any problems should be defined clearly, keyed to the appropriate criteria, and keyed to the parts or steps of the procedure to which they apply. Recommendations for correcting problems may be included for consideration during the assessment and resolution of review findings (see Section 5.5). However, it is important to ensure that these recommendations not be allowed to bias the assessment and resolution process.

5.4.3 Validation of the Performance Effectiveness of Existing Procedures

Validation is concerned with the effectiveness of procedures in actual use. Can a procedure be followed without difficulty by the individual or team expected to use it? If the procedure is followed, does successful performance result? Is the procedure consistent with actual system/equipment characteristics, symptoms, and responses?

Performance exercises are necessary to validate procedures. The exercises may be conducted as walk-throughs in which procedural steps are acted out but not executed. If a real-time simulator is available, the procedural steps can be executed. Then it is possible to fully assess the consistency of the procedure with actual system/equipment conditions and responses, the effects of personnel actions, and coordination and timing factors. In some cases it may be possible to validate procedures in the course of real operations, maintenance, or other activities.

Personnel Requirements. Normal staffing should be assigned to perform the procedure. The personnel selected should be the least experienced personnel available who may perform the procedure. A technical evaluator and a procedures design specialist should observe the exercises and record the findings. If the procedure is executed by a team and involves a large number of steps, additional observers may be needed to track the performance of each member of the team that is executing the procedure.

Material Requirements. The following materials will be needed for performance exercises:

- o Copies of procedures to be performed (observer copies should be annotated with personnel and location codes as applicable)
- o Copies of findings and recommendations from previous review activities (e.g., technical verification)
- o Scenarios that define the paths to be followed in multiple-path procedures. A scenario will also be needed if only part of a procedure is to be performed or a segment is to be skipped.
- o Copies of all reference materials/aids that may be used in performing the procedure
- o All tools, supplies, equipment used in performing the procedure
- o Protective clothing, breathing apparatus or other protective equipment that should be used in actually performing the procedure
- o Validation checklist
- o Copies of schedule.

Preparation of Validation Checklist. A checklist should be prepared for use by each observer. It should identify the base set of criteria to be watched for as exercises are performed. Discussions with performing personnel typically lead to findings beyond the base set of observation criteria. However, use of a checklist will ensure that major issues are watched for consistently.

It is recommended that the checklist identify a fairly small number of criteria. It should include criteria that cannot be evaluated fully in the tabletop situation of technical verification and procedure design verification (as discussed in Sections 5.4.1 and 5.4.2, respectively). The number of criteria should be limited because it is difficult to attend to performance dynamics when concerned with numerous detailed criterion statements. Examples of criteria that are appropriate for use in performance exercises are listed below.

- o Can the instructional steps be performed in the sequence indicated by the procedure?
- o Can personnel readily locate and identify all components referred to in the instructional steps?
- o Do the symptoms and equipment/system responses observable in the work situation agree with what is said in the procedure?
- o Do personnel perform steps that are not in the procedure? Do they omit steps specified in the procedure?

A complete example of a validation checklist is included in the review aids in the Appendix (Exhibit 5-4).

Comparison of Procedure Nomenclature/Terms to Equipment Labeling. An additional task included in this evaluation is to compare the component and parameter references given in the procedures to the labeling of the actual equipment used in executing the procedures to ensure that they match. This must be done in the work location.

System and component names and identification numbers, units of measure, control positions, etc., should not only be referred to consistently and accurately within the procedures; they should match the labels and location aids which personnel refer to in the work locations. Examples of differences which may be found include:

- o Different panel/cabinet identifier — the procedure gives the facility alphanumeric identifier while the panel is labeled with the vendor identifier

- o Different units of measure — the procedure tells the operator to verify level less than "X inches," but the display reads "percent."

Discrepancies should be noted on copies of the procedures. A technical evaluator will be needed to make the comparison and identify discrepancies. This information should be shown on the procedure copies used by observers of the performance exercises, so they may watch for the effects of discrepancies on performance.

Determination of Personnel Tasks and Locations. For procedures that are performed by more than one person, it is recommended that the allocation of procedural tasks be noted before performance exercises begin. If tasks are performed at several panels/work stations, then task locations should be noted as well. Personnel and location codes should be established for these purposes. An individual who is experienced in using the procedure should record the personnel and location code by each step or substep on a copy of the procedure. It may or may not be necessary to go to the work area to do this. Each observer of the performance exercises should have a copy of the procedure annotated with personnel and location codes.

Preparation of Scenarios. A brief narrative statement should be written to specify the conditions under which the procedure or procedure segment is assumed to be performed and the path to be followed. Scenarios are also used in performance exercises to validate the human factors engineering of design. The preparation of scenarios is discussed in Section 4.0 of this Review Plan, concerning human factors engineering review. An example scenario is provided in that section of the Appendix, Exhibit 4-11.

Other Preparation Steps. The procedures review coordinator should see that the following additional preparation steps are completed:

- o Obtain use of facilities in which the exercises are to be conducted. This may involve:
 - scheduling of time in the actual work area
 - arranging for use of a simulator and the services of a simulator operator
 - arranging for construction of a mockup of work area and equipment
 - arranging for use of actual equipment and space for testing.
- o Schedule personnel time, obtaining agreement of managers/line supervisors and participants.

- o Assemble required materials.
- o If exercises are to be conducted in a simulator, review scenarios with simulator operator. Ensure that each scenario is feasible in the simulator. Plan start and stop points and time slicing, as appropriate.
- o Brief participants on the objectives and steps of the performance exercises, including criteria, aids, documentation of findings, and schedule. It is important to emphasize that the exercises are not intended to evaluate those who perform the exercises, but rather to identify needs for procedural improvements (or other human factors improvements).

Observers should review the findings and recommendations from any previous review activities. They also should become thoroughly familiar with the validation checklist.

Conduct of Performance Exercises. The steps involved in conducting performance exercises include the following, for each procedure or procedure segment to be performed:

1. The procedures review coordinator should lead a discussion of the scenario (if applicable) and procedure. Questions should be resolved, and roles should be specified if more than one person is involved in performing the procedure. Observers should be assigned to observe the personnel performing the procedure.
2. Performing personnel should then conduct the procedure in real-time, or an approximation of real-time, including all necessary communications. Observers should make notes about any questions they may have concerning guideline criteria. It is usually easiest to do this on a copy of the procedure.
3. Performing personnel should again conduct the procedure, this time in a slow walk-through. They should point out and explain all of their actions. If a team is performing the procedure, this will require phasing of the actions of each participant. Observers should ask questions as they arise and make notes.
4. All participants and observers should discuss the procedure, with reference to each criterion in the validation checklist. Any other problem areas or questions that may have arisen about the usability and performance effectiveness of the procedure should also be discussed.
5. One observer should assemble all documentation from the exercise and prepare a statement of findings for submission to the procedures review coordinator. Any problems should be defined clearly, keyed to the validation guideline as applicable, and keyed to the parts or steps of the procedures to which they apply. Recommendations for correcting problems may be included for consideration in the assessment and resolution of procedures review findings (see Section 5.5)

5.4.4 Evaluation of the Procedures Management System

This evaluation addresses the system for developing, controlling, maintaining, and updating or revising procedures.

Personnel Requirements. One evaluator should be sufficient. The evaluator should have a background in procedure design and management, and should be detached enough from the existing system to maintain objectivity. The evaluator will need to talk with procedure users and other personnel with responsibilities in the procedure management system.

Material Requirements. The following materials will be needed to review the procedure management system:

- o Copies of all documentation which defines how procedures are to be developed, reviewed, updated/revised, and controlled at the facility
- o A list of personnel who may be contacted for information concerning the procedure management system.

Preparation of Guidelines for the Evaluation. This is an exploratory evaluation. It should be open to identification of any problems that may exist and to recommending solutions to fit the organizational structure and administrative practices of the particular facility. Generally applicable characteristics of effective procedures management systems may, however, be identified as guidance. Major characteristics are stated below in the form of questions that should be considered during the evaluation:

- o Is there clear and specific written guidance for procedure writers?
- o Does the guidance provide for review of new procedures and revisions, by experienced user personnel? Does the guidance specify a performance test before a new procedure or major revision is approved for use?
- o Is there an established schedule for periodic review of procedures?
- o Is there a written directive to define the steps necessary to update or revise a procedure?
- o Is there a written directive to define what should be done if a need for procedure change is identified between periodic reviews?
- o In all such directives/guidance, are personnel responsibilities clearly specified?
- o Are there appropriate, designated areas where procedures and other documentation referenced in procedures are kept?

- o Are the conditions under which procedures may be removed from the designated areas specified and enforced?
- o Are personnel prevented from making unauthorized personal copies of procedures?
- o Is responsibility assigned for making sure procedures are in good condition for use (e.g., legible, clean, complete copies)?

Other Preparation Steps. The procedures review coordinator should ensure that all relevant documentation is assembled. The coordinator should brief the evaluator (or arrange for briefing) on the system for procedure development, review, updating/revision and control. The coordinator should also identify personnel to provide additional information. Those personnel should be informed about the objective and major steps of the evaluation, the contribution expected from them, and the schedule.

Performance of Procedure Management System Evaluation. The recommended evaluation steps are summarized below.

1. Review the available documentation pertinent to the procedure management system.
2. Go into the work locations to look at the status of procedures in use and provisions for maintaining procedures in good condition and for controlling access. Talk informally with personnel to answer questions. (This must be arranged through the procedures review coordinator.)
3. Review results of needs assessment, if available (see Section 3.0).
4. Conduct interviews with selected personnel to get their views on actual practices and needs related to procedure management. (Needs assessment results may make additional interviews unnecessary.) If interviews are conducted, they should address questions and findings from preceding steps. They should also solicit undirected input from the respondents.
5. Write a statement of findings if no problems are identified, or formulate problem statements and possible solutions.
6. Discuss problems and solutions with selected personnel and refine as necessary (This may be unnecessary if interviews are conducted in step 4.)
7. Prepare findings and recommendations.

5.4.5 Assessment of Needs for Additional Procedures

This assessment can be performed by one or a combination of several methods, depending on the thoroughness considered appropriate:

- o A check may be made to ensure that the intent of applicable regulatory guidance has been met.
- o Documentation of performance history may be reviewed for indications of error in activities not covered by existing procedures.
- o Personnel may be asked to identify activities which they believe should be covered by procedures.*
- o Personnel may be asked to demonstrate and/or explain the steps involved in activities not covered by written procedures.

Personnel Requirements. At least one person will be needed with expertise in each functional area included in the review. A human factors specialist should be available to work with the technical expert on matters of methods and criteria.

Material Requirements. The following materials will be needed:

- o A list of all existing procedures and manuals for each functional area included in the review
- o Copies of the procedures and manuals or ready access to them
- o Job/task analysis data if available
- o Documentation of incidents, outages, etc., if performance history is to be reviewed
- o A questionnaire if the personnel survey method is to be used
- o A list of respondents (at least two technicians/operators from each applicable functional area) if the personnel survey method is to be used
- o Criteria for assessing needs for procedures.

Establishment of Criteria. Regulatory guidance can provide a baseline set of criteria for assessing whether needs for procedures have been covered completely. Guidance concerning procedures coverage may be given for specific facilities in Field Office Supplements to DOE Orders. General guidance is given in a number of documents, including the Code of Federal Regulations, DOE Orders, and industry standards. A summary of the general guidance is provided in the review aids in the Appendix (Exhibit 5-5). As part of the preparation for the assessment it will be necessary to identify the

*An overall, preliminary assessment of review needs is suggested in Section 3.0. A questionnaire/interview survey conducted for that purpose could provide information specific to the assessment of needs for additional procedures.

guidance applicable to the functional areas to be included in the review at the particular facility.

The above sources tend to identify major categories of activities for which procedures are required or recommended. To decide which specific activities within a category should be governed by written procedures, four main issues should be considered:

- o The memory load imposed by the activity and situational factors that may affect recall.
- o The extent of cues as to action requirements and sequence evident from the equipment itself.
- o The recoverability of error and potential consequences of unrecovered error.
- o The proficiency levels of personnel who may perform the activity.
- o Supervision of the activity or verification of correct performance.

Criteria related to each of these issues may be used to aid decision-making. An example set of criteria is provided in the Appendix (Exhibit 5-6).

Preparation of a Questionnaire to Identify Needs for Additional Procedures. If the personnel survey method is to be used, a questionnaire will have to be prepared. The following are examples of questions that would be appropriate:

- o We do not have a written procedure for _____. Review of records indicates that there has been some difficulty in performing that activity. What is your opinion about the need for a written procedure? Please explain.
- o Do you know of any cases when you or others have been uncertain or made errors because there was no procedure specifying requirements?
- o Do you have any recommendations about additional procedures in your area of work?

Other Preparation Steps. The procedures review coordinator should ensure that the necessary materials are available, schedule personnel time, and brief the participating personnel.

Performance of the Assessment. The following steps may be taken to assess needs for additional procedures. A selection may be made from these options:

1. Outline the task content of the activities performed by personnel in each functional area. (If job-task analysis has been performed as a basis for training in a functional area, it may be meet this need.)
2. Compare the results of step 1 to the list of procedures/manuals for each functional area. Check the latter as necessary to determine what is covered. Flag any activities that are not fully covered by the existing procedures/manuals.
3. Review applicable regulatory guidance and industry standards concerning provision of written procedures and compare to the results of step 2. Note where gaps in procedure coverage represent omissions in areas where procedures are recommended.
4. Review unusual occurrence/incident reports, operating loss, maintenance records, etc., as applicable:
 - Identify occurrences that involved human error.
 - Determine whether a procedure existed to guide the activity being performed.
 - For cases in which there was no procedure, evaluate whether the use of a procedure could have prevented the error.
5. Distribute questionnaires or interview personnel for their opinions as to needs for additional procedures.
6. Evaluate potential needs identified in previous steps by analyzing the activity with reference to human factors criteria used to determine needs for procedural guidance.

Where questions remain about need for a procedure it may be helpful to get personnel to demonstrate and/or explain their understanding of the required steps and contingencies. This should be done with reference to a scenario for the activity and a detailed list of performance requirements to define the success path(s). These materials should be prepared by the technical expert. The personnel asked to demonstrate/explain the activity should be briefed on the scenario but not shown the detailed list of performance requirements. At least two individuals should independently demonstrate/explain the activity. At least one should have minimal experience.

A statement of findings and recommendations should be prepared based on the results of all assessment steps performed.

*Additional guidance concerning documentation review is provided in Section 4.4.1.1.

5.5 Assessment and Resolution of Findings from the Procedures Review

This section applies to findings from technical verification, presentation design verification, and validation of existing procedures, as discussed in Sections 5.4.1 and 5.4.3. It may also be applied to findings concerning needs for new procedures (Section 5.4.5), although assessment of the significance of such needs will be accomplished largely if not entirely in the course of the review per se. This section does not apply to findings concerning the procedures management system. Assessment and resolution of findings in that area involve factors specific to the individual facilities.

5.5.1 Objectives

The objectives of the assessment and resolution process are:

- o To assess the significance of discrepancies that may be identified in the review, to decide which discrepancies should be corrected, and to decide their priority
- o To plan and schedule corrective actions.

5.5.2 Personnel

It is recommended that a team be formed to conduct the assessment and resolution of procedures review findings. Team recommendations may then be submitted to facility management or to the human factors review steering committee if one has been established (as suggested in Section 3.2.2).

Team composition is suggested below:

- o The procedures review coordinator
- o At least one person with key responsibilities for procedures management
- o A manager from each functional area/department that is involved
- o Technical and human factors personnel who conducted review activities, as applicable.

5.5.3 Preparation

If more than one review method has been used (e.g., both technical verification and presentation design verification), the findings applicable to each procedure from each

review method will need to be assembled. The procedures review coordinator should also ensure that any questions remaining from each review method have been answered.

5.5.4 Assessment Methods

A facility may decide to correct any or all of the discrepancies that are identified in a procedures review without formal assessment of their significance. Priorities for performing corrective actions may also be decided informally, based on knowledge of the criticality and frequency of use of different procedures and on other considerations of needs and schedules within the functional areas/departments affected. Suggestions for a more formal approach are provided here for use when resources dictate limited corrective action or when priorities are not clearly evident.

Two methods for assessment of review findings are discussed elsewhere in this Review Plan. Either can be applied to the assessment of procedures review findings.

General Criterion Ratings. The first method, described in Sections 3.2.5 and 3.2.6 is more general. It involves rating discrepancies according to a set of assessment criteria. The ratings may then be averaged to obtain single values that can be used to rank the discrepancies. The applicable criteria are listed below. Their wording has been modified to be more appropriate for procedures review findings.

- o Relevance of the discrepancy to issues of real concern to procedure users.
- o Safety impact: the potential of the discrepancy to degrade safety; i.e., how likely it is that this discrepancy will contribute to an error that could affect the safety of facility personnel or the public.
- o Potential payoff in terms of improved efficiency if the discrepancy is corrected.

Each criterion should be rated on a 1 to 5 scale. The averages will also range from 1 to 5. High ratings most warrant follow-up attention. A facility may decide, for example to correct all discrepancies that receive ratings of 3 or higher. The ratings may also be used to establish the priority for corrective action even if it is decided that all will be corrected.

Safety-Significance Algorithm. The second assessment method is discussed in Section 4.0. This method involves consideration of the following:

- o The potential for error arising from the discrepancy
- o The potential for error detection and recovery
- o The potential consequence of the error.

Values are assigned to these parameters based on analysis of underlying factors. Significance may then be expressed as the ratio of the potential that the discrepancy will induce error to the potential for recovery, multiplied by the consequence if the error is not recovered:

$$\text{Significance} = \frac{\text{Potential for Error}}{\text{Potential for Recovery}} \times \text{Consequence of Error}$$

The resulting significance values may be used to rank discrepancies and decide which will be corrected.

The details of this method are explained in Section 4.5 concerning assessment of human engineering design review findings. Some modifications will be necessary if this method is to be used for assessment of procedures review findings. The concepts are applicable, however.

5.5.5 Resolution

The remaining task is to recommend the actions needed to correct discrepancies and to prepare a projected schedule for making improvements. This material will provide input for final decisions by management.

The recommendations may range from minor corrections of technical or presentation discrepancies that occur in individual instructional steps, to complete editing and reformatting, to full-scale technical revision.

If substantial changes are made in organization, wording, and format of procedures, it is recommended that they be checked over for technical accuracy after this is done. Conversely, if a major technical revision is made, it should be checked for conformance to criteria for effective presentation design.

6.0 ORGANIZATIONAL INTERFACE REVIEW

Defining organizational interfaces as the communication links between different functional groups or departments within an organization provides the basis for evaluating the adequacy of the vertical and horizontal communication of an organization. Studies performed for nuclear and many other industries underscore the effects of vertical and horizontal organizational communication on the effectiveness of an organization's operations. Many of the communication problems identified by this research are generalizable to DOE facilities.

A survey of nuclear power plant maintenance found that communication and coordination problems are responsible for major delays in completing maintenance tasks.¹ Another study of nuclear power plant maintenance identified six problems responsible for increasing maintenance time and extending outages, all of which involved a communication component.² These included: (a) lack of materials (parts and tools), (b) worker attitude, (c) cooperation and coordination, (d) inadequate supervision, (e) red tape, and (f) poor planning. In a more recent study of ten nuclear power plants, three categories of communication-related problems were revealed.³ The most frequently cited was difficulty in interacting horizontally with other departments. Another was insufficient lead time to provide for advanced planning, which limits departments' abilities to organize, schedule, and perform work efficiently. A third was insufficient sharing of "big picture" information about plant issues (scheduling, workload, etc.) with lower level employees, resulting in unclear lines of responsibility, confusion, and resentment.

Based on this experience, the major issues in organizational communication that may impact the effectiveness of an organization are defined in this section. In addition, a set of evaluation criteria and measurement tools that may be used by DOE facilities to review coordination patterns and organizational interfaces in their organizations is presented.

6.1 Review Objectives

Within the domain of DOE nuclear facility contractors, many types and sizes of organizational structure may be found. Despite their diversity, common objectives can be stated for evaluation of organizational interfaces. The first objective is to ensure the adequacy of vertical communication within a contractor organization, between it and its cognizant DOE field office, and between the contractor organization and its own corporate management structure. The second objective is to ensure effective horizontal coordination among the various functional areas within a contractor facility (e.g., Operations, Maintenance, Health and Safety, Quality Control).

A third objective of this section is to provide DOE facility managers with a framework for evaluating the effectiveness of their organizational communication and to identify problem areas as perceived by personnel from various functional and organizational levels.

6.2 Establishment of Diagnostic Criteria

A comprehensive evaluation of the organizational interfaces found in a DOE facility must address criteria or standards necessary to assess the dimensions that impact organizational communication within a facility. These standards are referred to as diagnostic criteria and provide the framework for identifying problem areas in the organizational interface review. The Organizational Communication Questionnaire^{4,5} was developed as a diagnostic tool, and covers a wide spectrum of communication issues applicable to most types of organizations. The benefit of using it for assessing organizational communication issues is that it provides indices that have already been tested on a variety of organizations and found to have both high reliability and high validity ratings.

The Organizational Communication Questionnaire contains items covering 18 communication indices. Each communication index represents a set of individual questionnaire items that are related to a particular aspect of communication (e.g., timelines of information). Exhibit 6-1, in the Appendix, contains a list of these communication indices and their

related questionnaire items. The questionnaire is provided as Exhibit 6-2 in the Appendix. Some modifications have been made to tailor the questionnaire for use by DOE nuclear facilities.

Administration of the Organizational Communication Questionnaire in commercial nuclear power plants⁶ revealed six communication indices with lower than average ratings:

1. Timeliness of information
2. Redundancy of information and requirements to provide information
3. Gatekeeping/withholding information
4. Feedback
5. Information amount
6. Quality of work-related documentation.

These six indices represent problem areas that are most likely to be pertinent to the DOE facilities. Each problem area is described below.

6.2.1 Timeliness

This index represents the perceived satisfaction of personnel with the timeliness of the information they receive from different departments or job levels. Persistent lack of planning leads to crisis management and a "brush fire" approach to prioritizing and scheduling jobs. The higher the information source in the organization, the more time it takes for information to be transmitted downward. Information often becomes distorted as it is passed down through many management levels. As a result, supervisors resort to circumventing official lines of communication in order to convey information in a more timely and accurate manner.

6.2.2 Redundancy

This index represents how frequently information, including directives, statements of policy, changes in regulations, and requests for reports, is received more than once. Redundancy of information may be characterized in terms of the paperwork overload created by multiple layers of documentation requirements. Requirements for documentation may be both internally generated (facility, QC, QA, etc.) and externally generated (e.g., DOE, corporate management). This may result in supervisors' feeling overburdened

with paperwork that minimizes the time they spend interacting with their subordinates and the staffs of other departments about important issues. A related problem is the amount of time spent in preparing documentation that is never used. Communication about work requests is so poor at some plants that technicians often waste time planning twice for the same job, resulting in the inefficient use of personnel.

6.2.3 Gatekeeping/Withholding Information

This index refers to information not being transferred beyond a particular point in the communication flow. Gatekeeping is more of a problem among supervisory and upper job levels than among lower job levels. Information tends to flow freely among peers in the work group, but too little information is made available by upper levels to the personnel who actually perform the work. Gatekeeping tends to start at the very top of the communication flow. This results in a lack of trust between supervisors and management — an attitude that has a cascading effect through the organization. This phenomenon can result in barriers between departments and rival "empire building."

6.2.4 Feedback

This index measures the degree of satisfaction with feedback from various job levels and departments within the organization. In some facilities, upward communication is often considered a futile effort, since follow-up actions, or even acknowledgements, by management in response to upward suggestions or requests are rare. The need for more complete documentation and feedback from other departments is also required.

Lack of feedback regarding work performed by maintenance appears to be the most common problem. Maintenance often does not provide enough feedback to requestors regarding completed work and job histories.

6.2.5 Information Amount

This index measures satisfaction with the amount of information produced and transmitted by plant personnel for purposes of documenting work, relaying job-related information, reporting poor working conditions, and requesting clarification of work requests. Problems with not receiving enough job-related information to meet job requirements are common.

Judging the amount of information for different types of people is also difficult. For example, lower level employees may feel they do not get enough "big picture" information to understand the context of their work, or department heads may not have enough accurate information when attending meetings in which work priorities are set and work schedules are defined.

6.2.6 Quality of Work-Related Documentation

This index refers to the perceived quality of technical material related to guidelines and procedures for the performance of work. These include work requests, job orders, policies, and procedures. Several problems with work procedures may arise. One problem involves the updating of procedure files. So much time may be required to incorporate updates and changes into the working files that new procedures are not always flagged, making it difficult for personnel to recognize and follow designated changes.

6.2.7 Other Indices

Other indices developed from the Organizational Communication Questionnaire may also be pertinent to different facilities. The areas addressed by the other indices are outlined below:

- o Trust refers to the sense of openness and confidence that personnel feel in relationship to their supervisors.
- o Influence refers to personnel perceptions of the extent to which their career development can be furthered by their supervisors.
- o Mobility refers to personnel interest in advancing to higher positions within the organization.
- o Upward Directionality, Downward Directionality, and Lateral Directionality indicate mobility tendency based on patterns of communication with higher level personnel, subordinates, and peers.
- o Accuracy refers to personnel perceptions of the reliability of information received from others at different levels within the organization.
- o Summarization refers to the extent to which personnel take responsibility for identifying important aspects and minimizing unimportant aspects when transmitting information within their own departments and to other departments.
- o Expansion refers to the extent to which personnel take responsibility for providing additional detail when transmitting information within their own departments and to other departments.
- o Desire for Interaction refers to the importance personnel place on interaction with higher level personnel, subordinates, and peers.

- o Changing Information refers to the extent to which personnel must transform information before passing it on to others within their own departments or in other departments.
- o Satisfaction refers to overall satisfaction with organizational communications.

Exhibit 6-1 in the Appendix identifies the questionnaire items that make up all of the indices described above.

6.3 Methods of Problem Identification

This section describes what is entailed in an organizational communication survey. It provides guidelines for: selecting those who should participate in the respondent sample, conducting the survey, and analyzing the survey responses. Requirements for the review team are also discussed.

6.3.1 Organizational Interface Review Team

Most work in the area of organizational communication has been conducted by trained professionals working as internal or external consultants to an organization. However, in the case of DOE facility reviews, this review is being suggested as part of a larger human factors program review. If consultants can be used, the assistance of one or two organizational/industrial psychologists would increase the efficiency of the review without excessive time demands on facility staff. Professional consultants are also in the best position to develop survey instruments, evaluate the survey data, and protect the confidentiality of the survey participants.

If the use of consultants is not a viable option, an internal team of two to three professionals with relevant skills and knowledge will be needed. The team should include someone with experience in designing and conducting surveys and in analyzing survey data. Basic statistical and computer skills may be needed for the data analysis effort.

Strong interpersonal skills are also needed for this type of assessment. Survey respondents must trust the members of the evaluation team if they are going to be candid about their true feelings regarding interface problems. The importance of confidentiality of responses cannot be overemphasized. For this reason, members of the review team should not be selected from the target functional areas (see Table 6-1, in the Appendix).

6.3.2 Definition of the Organizational/Interface Review Process

A minimum of three months should be allocated for the entire organizational interface review process, which includes seven major steps:

1. Formulation of questionnaire items
2. Selection of respondents
3. Distribution and collection of questionnaires
4. Analysis and interpretation of questionnaire data
5. Development and administration of interviews
6. Analysis and interpretation of interview data
7. Development of recommendations to facility management.

Each step of the review process will be described in the paragraphs below.

Questionnaire Item Formulation. Candidate organizational communication issues or problem areas must be broken down into component parts or characteristics that describe each issue. This type of review will provide the topics or areas that specific questions need to address.

Before creating questions to tap each characteristic, several guidelines are useful when developing a questionnaire:

- o Each question should ask for a response in terms of behavior or performance.
- o Descriptive questions should be kept to a minimum so that as much questionnaire time as possible can be devoted to evaluative questions.
- o Multiple-choice items should be used where possible to minimize completion time.
- o Time to complete the questionnaire should be limited to 30 minutes.
- o Respondent anonymity must be guaranteed.

Questions should be developed by reviewing each communication issue and its component characteristics. Where a question or group of questions can be identified from an existing survey or questionnaire (see Exhibit 6-2 in the Appendix), it should be modified as necessary to suit the DOE facility situation.

An initial list of questions should be reviewed for wording consistency, readability, content overlap, and clarity. These questions must then be formatted into a questionnaire and sent to subject matter experts for review. Also, a pretest using a small group of three to five employees from the functional areas listed in Table 6-1 should be conducted. The purpose of the pretest and review is to identify any additional problems in question wording and comprehension and to determine whether the questionnaire can be completed within 30 minutes. Based on pretest and reviews, questions should be modified and the questionnaire shortened as necessary. (A sample questionnaire is included in the Appendix as Exhibit 6-2.

Selection of Respondents. Where facility size permits, it is recommended that a minimum of 25 people be selected to complete the questionnaires. The sample should be chosen to represent all functional areas and job levels. Operators, technicians, craftsman, line supervisors, and department managers should be drawn from the following areas: Operations, Maintenance, Instrumentation and Control (I&C), Health and Safety, and Quality Assurance/Quality Control (QA/QC). The top-level manager at the facility should also participate. Since Operations and Maintenance typically have more staff than the other functional areas, twice as many questionnaires may be obtained from personnel in those areas. Table 6-1, in the Appendix, summarizes the type of vertical and horizontal representation that is needed.

Questionnaire Distribution and Collection. Each facility should name a point of contact who selects the individuals to participate in the survey and distributes and receives the questionnaires. The point of contact will need:

- o Instructions for distributing questionnaires (e.g., categories of employees to select, when to distribute, when to follow up), answers to anticipated questions, and the name and phone number of an evaluation team member to call in case of problems
- o Sets of questionnaires and instructions and the name and phone number of the on-site point of contact for distribution to participants

- o Follow-up memos for the point of contact to issue once, and again two weeks after initial questionnaire distribution
- o Return envelopes to be used by employees to return completed questionnaires to the review team. Each participant must be given a guarantee of complete anonymity.

Analysis and Interpretation of Questionnaire Data. After the completed questionnaires are collected they must be reviewed to ensure that they were properly completed (e.g., one response per questionnaire item unless specified as a multiple response item). After the initial review of the questionnaires, frequency data for each item should be computed. In this way, items of raw data become meaningful when they are grouped in a frequency distribution by type of respondent (e.g., department or job level). To analyze the frequency distribution of the scores, a measure of the central tendency or central point around which the scores scatter must be computed. The simplest measure, the mean, which is the same as the familiar arithmetic average, should be computed for the total group and for each functional group of respondents. Total and group means for each set of questionnaire items dealing with a specific type of communication (e.g., feedback or timelines) should be calculated to provide an easy comparison of group responses. More information about a distribution than can be obtained from the mean scores is needed to tell whether scores cluster closely around their average or whether they scatter widely. The most common measure of the dispersion of scores around the average is called the standard deviation.

Mean and standard deviation scores should be calculated for the total group, and also by type of respondent (each functional area or job level), depending on the number of respondents. For those items that are components of communication indices (see Exhibit 6-1 of the Appendix), index scores should also be calculated. Index scores for each questionnaire are determined by summing the individual item component scores, and then dividing the sum by the number of component items. Looking at the index scores across functional departments or job levels gives the review team a way of measuring the degree of consensus across groups regarding the existence of organizational communication problems. Thus, comparing index scores across functional areas or job levels may provide the best way to evaluate the data. Since the majority of questionnaire items are rated on a 1 (low) to 7 (high) scale the mean scores can be used to profile individual facility responses. Table 6-2 presents a summary of the major departmental communication

problems identified in three commercial nuclear power facilities using the questionnaire provided in the Appendix. A quick glance at Table 6-2 reveals that some departments perceive more communication problems within their organization than others. Contingency tables may also be generated for the index scores, and the chi-square test may be used to estimate the statistical significance of differences between functional areas and job categories.

Once the calculations have been made, the review team must examine the summary statistics and interpret the results in terms of how they may be applied to interaction patterns within the facility. A list of candidate problem areas may be defined and used to formulate the topic areas to be addressed in the follow-up interviews.

Interview Development and Administration. Follow-up interviews should be held with personnel from each of the functional areas included in the questionnaire sample in order to:

- o Ask plant personnel about key topics and problems that emerged from the questionnaire data
- o Expand on the definition of problem areas identified from the questionnaire data and other sources
- o Identify and verify problem areas and illustrate them with real-world behavioral examples or critical incidents that illustrate the role and importance of organizational communication factors.

To define specific questions to be used in the interviews, a set of guidelines similar to those used in the development of the questionnaires should be followed, with one notable exception. For the questionnaire, a multiple-choice format was suggested to keep questionnaire completion time to a minimum. Since there is no way to define what types of responses may be given in the interviews, open-ended questions must be used.

Using a critical-incident interview technique⁷ that focuses on real world examples of communication problems, interviewees should be asked to describe specific events that had or might have had effects on functional effectiveness and safety. This approach focuses on salient success, failure, near-miss, and delay situations that would provide insight into critical factors in performance effectiveness. Personnel should be asked about communication problem areas such as completeness of work requests, advanced planning, and interdepartmental coordination. Following is an example of the type of

question used: "Please describe a situation in which the facility's productivity and operation have had problems due to conflicting priorities." Suggested interview questions are provided in the Appendix (Exhibit 6-3).

Within each facility, the same type of cross section of personnel used in the questionnaire survey should be used for the verification interviews (see Table 6-1 in the Appendix). Adjustments may be made in the numbers of operators, technicians, and craftsmen for the interviews to minimize the burden on personnel. Included in the sample should be representatives of various organizational levels of Operations, Maintenance, I&C, QA/QC, and Health and Safety or other major functional areas.

Interview Analysis and Interpretation. Responses to each interview question must be analyzed and categorized. Exhibit 6-4, in the Appendix, illustrates the type of interview response tally sheet that may be used to summarize responses to the interview questions. Separate tallies should be made for each facility interviewed. Because the interview questions are open-ended, there may be many multiple responses to an item. Each type of response must be treated equally in the data summarization process.

Once the response tallies for each interview item have been obtained, the number of responses per category should be converted into a percentage of total responses for each item. By using percentages, it is easier to interpret what the data is suggesting in terms of identifying specific problem areas for a given group of respondents (functional area or job level) or response patterns across all groups. For example, Figure 6-1 (in the Appendix) illustrates how ratings for Operations, Maintenance, and Management differ widely depending on the job category of the respondents. Only 20 percent of respondents who were operators, mechanics, or technicians had problems dealing with the Operations and Maintenance departments; whereas, 34 percent to 40 percent of top level managers had interaction problems with the same Operations departments, and 40 percent of the top level managers reported problems with interfacing with their Maintenance departments. In contrast, the graph to the right shows that top level managers have far fewer problems interacting with their peers in management (22 percent) than the operators and maintenance personnel in their organizations have interacting with them (48 percent).

Integration of Findings. Interview and questionnaire results should be compared. Then a problem statement should be written that integrates results from the two sources and

describes the nature and extent of organizational interface problems that have been indicated.

Development of Recommendations to Facility Management. For development of recommendations, the review team should be augmented by additional personnel who have in-depth knowledge of the facility and the activities performed in the different functional areas. At this point, personnel in the areas from which questionnaire and interview participants were drawn need to become involved in the process of evaluating the findings and developing recommendations.

Translating the problem statements into recommendations for management to act on is not an easy undertaking. Some techniques and guidelines that may be used to formulate recommendations are suggested below:

- o Brainstorm alternative solutions to the problem (see Section 6.4).
- o Discuss the "what," "where," "when," "who," "why," and "how" of each alternative.
- o Invite subject matter experts from outside the facility to contribute.
- o Visit similar facilities to gain insight into what solutions may have worked elsewhere.
- o Prepare a cost-benefit analysis of the alternatives to select the best one.
- o Develop an action plan outlining the problem statement, impact of problem, solution, implementation strategy, schedule, and benefits.
- o Anticipate and plan for any objections or questions regarding the action plan.
- o Use adequate documentation: charts, graphs, and references.

6.4 Methods of Problem Solving

Once the problem definition or diagnostic phase of the organizational interface review is complete, the focus of the evaluation team must shift to concentrate on defining the best approach to solve or resolve the interface issues. Therefore, to ensure that the evaluation team's recommendations for change are tailored to the important issues and take into account resource availability, a review of candidate solutions is warranted.

Five solutions thought to be the most effective for dealing with organizational interfaces include quality circles, interdepartmental job coordination meetings, maintenance management information systems, orientation training, and policies and procedures. In the paragraphs below, each solution strategy will be defined in terms of its methodological approach and resource requirements.

6.4.1 Quality Circles

Stemming from the Japanese efforts to improve the quality control of their products, quality circles (sometimes referred to as pride circles) have developed in many U.S. organizations and taken on a broader focus.⁸ Quality circles may be defined as small groups of employees (approximately 10) who do similar or related work and meet regularly (usually one hour a week) on company time to identify, analyze, and solve work-related problems. The decision to implement quality circles as a vehicle for improving organizational interfaces involves a significant commitment by the organization's management. Eight to ten training sessions are required to familiarize circle participants with the quality circle process, problem-solving skills, and participative management strategies. Each circle has a facilitator to guide the group interactions; facilitators require additional front-end training to prepare them for their unique roles.

The decision to implement quality circles in an organization is a big one. It involves the long-term commitment of many personnel resources to bring such a program to fruition. The development, training, and implementation process may take one to two years. Many large manufacturing organizations have been impressed with the positive recommendations and more participative atmosphere that have resulted from the quality circles. However, no organization should consider implementing quality circles for short-term gains.

6.4.2 Interdepartmental Job Coordination Meetings

In contrast to quality circles, described above, regular (e.g., daily, interdepartmental job coordination meetings for supervisors focus on the sharing of information between departments which is crucial to the efficient operation of the facility. During job coordination meetings, participants review specific work requirements in order to determine priorities and to resolve scheduling conflicts between departments. In these meetings, representatives from the different departments discuss the status of ongoing work orders, plan upcoming work, and review completed work. The purpose of such

meetings is to improve the quality, timeliness, and amount of information transmitted between departments and to encourage better feedback between departments and between upper management and the lower levels.

Daily interdepartmental job coordination meetings should last approximately 15 minutes and should follow a standard agenda similar to that shown in Table 6-3 (in the Appendix). This structure actually serves two purposes in the job coordination meeting: it provides guidelines for the meeting and serves as an information collection form to characterize specific communication problems. Participants discuss and resolve work problems, plan future work, and provide feedback to one another.

The advantage of the job coordination meetings over the more formal quality circle concept is that it institutionalizes daily interdepartmental contact to address interface issues while minimizing the time and training requirements associated with the interaction.

6.4.3 Maintenance Management Information Systems (MIS)

With the rapidly increasing high technology systems needed to operate the DOE facilities, maintenance management information requirements are also growing. Automated systems for handling both corrective and preventive maintenance have been introduced at a number of DOE facilities as well as at commercial nuclear plants. The organizational interface aspects of these systems emphasize the availability of timely and accurate information to a broad spectrum of system users. These systems would reduce the need for face-to-face corroboration prior to the initiation of work. A maintenance MIS, whether automated or not, should provide for the timely notification of functional areas regarding work requirements, schedules, and status, as well as provide feedback between affected departments.

The design of an automated maintenance MIS can require a significant investment of resources. Facilities have spent as much as two years in defining and coding their equipment inventories and performing needs assessments, which are keys to the system's success. A dedicated design team is needed for the effort. Some hardware/software packages are commercially available to minimize design costs; however, these packages have limited flexibility to tailor the system for a specialized application. The user of canned programs often becomes bound to their structure, rather than having the system serve as a tool for the user.

5.4.4 Orientation Training

Another approach to improving organizational interfaces is to develop a set of orientation training modules that address lines of authority, areas of responsibility, and other coordination issues tailored to the structure of each facility. Training modules may be designed to provide new personnel with the following:

1. An understanding of how the system works
2. Identification of roles and required authorizations
3. Explanation of time/performance requirements for each responsible individual
4. Encouragement towards interdepartmental information exchange and feedback
5. Knowledge of how to prepare required forms, including the formulation of problem descriptions and the accurate identification and location of equipment.

The approach for developing orientation modules on organizational communication and the work request process is to first define specific training objectives. In conjunction with the definition of training objectives, skill and knowledge requirements or enabling skills must be identified to ensure that the objectives are met. It often is necessary to tailor such training modules for different functional areas/departments and for different job levels.

Members of the organizational interface review team should meet with subject matter experts to establish the training requirements. The available documentation of interface requirements will be needed as reference data for the preparation of the training modules. If training personnel are available to develop the training modules, they should work in conjunction with the review team and subject matter experts to ensure that the communication issues identified in the organizational interface review are addressed in the modules. To optimize the usefulness of the modules, a job-performance-aid (JPA) format is suggested. JPA formats involve the integration of graphics and text and could be used to provide procedural guidance as well as descriptive information about specific functions or interfaces to be covered.

Representatives from the facility's major functional areas should be asked to review each module to verify its technical accuracy. In addition, comments on the modules should be requested from the first set of recipients for evaluation purposes. Modifications to the modules should be made on the basis of such input.

6.4.5 Modification of the Organizational Structure

The organizational structure itself can promote or deter effective communications. A recent study of the organizational effectiveness and safety performance of commercial nuclear power plants found that the plants with more vertical ranks and broader spans of control were poorer performers.⁹ It found that coordination among the functional areas was a key to successful operation. Organizational structures can be modified by a concerted effort on the part of the organization's management to optimize, clearly delineate, and document the lines of authority, span of control, and interaction patterns for its personnel. Often, the organizational structure is influenced by the personalities of the job incumbents or by conformity to known stereotypes rather than objectively designed to optimize the effectiveness of the organization.

Management can make significant changes in organizational interfaces by rearranging the organizational structure and mandating specific interaction procedures to accommodate routine and problem conditions. However, maximum gains in this area are only the product of: careful analysis of the problems, definition of organizational changes to address them, and distribution of the information and authority necessary to institutionalize the changes. Management's commitment to and support of such efforts are essential to their success. In addition, input from those functional areas or job levels most affected by the changes should be incorporated into the development of any policy or guideline documentation.

6.5 Assessment of Possible Solutions To Improve Organizational Interfaces

6.5.1 Criteria

Just as diagnostic criteria were needed to help identify organizational interface problems, assessment criteria are necessary to weigh or rate the relative desirability of each strategy for solving the organizational interface problems. A set of assessment criteria is suggested below for use in each facility in making the decision of which solution, or combination of solutions, to implement.

- o Relevance to Organizational Interface Issues. This criterion estimates the degree to which the candidate solution addresses the improvement of real-world organizational communication issues identified at the facility. High relevance ratings are optimum.
- o Payoff to Facility. This criterion estimates the relative amount of improvement in coordination and organizational effectiveness that can be expected if the solution is implemented. High potential payoffs are most desirable.
- o Evidence of Effectiveness. This criterion assesses whether or not the proposed solution has been used in analogous organizations to improve the internal communications and effectiveness of their operations. High ratings regarding the perceived appropriateness of the techniques are desirable.
- o Ease of Implementation. This criterion assesses the level of involvement on the part of the facility's management and technical personnel that will be necessary to implement candidate solution. The greater the involvement that is required, the lower the rating for ease of implementation. High ratings are preferred.

6.5.2 Assessment Procedure

The organizational interface review team may use the criteria definitions provided above to determine the suitability of the potential solutions. A five-point rating scale (1=low; 5=high) can be used by each member of the evaluation team to rate the interventions on each criterion. Exhibit 6-5, in the Appendix, presents a sample form to be used for completion of the assessment criteria ratings. Once individual ratings have been obtained, mean ratings for the group can be calculated to determine the best estimate of the desirability of each option. These ratings should be addressed in the preparation of recommendations to the facility's management as part of the rationale for selecting one type of solution over other options. Trade-offs will have to be made if one technique seems most preferable in terms of one criterion (e.g., relevance) but is less desirable in terms of others (e.g., ease of implementation).

7.2 Application

Training problem identification is the "trigger" for a training program review. Problem identification can come from a variety of sources, such as:

- o Accident/Incident Reports
- o Human Factors Engineering Review
- o Procedures Review
- o Organizational Interface Review.

In any case, once a training problem has been identified, certain steps should be taken in order to correct it. These steps are referred to as a Training Review.

7.2.1 Training Review Objective

The objective of a Training Review is two-fold:

1. Validate that the training problem identified is in fact a training problem, and
2. Once validated, correct the problem.

During the training review process, other problems related to the identified training problem may surface. For example, the operation or maintenance procedure used to perform the function may be inadequate. These should be dealt with separately, using appropriate DOE guidance.

7.2.2 Training Review Criteria

Several types of criteria may be used in a training review. The guidance developed to date for DOE nuclear facilities includes the following:

- o Program organization and management
- o Qualification of training staff
- o Trainee selection
- o Content and conduct of training (includes initial training and periodic update/requalification training)
- o Trainee examinations and subsequent on-the-job competency checks
- o Program supporting resources.

APPENDIX

It is advisable to conduct a thorough training review in order to ensure that all facets of the problem are identified and corrective action taken.

7.2.3 Training Review Method

The training review should always be done using training staff personnel as well as technical, operations, or maintenance personnel as appropriate. This will ensure that the corrective actions taken will be appropriate and that all parties affected concur in the action.

In most cases the starting point is to review all course materials that relate to the training problem identified. The training staff will be most helpful since they will be familiar with course conduct and content.

Once the problem is isolated within a course, a decision can be made concerning what corrective action is to be taken. This decision must be carefully made as it may have far reaching consequences on other facets of the training process. For example, changing course content in the affected course may affect materials taught in a related course. In other words, fixing the problem in one course may very well require changes to be made in one or more related courses, or even the creation or deletion of a course.

It is stressed that training development and evaluation efforts should be coordinated with other human factors applications to achieve integrated, mutually reinforcing results. Equipment design, procedures, communication processes, and training combine to produce the total human factors environment. They should compliment and be consistent with each other. As changes are made in any one of these areas, corresponding changes may be needed in others to maintain human factors integration.

3.0 SELECTION OF AREAS FOR REVIEW

REVIEW AIDS

The resolution of review findings should not necessarily specify the details of each change to be made. It should identify the types of changes needed and classify procedures accordingly. It should also identify the types of personnel needed to develop the changes. A projected schedule can be prepared based on the types of changes.

EXHIBIT 3-1

EXAMPLE CRITICAL INCIDENT QUESTIONNAIRE ITEMS FOR A NEEDS ASSESSMENT

Workspace Layout and Environment

"Describe at least three aspects of the workspace, furniture, equipment layout, or environmental conditions that you find particularly bothersome. Describe specific incidents or ways in which these have been ineffective and have interfered with job performance."

Panel Design

"Can you think of any occurrences when someone has activated the wrong control, activated a control inadvertently, or activated a control incorrectly?" (Probes: Why did this happen? What system and panel were involved? How and when was the mistake discovered? What was the consequence?)

"Describe any changes to the facility that you feel would improve worker's capability to recognize and control normal and abnormal plant operating conditions."

"What do you consider to be the three most confusing or difficult systems to work on and why? Give an example of an incident in which there was difficulty with the system."

Annunciator Warning System

"Describe any features of your annunciator warning system that you feel have resulted in inefficient or erroneous fault isolation."

Computer-Based Systems

"Describe at least three characteristics of your computer-based systems that you consider awkward or difficult to use under normal, abnormal, and emergency conditions."

Corrective Maintenance

"Can you think of incidents in which a defect of the corrective maintenance program caused an operational problem? If so, please describe what happened and explain the problems with the maintenance program."

"Can you think of any situations in which characteristics of the maintenance program caused delay or difficulty in performing corrective maintenance? If so, please explain."

"Can you think of any situations when equipment design or characteristics of the workspace contributed to error, difficulty, or delay in performing corrective maintenance? If so, please explain."

Preventive Maintenance, Testing, and Calibration

Note: repeat questions stated under the heading Corrective Maintenance, but replace "corrective maintenance" with "Preventive Maintenance, Testing, and Calibration."

Communications

"Describe any problems with the facility communications systems (phones, page phones, loudspeakers, radios, etc.) that have prevented or interfered with your ability to communicate with other personnel."

Organizational Interface

"Describe any problems with receiving inadequate information from other departments."

"Describe any work delays that are caused by poor communications between departments/functional areas."

Procedures

"Describe at least three incidents in which your procedures did not provide clear guidance and resulted in ineffective or erroneous performance."

Training

"Describe at least three characteristics of your training (classroom, OJT, self-study, or other) that you feel were inadequate in preparing you for your job responsibilities."

EXHIBIT 3-2

EXAMPLE SCALAR QUESTIONNAIRE ITEMS FOR A NEEDS ASSESSMENT

Please answer all of the questions from the perspective of your functional area.

How satisfied are you with the following aspects of your facility?

	Very Dissatisfied 1	Somewhat Dissatisfied 2	Neither Satisfied Nor Dissatisfied 3	Fairly Satisfied 4	Very Satisfied 5
Workspace Layout	_____	_____	_____	_____	_____
Environment	_____	_____	_____	_____	_____
Equipment Design for Operability	_____	_____	_____	_____	_____
Equipment Design for Maintainability	_____	_____	_____	_____	_____
Annunciator Warning System	_____	_____	_____	_____	_____
Computer-Based Systems	_____	_____	_____	_____	_____
Corrective Maintenance	_____	_____	_____	_____	_____
Preventive Maintenance, Test, and Calibration	_____	_____	_____	_____	_____
Safety-Radiological	_____	_____	_____	_____	_____
Safety-Industrial	_____	_____	_____	_____	_____
Communication Systems	_____	_____	_____	_____	_____
Organizational Interfaces	_____	_____	_____	_____	_____

	Very Dissatisfied 1	Somewhat Dissatisfied 2	Neither Satisfied Nor Dissatisfied 3	Fairly Satisfied 4	Very Satisfied 5
Procedures	_____	_____	_____	_____	_____
Operating	_____	_____	_____	_____	_____
Maintenance	_____	_____	_____	_____	_____
Emergency	_____	_____	_____	_____	_____
Training	_____	_____	_____	_____	_____
Comments:	_____				

TABLE 3-1

**TYPICAL CROSS SECTION OF DOE FACILITY PERSONNEL SELECTED
FOR A NEEDS ASSESSMENT SURVEY**

<u>Functional Area</u>	<u>Operators/ Technicians/ Craftsman</u>	<u>Line Supervisors</u>	<u>Department Managers</u>	<u>Facility Manager</u>
Operations	3	1	1	
Maintenance	3	1	1	1
I&C	3	1	1	
Health and Safety	2	1	1	
Quality Control/ Quality Assurance	2	1	1	
Training	2	1	1	
Technical Documentation and Procedures	<u>2</u>	<u>1</u>	<u>1</u>	-
Subtotals	17	7	7	1

Total: 32 personnel per facility receiving questionnaires out of a staff of 96.

3.0 SELECTION OF AREAS FOR REVIEW

REFERENCES

1. Flannagan, J. The critical incident technique. Psychological Bulletin, 1954, 51, 327-358.
2. Guidelines for control room design reviews (NUREG-0700). Division of Human Factors Safety, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, D.C., 1981.

4.0 HUMAN FACTORS ENGINEERING REVIEW

REVIEW AIDS

EXHIBIT 4-1
EXAMPLE OF AN OBSERVATION CHECKLIST FOR
HFE REVIEW OF OPERABILITY (partial)

(Source: Essex Corporation, Systems Operability and Design Group, 1983.)

This checklist includes a comprehensive set of HFE criteria that are appropriate for an observation survey of displays (excluding CRT displays). The criterion source is NUREG-0700 (reference 18).

Similar checklists are needed to address other HFE topics. Because of the number of criteria involved and length limitations of this Review Plan, a full set of checklists to cover each topic is not given.

EXHIBIT 4-1 (continued)

N/A	YES	NO	COMMENTS

ALL DISPLAYS

1. For highest contrast, visual displays should have black markings on a white scale; however, this does not mean that color should not be used as long as the colors used provide good contrast — 6.5.1.3c(1)&(2).
2. The color used for coding any display should contrast well with the panel background — 6.5.1.6e(2).
3. Any given color used for display coding should be recognizable from all other display code colors for all illumination conditions — 6.5.1.6e(3).

ALL INDICATOR LIGHTS

4. Ambient lighting should not be so bright or reflective that it causes indicator lights to appear on when they are off, or off when they are on — 6.5.3.1b.

SIMPLE INDICATOR LIGHTS

5. Colors used for indicator lights should be clearly identifiable — 6.5.3.2a(3).

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
6. Where meaning is not apparent, message label should be located in close proximity to the indicator light — 6.5.3.2a(1).				
LEGEND LIGHTS				
7. Legends should be legible under ambient lighting with indicator lights off — 6.5.3.3a(2).				
8. Legend lettering should contrast well with background under both ambient and trans-illuminated lighting — 6.5.3.3a(3).				
9. General design of legend light indicators should be consistent throughout the control room — 6.5.3.3b(1).				
10. Legend symbols should be clear and unambiguous as to their meaning — 6.5.3.3b(3).				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
11. Legend text should be short, concise, and unambiguous — 6.5.3.3b(4).				
12. Legend messages should contain no more than three lines of text — 6.5.3.3b(5).				
13. Nomenclature and abbreviations on legend light indicators should be standard, and consistent with usage throughout the control room and in the procedures — 6.5.3.3b(6).				
14. The wording in a legend should only signify the stated condition when the light is illuminated (e.g., an OFF legend that means off when the light is out is incorrect) — 6.5.3.3b(7).				
METERS AND RECORDERS				
15. When scale multipliers are used, they can be clearly seen and they use the powers-of-ten to indicate multiplication or division — 6.5.1.2e, 6.5.1.4f & 6.5.4.1c.				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
16. Character style used on any display should be simple block style with no serifs or embellishments, upper-case only, and be consistent — 6.5.1.3b & 6.5.3.3b(2).				
17. If information is required to use a scale, the message should be placed in close proximity to the scale (i.e., printed on the display face or adjacent to it) — 6.5.1.4a(1)&(2) & 6.5.4.1c.				
18. Information not needed in using a display should not be printed on the display face (i.e., patent notices, manufacturer's trademark, etc.) — 6.5.1.4b & 6.5.4.1c.				
19. Messages printed on display faces should be as brief as clarity permits — 6.5.1.4c & 6.5.4.1c.				
20. Individual numerals on any type of fixed scale (i.e., circular, linear) should be vertical — 6.5.2.4a.				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
21. Scales for quantitative reading should be provided with graduations consistent with the progression of their numerals — 6.5.1.5a & 6.5.4.1c.				
22. No more than nine graduations should separate numerals on scales — 6.5.1.5a(1) & 6.5.4.1c.				
23. Major and minor graduation should be used if there are up to four graduations between numerals on scales — 6.5.1.5a(2) & 6.5.4.1c.				
24. Major, intermediate, and minor graduations should be used if there are five or more graduations between numerals on scales — 6.5.1.5a(3) & 6.5.4.1c.				
25. Values indicated by unit graduations should progress by 1, 5, or 10, or those values multiplied by some power of 10, or at least progress by 2 or 2 multiplied by some power of 10 — 6.5.1.5a(3) & 6.5.4.1c.				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
METERS				
26. Circular scale values should increase with clockwise movement of the pointer — 6.5.2.1a.				
27. Vertical straight scale values should increase with upward movement of the pointer — 6.5.2.1b.				
28. Horizontal straight scale values should increase with pointer movement to the right — 6.5.2.1c.				
29. Pointer tips should be simple (e.g., arrow-head, triangular, or blunt-tipped needle) — 6.5.2.2a(1).				
30. Pointer tips should be selected to minimize concealment of scale graduation marks or numerals — 6.5.2.2a(2).				
31. Pointers should be mounted close to the scale to avoid parallax — 6.5.2.2b(2).				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
32. Pointer/background contrast and pointer size should be adequate to permit rapid recognition of pointer position — 6.5.2.2c.				
33. Zone markings should be conspicuous and distinctively different for different zones — 6.5.2.3a.				
34. Zone marking should not interfere with reading of quantitative markings — 6.5.2.3b.				
35. If colored zones are used:				
a. Red should mean unsafe, danger, or out of tolerance.				
b. Green should mean safe, or in tolerance.				
c. Amber (yellow) should mean hazard, caution, potentially unsafe or marginal value — 6.5.1.6c(2) & 6.5.2.3c				
36. Where pointer movement is more than 360°, the zero point should be located at the 12 o'clock position — 6.5.2.4b(1).				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
37. Where positive and negative values are displayed around a zero or null position, the zero or null point should be located at the 12 o'clock position — 6.5.2.4b(2).				
38. Where the scale covers less than a full rotation of the pointer, scale end-points should be indicated by a break in scale — 6.5.2.4c(1).				
39. Scale end-point breaks should be at least one numbered interval in length — 6.5.2.4c(2).				
40. Scale end-point breaks should be oriented at the 6 o'clock position — 6.5.2.4c(3).				
ALL CHART RECORDERS				
41. Pens, inks, and paper used in chart recorders should be of a quality to provide clear, distinct, and reliable marking (i.e., ink does not clog pens or smudge on paper) — 6.5.4.1a.				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
42. Scales printed on the recording paper should be the same as scales shown on the recorder — 6.5.4.1b.				
43. Chart recorders which must be monitored by the operator should be located within the primary operating area — 6.5.4.1h.				
44. All data should be visible through the window of the chart recorder and not require an operator to open the door — 6.5.4.1k.				
PEN RECORDERS				
45. Labels should identify the parameters on all multiple-pen recorders, and the parameters should be listed in the order of the associated scales — 6.5.4.2a(1).				
46. On multiple-pen recorders, each pen should use a different colored ink — 6.5.4.2a(2).				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
47. Colors used on multiple-pen recorders should be distinctly different and should afford good contrast with the paper — 6.5.4.2a(2).				
IMPACT RECORDERS				
48. Imprint heads on impact recorders should be easy to view. Odd and inconvenient viewing angles should be avoided — 6.5.4.2b(2).				
49. The number-printing mechanism on impact recorders should be designed and maintained to provide clear, sharp, and small numbering to avoid crowding of data — 6.5.4.2b(3).				
DRUM STYLE COUNTERS				
50. Multidigit numbers formed by several counter drums should be oriented horizontally from left to right — 6.5.5.1a(1).				
51. If more than four digits are required on drum-type counters, they should be grouped and the grouping separated as appropriate by commas, by a decimal point, or by additional space — 6.5.5.1a(3).				

EXHIBIT 4-1 (continue)

	N/A	YES	NO	COMMENTS
52. For high contrast, black numerals on a white drum surface is recommended — 6.5.5.1a(4).				
53. Drum surfaces and surrounding areas should have a matte finish to minimize glare — 6.5.5.1a(5).				
54. Drum-type counters should be mounted perpendicular to the operator's line of sight — 6.5.5.1b(1).				
55. Drum-type counters should be mounted as close as possible to the panel surface to minimize shadows and maximize viewing angle — 6.5.5.1b(2).				
56. Windows on drum-type counters should allow only one digit per drum to appear in the window at any one time — 6.5.5.1b(3).				

EXHIBIT 4-1 (continued)

	N/A	YES	NO	COMMENTS
57. Numbers should change by snap action rather than through continuous movement on drum-type counters — 6.5.5.1c(1).				
58. Counter drums should move upward with increasing values — 6.5.5.1c(2).				
ELECTRONIC COUNTERS				
59. Numerals on multidigit electronic counters should be oriented to read horizontally from left to right — 6.5.5.2a(1).				
60. Simple, uniform character font style should be used on electronic counters (i.e., variable stroke widths, slanted characters, etc., should be avoided) — 6.5.5.2a(2).				

EXHIBIT 4-2
EXAMPLE OF AN OBSERVATION CHECKLIST FOR
HFE REVIEW OF MAINTAINABILITY

(Excerpt from: Greth, R.L. & Block, C.A. (1983). Methodology investigation - Human factors engineering test procedure for Army aviation, Appendix C design checklist for maintainability. Fort Rucker, AL: U.S. Army Aviation Development Test Activity.)

<u>Detailed Design Considerations</u>	<u>YES</u>	<u>NO</u>	<u>N/A</u>	<u>COMMENTS</u>
1. Equipment uses standard parts to the extent possible. (MIL-STD-1472C, para 5.9.1.1)				
2. Special adjusting tools are securely mounted in a readily accessible location. (MIL-STD-1472C, para 5.9.1.2)				
3. Equipment is replaced in modular packages. (MIL-STD-1472C, para 5.9.1.3)				
4. Equipment can be rapidly and easily removed and replaced by one person, within weight limitations contained in Paragraph 5.9.11.3 of MIL-STD-1472C (ref 29). (MIL-STD-1472C, para 5.9.1.3)				
5. Number of inputs to and outputs from a unit are minimized by grouping functions. (MIL-STD-1472C, para 5.9.1.4)				
6. Unitized functions allow each item to be checked and adjusted separately. (MIL-STD-1472C, para 5.9.1.5)				
7. Equipment is designed to facilitate rapid and positive fault detection and isolation. (MIL-STD-1472C, para 5.9.1.6)				

YES = Adequate NO = Inadequate N/A = Not Applicable

Detailed Design Considerations	YES	NO	N/A	COMMENTS
8. Equipment is designed for easy assembly and disassembly. (MIL-STD-1472C, para 5.9.1.7)				
9. Equipment can be removed, replaced, and repaired wearing personal and special purpose clothing and equipment, if applicable. (MIL-STD-1472C, para 5.9.1.8)				
10. Similar components cannot be physically interchanged unless functionally the same. (MIL-STD-1472C, para 5.9.1.9a)				
11. Components cannot be improperly mounted. (MIL-STD-1472C, para 5.9.1.9b)				
12. Coding, etc. is used for easy identification of components. (MIL-STD-1472C, para 5.9.1.9c)				
13. Alignment pins, etc. are used for easy mounting of components. (MIL-STD-1472C, para 5.9.1.9d)				
14. Cables and connectors are designed for easy identification, orientation, and alignment. (MIL-STD-1472C, para 5.9.1.9e)				
15. Parts are mounted so that a lower layer does not support an upper layer. (MIL-STD-1472C, para 5.9.2.1)				
16. Similar, but not functionally related, items are mounted with a standard orientation but are readily identifiable and distinguishable. (MIL-STD-1472C, para 5.9.2.2)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES NO N/A COMMENTS
17. Delicate items are located or guarded so that they aren't susceptible to damage during service. (MIL-STD-1472C, para 5.9.2.3)	
18. Maintenance controls comply with para 5.4 controls and para 5.5 labeling of MIL-STD-1472C (ref 29). Refer to Sections 2.3 and 2.4. (MIL-STD-1472C, para 5.9.3)	
19. Knobs are used for calibration controls when frequent adjustments must be made. (MIL-STD-1472C, para 5.9.3.1)	
20. Screwdriver adjustments made without the aid of vision are designed to preclude screwdriver slipping. (MIL-STD-1472C, para 5.9.3.2)	
21. Reference scales or other feedback methods are available and visible for all adjustment controls. (MIL-STD-1472C, para 5.9.3.3)	
22. Adjustment or calibration controls with limited degree of motion have mechanical stops that prevent damage. (MIL-STD-1472C, para 5.9.3.4)	
23. Sensitive adjustment points are guarded against inadvertent movement. (MIL-STD-1472C, para 5.9.3.5)	
24. Hand or arm support is provided when adjustment is performed in a vibration or acceleration environment. (MIL-STD-1472C, para 5.9.3.5)	

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
25. Internal controls are not located close to dangerous voltage, rotating machinery, or other hazards without shielding and labeling. (MIL-STD-1472C, para 5.9.3.6)				
26. Structural members do not prevent access to or removal of items. (MIL-STD-1472C, para 5.9.4.1)				
27. Replaceable items are not mounted so that they are difficult to remove. (MIL-STD-1472C, para 5.9.4.1)				
28. The removal of panels, cases, and covers is not blocked by structural members or other items. (MIL-STD-1472C, para 5.9.4.1)				
29. Large, difficult to remove items do not prevent convenient access to other items. (MIL-STD-1472C, para 5.9.4.2)				
30. Check points, adjustment points, test points, cables, etc. are accessible and visible during maintenance. (MIL-STD-1472C, para 5.9.4.3)				
31. Space exists for the use of test equipment and other tools. (MIL-STD-1472C, para 5.9.4.3)				
32. Equipment requiring rear access is free to open or rotate the full distance and remain in the open position without hand support. (MIL-STD-1472C, para 5.9.4.4)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
33. Critical items requiring rapid maintenance are most accessible. (MIL-STD-1472C, para 5.9.4.5)				
34. Items requiring most frequent access, when criticality is not an issue, are most accessible. (MIL-STD-1472C, para 5.9.4.5)				
35. High-failure-rate items are replaceable without having to remove other items. (MIL-STD-1472C, para 5.9.4.6)				
36. Mechanical items are removable with common tools. (MIL-STD-1472C, para 5.9.4.6)				
37. Access to equipment does not require removal of equipment maintained by another technician. (MIL-STD-1472C, para 5.9.4.7)				
38. Mechanical items can be lubricated without disassembly. (MIL-STD-1472C, para 5.9.5.1)				
39. Extended fittings are provided for lubrication of difficult to access equipment. (MIL-STD-1472C, para 5.9.5.1)				
40. Type and frequency of lubrication is specified by label near the lube port. (MIL-STD-1472C, para 5.9.5.2)				
41. Lubrication chart of permanent construction is mounted at the operator station. (MIL-STD-1472C, para 5.9.5.2)				
42. Cover and shield holes are large enough for mounting screw clearance without perfect case alignment. (MIL-STD-1472C, para 5.9.6)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES NO N/A COMMENTS
43. Item orientation within its case is obvious. (MIL-STD-1472C, para 5.9.7.1)	
44. Cases lift from items, if possible. (MIL-STD-1472C, para 5.9.7.2)	
45. Cases are sufficiently larger than items to minimize potential damage to items. (MIL-STD-1472C, para 5.9.7.3)	
46. Guides, tracks, and stops are provided for case removal and replacement. (MIL-STD-1472C, para 5.9.7.4)	
47. Unsecured covers are obvious. (MIL-STD-1472C, para 5.9.8.1)	
48. Instructions for opening covers are permanently displayed, if not obvious. (MIL-STD-1472C, para 5.9.8.2)	
49. Bulkheads, brackets, and other units do not interfere with removal or opening of covers. (MIL-STD-1472C, para 5.9.8.3)	
50. An access is provided for frequent maintenance which would otherwise require opening a cover, removing a case, or dismounting an item. (MIL-STD-1472C, para 5.9.9.1)	
51. Nonremovable access covers are self-supporting. (MIL-STD-1472C, para 5.9.9.2)	
52. Accesses and covers are devoid of sharp edges. (MIL-STD-1472C, para 5.9.9.2)	

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
53. Accesses are labeled with nomenclature for items reached through it, auxiliary equipment used with it, and procedures. (MIL-STD-1472C, para 5.9.9.3)				
54. Accesses are labeled with warning signs of hazards beyond. (MIL-STD-1472C, para 5.9.9.3)				
55. Access warning labels are 25% larger than extended instructions. (MIL-STD-1472C, para 5.9.9.3)				
56. Instructions on hinged doors are readable when the door is open. (MIL-STD-1472C, para 5.9.9.3)				
57. Access openings for adjusting or handling interior items are large enough for the operation and provide an adequate view. (MIL-STD-1472C, para 5.9.9.4.1)				
58. Access covers have grasp areas or other means for opening them. (MIL-STD-1472C, para 5.9.9.4.1)				
59. Dimensions for access openings conform to Figure 45, MIL-STD-1472C (ref 29). (MIL-STD-1472C, para 5.9.9.4.1)				
60. Allowance is made for the clearance of operator's gloved or mittened hand on externally located accesses. (MIL-STD-1472C, para 5.9.9.4.1)				
61. Accesses are equipped with an interlock to de-energize hazardous equipment. (MIL-STD-1472C, para 5.9.9.4.1)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
62. Openings requiring visual access only are not covered, except where required for adequate system performance. (MIL-STD-1472C, para 5.9.9.5)				
63. Number of fasteners used is the minimum required given other requirements. (MIL-STD-1472C, para 5.9.10.1)				
64. Fastener removal, if not hand-operated, can be accomplished using standard tools. (MIL-STD-1472C, para 5.9.10.1)				
65. Hinges and tongue-and-slot catches are used. (MIL-STD-1472C, para 5.9.10.2)				
66. Captive bolts and nuts are used where necessary. (MIL-STD-1472C, para 5.9.10.3)				
67. Captive fasteners are used on cases and covers. (MIL-STD-1472C, para 5.9.10.3)				
68. Fasteners are of the same type and size. (MIL-STD-1472C, para 5.9.10.3)				
69. Where quick-opening fasteners cannot be used, the minimum number of the largest screws possible will be used. (MIL-STD-1472C, para 5.9.10.4)				
70. Screws, bolts, and other fasteners that require more than 14 N-m (10ft-lbs) torque have hex type external grip-heads. (MIL-STD-1472C, para 5.9.10.5.1)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
71. Screws, bolts, and other fasteners that require less than 14 N-m (10ft-lbs) torque have hex type internal, external, or combination grip-heads. (MIL-STD-1472C, para 5.9.10.5.2)				
72. Internal grip-head fasteners are used only where a straight or convex smooth surface is required. (MIL-STD-1472C, para 5.9.10.5.2)				
73. Straight-slot or phillips type internal grip fasteners are not used except as wood fasteners or on standard commercial items. (MIL-STD-1472C, para 5.9.10.5.2)				
74. Identical screw and bolts heads are used on each panel or components. (MIL-STD-1472C, para 5.9.10.5.3)				
75. Combination bolt heads (e.g., slotted and hex) are used. (MIL-STD-1472C, para 5.9.10.5.3)				
76. Mounting bolt heads and fasteners are readily accessible. (MIL-STD-1472C, para 5.9.10.6)				
77. Assembly and subassembly mounting fasteners require only one complete turn for disconnection, where practical. (MIL-STD-1472C, para 5.9.10.7)				
78. For machine screws and bolts, the number of turns and required force is no more than necessary. (MIL-STD-1472C, para 5.9.10.7)				
79. Fastener requirements are posted on an instructional label or placard. (MIL-STD-1472C, para 5.9.10.8)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
80. Rests and stands are provided when required and are part of the basic unit, rack, or console chassis. (MIL-STD-1472C, para 5.9.11.2)				
81. All cables, hoses, and other accessories, etc., can be easily removed or disconnected from equipment before handling. (MIL-STD-1472C, para 5.9.11.2)				
82. Lifting and carrying weight limits conform to Table XXIV in MIL-STD-1472C (ref 29). (MIL-STD-1472C, para 5.9.11.3.1.1 and 5.9.11.3.2)				
83. Items weighing more than one-person lifts are prominently labeled with weight and lift limitation. (MIL-STD-1472C, para 5.9.11.3.1.2)				
84. Horizontal push and pull forces conform to Table XXV (or Figure 21) of MIL-STD-1472C (ref 29). (MIL-STD-1472C, para 5.9.11.4.1)				
85. Vertical push and pull forces conform to Table XXVI (or Figure 21) of MIL-STD-1472C (ref 29). (MIL-STD-1472C, para 5.9.11.4.2)				
86. Removable or carried units designed to be removed and replaced have handles or other suitable means for manipulating. (MIL-STD-1472C, para 5.9.11.5.1)				
87. Items have at least two handles, or one handle and one grasp area. (MIL-STD-1472C, para 5.9.11.5.1)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
88. If possible, handles or grasp areas are located relative to the center of gravity. (MIL-STD-1472C, para 5.9.11.5.2)				
89. Handles or grasp areas have at least 50mm (2 in.) of clearance from obstructions. (MIL-STD-1472C, para 5.9.11.5.2)				
90. Nonfixed handles have a stop position so that the handle is perpendicular to the carrying surface. (MIL-STD-1472C, para 5.9.11.5.3)				
91. Nonfixed handles can be placed in position with one hand. (MIL-STD-1472C, para 5.9.11.5.3)				
92. A nonslip grasp surface is provided if an item's bottom surface is used as a handhold during removal. (MIL-STD-1472C, para 5.9.11.5.4)				
93. Handle dimensions conform to Figure 48 of MIL-STD-1472C (ref 29). (MIL-STD-1472C, para 5.9.11.5.5)				
94. Handles used with bare hands have surfaces that are not electrically or thermally conductive. (MIL-STD-1472C, para 5.9.11.5.7)				
95. Equipment items cannot be mounted improperly. (MIL-STD-1472C, para 5.9.12.1)				
96. Common hand tools are used to replace field removable items. (MIL-STD-1472C, para 5.9.12.2)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
97. Guidepins or other means are used to assist in mounting. (MIL-STD-1472C, para 5.9.12.4)				
98. An item cannot be inserted in the wrong position. (MIL-STD-1472C, para 5.9.12.5)				
99. Coding identifies the correct item for replacement and its proper orientation. (MIL-STD-1472C, para 5.9.12.5)				
100. Items frequently checked are mounted on rollout racks, slides, or hinges. (MIL-STD-1472C, para 5.9.12.6)				
101. Rollout racks do not shift the center of gravity to cause the rack or console to fall. (MIL-STD-1472C, para 5.9.12.6)				
102. Racks and drawers have limit stops if frequent item checking is required. (MIL-STD-1472C, para 5.9.12.7)				
103. Limit stops can be easily overridden for item removal. (MIL-STD-1472C, para 5.9.12.7)				
104. If necessary, interlocks prevent damage to equipment when a rack or drawer is opened. (MIL-STD-1472C, para 5.9.12.8)				
105. Hinged items have a brace to hold the equipment in the out position. (MIL-STD-1472C, para 5.9.12.9)				
106. Sliding, rotating, or hinged equipment with rear access requirements are free to open fully and stay open without hand support. (MIL-STD-1472C, para 5.9.12.10)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
107. Units are laid out so that a minimum of place-to-place movement is required during check-out. (MIL-STD-1472C, para 5.9.12.11)				
108. Removal of each replaceable item requires a minimum of opening or removing covers or panels. (MIL-STD-1472C, para 5.9.12.12)				
109. Cables containing individually insulated conductors with a common sheath are coded. (MIL-STD-1472C, para 5.9.13.1)				
110. Long conductors, bundles, or cables are secured to the equipment chassis with clamps. (MIL-STD-1472C, para 5.9.13.2)				
111. Cables are long enough to allow each functioning unit to be checked in a convenient place. (MIL-STD-1472C, para 5.9.13.3)				
112. Test cables do not interfere with controls and displays. (MIL-STD-1472C, para 5.9.13.4)				
113. Cables are readily accessible for inspection or repair. (MIL-STD-1472C, para 5.9.13.5)				
114. Cables are protected from damage. (MIL-STD-1472C, para 5.9.13.6)				
115. Cables routed through holes in metal use grommets or other means for damage protection. (MIL-STD-1472C, para 5.9.13.7)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
116. Cables are labeled to indicate the equipment and connectors to which they belong. (MIL-STD-1472C, para 5.9.13.8)				
117. Quick-disconnect plugs are used as connectors. (MIL-STD-1472C, para 5.9.14.1)				
118. Plugs are keyed to preclude the insertion of the wrong plug in a receptacle. (MIL-STD-1472C, para 5.9.14.2)				
119. Electrical connector markings conform to requirement 67 of MIL-STD-454 (ref 18). (MIL-STD-1472C, para 5.9.14.3)				
120. Electrical plugs and receptacles are identified by color, shape, or other equipment means. (MIL-STD-1472C, para 5.9.14.3)				
121. Plugs and receptacles have aligning pins or other similar devices. (MIL-STD-1472C, para 5.9.14.4)				
122. Aligning pins extend beyond the electrical pins. (MIL-STD-1472C, para 5.9.14.5)				
123. Aligning pins or mechanisms are oriented in the same position. (MIL-STD-1472C, para 5.9.14.6)				
124. Aligning pin or mechanism position is shown by durable strips, arrows, or other indications. (MIL-STD-1472C, para 5.9.14.7)				
125. Connectors are spaced far enough apart so that each can be grasped firmly. (MIL-STD-1472C, para 5.9.14.8)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
126. Space between connectors and adjacent obstructions is at least 25mm (1 in). (MIL-STD-1472C, para 5.9.14.8)				
127. Sequentially removed and replaced connectors have a 25mm (1 in) clearance in a swept area of at least 270° around it at the start of a sequence. (MIL-STD-1472C, para 5.9.14.8)				
128. Connectors requiring high torque have space for the use of a connector wrench. (MIL-STD-1472C, para 5.9.14.8)				
129. Rear of plug connectors is accessible for testing and servicing. (MIL-STD-1472C, para 5.9.14.9)				
130. "Remove and replace" drawer modules have connectors mounted on the back of the drawer that mate with connectors in the cabinet. (MIL-STD-1472C, para 5.9.14.10)				
131. Electrical equipment replacement items have simple plug-in connectors. (MIL-STD-1472C, para 5.9.14.11)				
132. Disassembly of connectors for changing pin connections can be done without special tools. (MIL-STD-1472C, para 5.9.14.12)				
133. Adapters, if required, can be hand-tightened. (MIL-STD-1472C, para 5.9.14.12)				
134. Dust covers are captive type. (MIL-STD-1472C, para 5.9.14.13)				

Detailed Design Considerations	YES	NO	N/A	COMMENTS
135. Test points for adjustment are located close to the controls and displays used in the adjustment. (MIL-STD-1472C, para 5.9.15.1)				
136. It is not necessary to remove subassemblies from assemblies to reach test points. (MIL-STD-1472C, para 5.9.15.2)				
137. Marking and color coding of test points conform to MIL-STD-415 (ref 17). (MIL-STD-1472C, para 5.9.15.3)				
138. Storage space for leads, probes, spares, manuals, and special tools is provided within test equipment, handling case, or lid. (MIL-STD-1472C, para 5.9.16.1)				
139. Instructions for portable test equipment operation are on the equipment face, in a lid, or in a special compartment. (MIL-STD-1472C, para 5.9.16.2)				
140. Portable test equipment instructions include a reminder to calibrate equipment, if necessary. (MIL-STD-1472C, para 5.9.16.2)				
141. There is an indication of power failure. (MIL-STD-1472C, para 5.9.17.1.1)				
142. Displays indicate when equipment has failed or is out-of-tolerance. (MIL-STD-1472C, para 5.9.17.1.2)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
143. Critical malfunctions are indicated by an auditory alarm for equipment not regularly monitored. (MIL-STD-1472C, para 5.9.17.1.3)				
144. There is a positive indication of fuse or circuit breaker trip. (MIL-STD-1472C, para 5.9.17.2.1)				
145. Fuses are readily accessible and do not require special tools for replacement. (MIL-STD-1472C, para 5.9.17.2.2)				
146. Circuit breakers are within easy reach of crewmembers. (MIL-STD-1472C, para 5.9.17.2.2)				
147. The area of equipment secured by a fuse or circuit breaker is identified. (MIL-STD-1472C, para 5.9.17.2.3)				
148. Fuse current ratings are permanently marked on the fuse holder. (MIL-STD-1472C, para 5.9.17.2.3)				
149. "Spare" is marked adjacent to spare fuse holders. (MIL-STD-1472C, para 5.9.17.2.3)				
150. Fuse ratings are expressed in whole numbers and common fractions. (MIL-STD-1472C, para 5.9.17.2.3)				
151. Fuse and circuit breaker labels are legible in the anticipated ambient illumination. (MIL-STD-1472C, para 5.9.17.2.3)				
152. Circuit breakers controlling power are toggle bat or legend switch type controls. (MIL-STD-1472C, para 5.9.17.2.4)				

EXHIBIT 4-2 (continued)

Detailed Design Considerations	YES	NO	N/A	COMMENTS
153. Printed circuit boards are easy to remove and replace. (MIL-STD-1472C, para 5.9.18)				
154. Feedback is provided when the printed circuit board is securely connected. (MIL-STD-1472C, para 5.9.18)				

HUMAN ENGINEERING DISCREPANCY REPORT

HED # PLANT: _____ DATE: _____

REVIEWER NAME: _____

HED TITLE: Inconsistent J-Handles on Reactor Trip Controls

DISCREPANCY ORIGIN: _____

ITEMS INVOLVED:

INDIVIDUAL ☒ _____

GENERIC ☐ _____

EXCEPTION ☐ _____

ITEM TYPE	NOMENCLATURE	PANEL	LOCATION
Reactor Trip	Rx TRIP CONTROL	A C	

PROBLEM DESCRIPTION:

Panel A:

Panel C:

SPECIFIC OPERATOR ERROR(S) THAT COULD RESULT FROM HED:

Erroneous activation of control.

SUGGESTIONS FOR POTENTIAL BACKFITS

Add an arrow, labeled "TRIP", to the Rx TRIP on Panel C.

Panel C:

DATA COLLECTOR _____ DATE _____

PROJECT DIRECTOR _____ DATE _____

PROJECT MANAGER _____ DATE _____

DISPOSITION

HED REVIEW TEAM CHAIRMAN _____ DATE _____

EVALUATION COMPLETED
PROGRAM MANAGER _____ DATE _____

(Source: Essex Corporation, Systems Operability and Design Group, 1984.)

EXHIBIT 4-4
EXAMPLE OF AN HFE DISCREPANCY REPORT

(Source: Essex Corporation, Systems Operability and Design Group, 1981.)

Item Number	Item Description	Location	Discrepancy	Priority	Recommended Backfit
29	Turbine stress evaluator, ATT and low pressure turbine valve vertical meters	870-6B	These should be on the 680-9 panel with the other turbine controls	3	Ideally these should be moved to the 680 but given the design the only way to address is by extensive training and labeling
30	Trend recorder controls: 1. Filter train A recorders 2. SSW loop A flow and press rec 3. Filter train B recorders 4. SSW loop B flow and press rec 5. Hydrogen analyzer rec	870-2B 870-1B 870-8B 870-7B 870-4B 870-10B	These controls are associated with trend recorders located to the left of the controls. In some cases the controlled recorders are separated by an intervening recorder. The visual association of these controls is very difficult to make.	3	1. Move controls directly under the recorders, or 2. Use demarcation lines to provide a visual association
31	Unlabeled 10 position rotary control that should be labeled "Recombiner is select"	870-4B 870-10B	This control has 10 positions when only three are used, according to operating procedures	3	1. Replace with three position control, or 2. Remove labels for unused positions and interlock to prevent placing control in unused positions

Documentation Review

Part A: Report Screening Summary

[illegible]

A-42

EXHIBIT 4-5 (continued)

**Documentation Review
Part B: HFE Discrepancy Summary
Documentation Review**

Reviewers: _____

Date: _____

Type of Report (UOR, JIR, etc): _____

Report Number: _____

Report Date: _____

Analysis and Summary of Report

1. Unit/work area involved: _____

2. Operating status when event occurred: _____

3. Result:

___ Incident without consequence

___ Personnel injury, contamination, or excessive radiation dosage

___ Radioactive release or contamination spread

___ Equipment damage

___ Off - normal equipment status without damage

___ Violation of Technical Specification or other safety criteria

___ Reduced operational availability;

___ Trip _____ hrs

___ Shutdown _____ hrs

___ Derated to _____ %, _____ hrs

___ Other (specify)

EXHIBIT 4-5 (continued)

4. Error Classification (check all that apply)

- ☐ Operator Error
- ☐ Maintenance Error
- ☐ Test/Calibration Error
- ☐ Other (specify) _____

5. Error Description (check all that apply)

- ☐ Problem in monitoring (e.g., failure to detect/properly identify critical condition, parameter out of range, faulty equipment lineup/condition; misreading of alarms, displays, indicators)
- ☐ Problem in control action (e.g., wrong control, wrong setting/alignment, accidental actuation, omission of control action)
- ☐ Problem in communication/coordination
- ☐ Incorrect decision
- ☐ Problem in timing

EXHIBIT 4-5 (continued)

NOTE

The summary statement, item 6, should explain checks under items 4 and 5.

6. Summary statement of the event:

7. HFE discrepancies that appear to have contributed to the event:

8. Immediate and follow-up action taken to correct problem:

Conclusions

9. Does it appear that HFE discrepancies contributing to this event have been fully corrected? ☐ yes ☐ no

If no, explain:

10. Could an event of this kind happen again? ☐ yes ☐ no

EXHIBIT 4-7

EXAMPLE OF A QUESTIONNAIRE FOR HFE
REVIEW OF CONTROL ROOM OPERABILITY

(Source: K. Mallory, et al. (1980). Human engineering guide to control room evaluation, Volume I - Control room evaluation, Appendix III (NUREG/CR-1580). Washington, DC: U.S. Nuclear Regulatory Commission.)

APPENDIX III
HUMAN ENGINEERING OPERATOR QUESTIONNAIRE

Date: _____ HFE Analyst — Briefing: _____

Unit: _____ Interview: _____

Licensed Operator _____ How Long? _____

or

Trainee _____ How Long? _____

A. Staffing and Workload

1. Please describe Tech. Spec. requirements for CR staffing.

- a) If actual staffing differs from Tech. Specs., please describe actual staffing.

2. In your opinion, under worst-case conditions, what is the maximum number of operators actually needed to effectively operate the control room during each of the following:

- a) Normal operations _____
- b) Startup/shutdown _____
- c) Transients/emergency operations _____

EXHIBIT 4-7 (continued)

3. How many units do you presently operate? _____

a) If you operate two or more, are they: (check one)

 identical

 nearly identical

1 mirror images of each other

 dissimilar

b) If you operate two or more units, have you ever experienced any difficulties in shifting from one CR to another? yes no

4. Please describe your administrative or record keeping tasks (log entries, reading of parameters, etc.).

[illegible]

EXHIBIT 4-7 (continued)

- a) Have these responsibilities ever interfere with your operational duties, especially during off-normal conditions? ____ yes ____ no

5. Have you observed any problems associated with shift turnover?
____ yes ____ no

6. Please describe any recommendation you may have to improve shift turnover.

B. Workspace Design

1. Can the status of your plant be monitored from one central position?
____ yes ____ no

2. Are specific stations assigned to operators and watch foreman?
____ yes ____ no

EXHIBIT 4-7 (continued)

3. During normal or off-normal operations, do the actions or tasks of another operator ever interfere with performance of your tasks?
____ yes ____ no

4. Have you ever experienced any difficulty in reaching a required control or seeing/reading a required display? ____ yes ____ no

5. Have you ever experienced any problems locating the correct control or display (for example, operating the wrong switch or inaccurately operating the correct switch)? ____ yes ____ no

6. Are panels arranged within your CR in a manner which is logical for normal and emergency operations? ____ yes ____ no

7. Are controls and displays pertaining to systems or subsystems grouped logically and distinctively within each panel? ____ yes ____ no

EXHIBIT 4-7 (continued)

8. Does your panel lack important information, controls or displays, which would help you perform your job more effectively or safely? ☐ yes ☐ no

9. Are important data, controls or displays, inaccessible, or difficult to access, because of placement (for example, located in back panels out of operator's view)? ☐ yes ☐ no

10. Does your CR contain controls, displays or other equipment which is inoperative, not used, or unnecessary for you to do an effective job? ☐ yes ☐ no

11. Do you find mimics or graphic/pictorial panel arrangements, if used, helpful in performing your job? ☐ yes ☐ no ☐ N/A

- c) If "no," please describe why you feel they are not helpful and any recommendations you may have to make them more so.

EXHIBIT 4-7 (continued)

12. Have you ever inadvertently disturbed control settings (for example, accidentally bumping a switch)? ____ yes ____ no

13. Have groups of controls or displays which look identical or very similar been marked or coded to permit easy discrimination between them?
____ yes ____ no

- a) If "no," please describe areas where you feel marking or coding would enhance your ability to discriminate between components.

14. Please describe the administrative procedure for adding operator-recommended modifications to labeling, demarcation lines, mimics, or for adding guarding for certain controls, or otherwise modifying the panel.

15. Do you find operator-added modifications helpful? ____ yes ____ no

EXHIBIT 4-7 (continued)

- a) If "no," please describe those modifications which you find to be a hindrance.

16. Are major panels, sub-panels and panel segments clearly and consistently labeled? ☐ yes ☐ no

17. Is the Control Room (CR) arranged to be effectively operated by the minimum shift required?

During normal operations ☐ yes ☐ no

During transients/emergency operations ☐ yes ☐ no

C. Workspace Environment

- I. Do CR features of an environmental nature, such as listed below, ever interfere with effective performance of your job? If "yes," please describe the nature and source of each problem and their effects on job performance.

a) Ventilation ☐ yes ☐ no

b) Temperature/humidity ☐ yes ☐ no

EXHIBIT 4-7 (continued)

c) Illumination ☐ yes ☐ no

d) Noise levels ☐ yes ☐ no

e) Excessive traffic through the CR ☐ yes ☐ no

f) Other environmental factors ☐ yes ☐ no

2. Are there problems with time and distance involved in leaving CR to prepare food or use facilities? ☐ yes ☐ no

D. Communications

1. Are there problems with communications procedures or equipment which interfere with receiving or transmitting required information in any of the following instances? If "yes," please describe.

a) CR to field/auxiliary operators ☐ yes ☐ no

b) Field to CR ☐ yes ☐ no

EXHIBIT 4-7 (continued)

c) CR to supervisor ☐ yes ☐ no

d) Between units ☐ N/A ☐ yes ☐ no

e) CR to NRC ☐ yes ☐ no

f) CR to others (please specify) ☐ yes ☐ no

2. Are you aware of any instances in which intra-control room (operator-to-operator) communications have been lost or misheard due to distance or noise levels? ☐ yes ☐ no
-
-
-

3. Does the operation of communications equipment, or requirements for communications interfere with operations: (Please describe if "yes.")

a) During normal operations ☐ yes ☐ no

b) During off-normal operations ☐ yes ☐ no

EXHIBIT 4-7 (continued)

c) During transients/emergencies ☐ yes ☐ no

4. Have you experienced any problems with using communications equipment in any of the following areas? (If "yes," please describe the problems.)

a) Location of the equipment ☐ yes ☐ no

b) Operation of the equipment ☐ yes ☐ no

c) Ability to receive or transmit messages
(speech intelligibility) ☐ yes ☐ no

d) Number of transmitters/receivers ☐ yes ☐ no

e) Failed or broken equipment ☐ yes ☐ no

E. Annunciator/Warning System

1. Please describe your alarm annunciator system and its operation from incoming alarm to acknowledge to condition cleared.

EXHIBIT 4-7 (continued)

2. Does the annunciator system in your CR provide you with specific information about the nature of an abnormal event? ☐ yes ☐ no

3. Do alarm annunciators provide you with information about the necessary action to be taken in response? ☐ yes ☐ no

4. Alarm annunciators located above the instrumentation of systems which they monitor? ☐ always ☐ frequently ☐ infrequently

5. Are alarm annunciators prioritized in any way? ☐ yes ☐ no

6. Please describe any use of color coding used in the annunciator system.

7. Do you have any problems reading annunciator messages from any point in the CR from which these messages must be read? ☐ yes ☐ no

EXHIBIT 4-7 (continued)

8. Are the auditory warning signals differentiated to provide meanings, such as priority alarms or locality of system components? ☐ yes ☐ no

9. Do "nuisance" or "false" alarms ever interfere with your performing your job effectively?

Under normal conditions ☐ yes ☐ no

Under emergency conditions ☐ yes ☐ no

- a) If "yes," please identify frequent nuisance alarms and the problems they present.

10. Are alarm acknowledge/silence/reset controls available to the operator?

Are there sufficient number ☐ yes ☐ no

Are they easily accessible from all panels ☐ yes ☐ no

11. Are alarm annunciators provided with a test capability?

For visual/lamps ☐ yes ☐ no

For audible ☐ yes ☐ no

12. Do you have any recommendations which would enhance the operator usability of your annunciator system?

EXHIBIT 4-7 (continued)

F. Operator Protective Equipment

1. Please describe the operator protective equipment available in your CR.

2. Please describe the quantity and location of the equipment.

3. Does the face mask interfere with visibility? ____ yes ____ no

4. Does your protective breathing apparatus interfere with the following:

a) Operator-to-operator communications ____ yes ____ no

b) Use of communications equipment ____ yes ____ no

5. Have you ever encountered difficulty in performing required tasks as a result of wearing protective equipment? ____ yes ____ no

6. Do you feel sufficiently practiced in donning protective equipment so that, if the need arises, you feel you could don it easily and quickly?
____ yes ____ no

7. Do you have any other comments or suggestions concerning the suitability of the available protective equipment or its use?

EXHIBIT 4-7 (continued)

G. Computers

1. Please describe the functions performed by the computer to assist you in operating the system.

2. Do you find the computer useful and reliable? ____ yes ____ no

3. Do you feel that operators are adequately trained to use the computer?
____ yes ____ no

4. What changes or additions in computer usage would you recommend?

H. Procedures/Documentation

1. Do you find that your procedures documents are difficult to access because of labeling, indexing or storage? ____ yes ____ no

EXHIBIT 4-7 (continued)

2. Are your procedures sufficiently detailed to permit effective operation of your CR during normal and emergency operations? ☐ yes ☐ no

3. Are there procedures which you find difficult to execute?
☐ yes ☐ no

4. Please list the procedures which address operation of the most difficult or critical systems.

I. Operations

1. Do you feel that too many functions are performed automatically by the system in controlling abnormal event? ☐ yes ☐ no

2. Can you provide examples where direct control by the operator would be preferable to automatic control? ☐ yes ☐ no

EXHIBIT 4-7 (continued)

3. Can you suggest examples where automatic control would be preferable, where not currently provided? ____ yes ____ no

4. Please describe any additional operational problems you have experienced with the current panel design.

5. Please describe any recommendations you would make in design or procedure which would enhance the effectiveness of the operator's job.

J. Operator Work Scheduling

1. Would you prefer a different system of shift scheduling?
____ yes ____ no

- a) Do you have any comments or suggestions for improving the effects of shift scheduling on the operator?

2. Have you ever experienced any negative effects in changing from one shift to another, in yourself or in other operators? ____ yes ____ no

- a) If "yes," has this effected operating abilities? ____ yes ____ no

EXHIBIT 4-7 (continued)

- b) Any comments or recommendations?

3. How many overtime hours do you generally work in a month? _____

- a) Do you feel that extended shifts or overtime degrades your ability to perform your job effectively? ____ yes ____ no
- b) Have you ever experienced any problems in operating the plant as a result of working extensive overtime? ____ yes ____ no
- c) Any comments or suggestions?

4. Are you aware of any operators who have experienced personal problems as a result of working shifts and/or overtime? ____ yes ____ no

- a) Any comments?

EXHIBIT 4-6
EXAMPLES OF ITEMS FOR A PERSONNEL INTERVIEW OR
SELF-ADMINISTERED QUESTIONNAIRE SURVEY
(Control Room Operating Personnel)

1. Do you know of any areas on the board where toggle, lever, or pushbutton controls should be replaced with rotary controls because of accidental activation? YES NO N/A
 If yes, please explain

2. Have you ever accidentally activated an adjacent control because it was positioned too close to the one you wanted to manipulate? YES NO N/A
 If yes, please explain

3. Have you ever had difficulty activating a control because an adjacent control was in the way? YES NO N/A
 If yes, please explain

4. Can you recall any controls that you are never required to used? YES NO N/A
 If yes, please explain

5. Are there any controls that are duplicated unnecessarily? YES NO N/A
 If yes, please explain

6. Can you recall any knobs or handles of control switches that slip or are loose on their shafts? YES NO N/A
 If yes, please explain

7. Are there are controls that are difficult to adjust to the precise level you need? YES NO N/A
 If yes, please explain

EXHIBIT 4-8
EXAMPLE OF A QUESTIONNAIRE FOR
HFE REVIEW OF MAINTAINABILITY

(Excerpt from: Seminara, J.L., Gonzalez, W.R. & Parsons, S.O. (1981). Human factors review of nuclear power plant maintainability (EPRI-NP-1567). Palo, Alto, CA: Electric Power Research Institute

BIOGRAPHICAL DATA

YOUR POSITION _____

YEARS OF POWER PLANT EXPERIENCE _____ NUCLEAR _____ FOSSIL _____

MILITARY RELATED EXPERIENCE _____

WORK EXPERIENCE (ELECT., MECH., I & C, OPERATIONAL, ETC.) _____

PLANTS WORKED AT _____

AGE _____ HEIGHT _____ WEIGHT _____

EDUCATION _____

SPECIAL MAINTENANCE OR I & C TRAINING _____

SPECIAL REMARKS _____

EXHIBIT 4-8 (continued)

FACILITIES

1. How well has your workshop been integrated into the overall plant? Should it have been located differently to help you get your job done more easily?

2. To minimize the distances that you must cover, what elements of the plant should be located closest to your shop. Rank the following from "1" to "10", with "1" representing the facility that should be closest to your shop.

___ Control Room	___ Administration Bldg.	___ Plant Safety
___ Warehouse	___ Training Department	___ Technical Library
___ QC Office	___ Engineering Office	___ Other _____
___ Tool Room	___ Health Physics	___ Other _____

3. How do plant security requirements and regulations affect your work? How much time on the average per day is spent getting into the plant, getting past security barriers with the plant, etc?
4. Are there any problems getting materials transported into the plant? Are there problems here due to security requirements?
5. Has your plant been designed to minimize the equipment components placed in contaminated areas, i.e., could some of the hardware which you maintain in contaminated areas just as easily been put outside the contaminated areas?

EXHIBIT 4-8 (continued)

6. Do fire protection requirements affect your work? Can improvements be made in this area?
7. Is your workshop sized and arranged properly to allow efficient maintenance operations? Are the electrical, mechanical, and I & C shops in the right relationship to each other?
8. Is sufficient storage capability provided for parts and tools to avoid damage to components? Is the design of storage facilities adequate to prevent equipment damage?

ENVIRONMENTAL CONSIDERATIONS

9. Are all or most systems that you maintain sheltered or are some exposed to the elements? Have you encountered problems in performing maintenance on hardware that is exposed to weather?
10. Some maintenance activities are typically conducted in high noise environments. What problems, if any, has this created in your work? Can you suggest improvements?
11. Is adequate illumination provided to allow you to conduct maintenance tasks? What improvements can you recommend?

EXHIBIT 4-8 (continued)

12. Does your work require exposure to high temperatures and humidity? Have all precautions been taken to minimize the risks to you and others? Does excessive body heat and humidity build up when you are wearing protective clothing?
13. Work in high radiation areas presents special problems.
 - a. Have hardware systems in contaminated areas been designed so that they can be easily maintained by men wearing gloves, respirators, helmets, etc.?
 - b. Are Health Physics procedures and support adequate?
 - c. What precautions are taken to minimize exposure time and to avoid "burning up" maintenance personnel? Do you "dry run" tasks with mockups?
 - d. Are there any problems in turning over a job to another crew before it is completed because allowable time in the contaminated area is limited?
 - e. What general improvements can you recommend to make it easier and/or safer to conduct maintenance in contaminated areas?
 - f. Have you experienced problems with contractor or other outside personnel working in high radiation areas?

EXHIBIT 4-8 (continued)

14. Have you experienced problems with steam, asbestos fibers, slippery surfaces, etc. in the course of your work? Can improvements be suggested to minimize any dangers from these sources?

ACCESSIBILITY

15. Is adequate clearance provided around equipment that you maintain to allow easy work motions and space for work aids, transportation units, and lifting devices? What specific areas could stand improvements?
16. Are access openings designed so that people and components can move through them adequately? Can you cite some good and bad examples?
17. Are access openings designed for proper visibility within?
18. Have stairs, ladders, and platforms been provided where necessary to allow ready access to equipment that you maintain?
19. Have equipment systems been packaged or arranged so that the potential for damage is minimized in removing and replacing defective parts?

EXHIBIT 4-8 (continued)

20. Are access openings in high-radiation areas designed to allow for suited operations, including airpicks and respirators, when necessary?
21. If access to equipment that you maintain were ideal or unrestricted, what percentage savings in maintenance time would you estimate on the whole?

MOVEMENT OF PERSONNEL AND EQUIPMENT

22. Have sufficient elevators of the right type been provided to support maintenance activities?
23. Have cranes been positioned for maximum effectiveness? Does crane scheduling limit you in any way, i.e., are cranes available when you need them?
24. Have adequate provisions been made for the utilization of hoists and rigging?
25. Are there adequate clearances for wheeled vehicles when they are necessary to support maintenance activities?

EXHIBIT 4-8 (continued)

26. Are you required to manhandle heavy items because it is not possible to effectively utilize lifting or transportation devices? How heavy are the heaviest units you must lift manually and how high off the ground?
27. Are portable units designed with adequate handles and grasp areas?
28. Describe a case or situation where equipment was damaged or almost damaged because of inadequate handling devices or transportation aids.

EQUIPMENT DESIGN FOR MAINTENANCE

29. Some equipment is easy to disassemble for maintenance and others seem designed as if they were not meant to be taken apart. In general, how well have the systems you typically maintain been designed? Examples of the best and worst cases, please.
30. Are all interchangeable units, e.g., connector plugs, physically coded or keyed so that it is impossible to insert or replace a wrong unit?

EXHIBIT 4-8 (continued)

31. Is the equipment designed so that replacing one unit does not require removal of other units for access?
32. Are delicate components specially located or guarded so that they will not be damaged when being handled or worked on, or when work is being performed on adjacent components? Are there cases where a piece of equipment is damaged in disassembly or reassembly?
33. Is there equipment that requires excessive or recurrent maintenance? Are there obvious design changes that would correct this situation?

MALFUNCTION DIAGNOSIS

34. Effective maintenance depends on accurate and timely diagnosis of problems. What problems have you experienced in diagnosing equipment malfunctions or detecting malfunction trends? Do the operators provide good support here?
35. To what extent is test or diagnostic capability built into the systems being maintained? For example, do you have in-place vibration monitors?

EXHIBIT 4-8 (continued)

36. To what extent do maintenance and I & C personnel rely directly on meters, chart recorders, and other instrumentation in the control room for determining malfunction trends or diagnosing malfunctions?

CODING AND LABELING

37. Have cables, wires, controls, and plumbing lines been properly coded to permit easy identification?
38. Are access covers, valve controls, etc., properly labeled with full identifying information?
39. Are appropriate labels used for test points?
40. How easy is it to find what you are looking for in the plant? What could be done to better orient a new man in finding his way around and avoiding "hot spots" or working on the wrong piece of equipment?

EXHIBIT 4-8 (continued)

PROCEDURES AND TECHNICAL DATA

41. Are maintenance procedures sufficiently clear and detailed to permit error-free maintenance tasks? Are improvements in procedures needed?
42. Are vendor-supplied maintenance manuals and technical data adequate to allow proper maintenance of equipment?
43. In general, is too much or too little emphasis being placed on procedures and "doing things by the book"?

TOOLS AND TEST EQUIPMENT

44. Have you experienced any problems in having the right tools available to do the job?
45. Have the systems that you maintain been designed to minimize the number of special tools required?
46. Have you encountered any problems in having the right test equipment available to check out system operations?

EXHIBIT 4-8 (continued)

47. Is adequate space generally provided for placing test equipment where needed for checkout purposes, e.g., are console units provided with trays on which test equipment can be mounted?
48. Have you experienced any special problems in using tools or test equipment in high-radiation, high-temperature or high-humidity areas? What recommendations can you make to remedy these problems?

COMMUNICATIONS

49. Have adequate provisions been made to allow you to communicate with others in the course of your work in all parts of the plant? What improvements are needed?
50. Can you describe a case where the lack of effective communications led to a problem or near problem?

SAFETY

51. Has the equipment that you maintain been designed to minimize safety hazards, e.g., sharp edges, electrical hazards, projections to get snagged on, etc.? Do labels or placards identify all potential safety hazards?

EXHIBIT 4-8 (continued)

52. Has the equipment that you maintain been designed or installed to avoid damage through use or abuse, e.g., wires that can be pinched by doors, cables which project and can be tripped over, components that make natural footholds in reaching upwards, or units that make convenient footrests?

SPARES

53. Are spare parts generally available when needed for maintaining plant systems or test equipment?

54. Have you run into any problems determining the availability of spares, identifying which spare part is needed, or in gaining access to spare parts?

ADMINISTRATIVE

55. How much of your time is involved with paperwork (percent of average work week)? Is this a reasonable or unreasonable demand on your time?

56. How much overtime do your men work in an average year? _____ HRS. How much of this OT occurs during major outages? _____. Have you observed any problems due to excessive OT demands of the job?

EXHIBIT 4-8 (continued)

57. During major outages, are you required to work other than normal day shifts? Have you observed any problems associated with adjustments to off-normal shifts?
58. When shift work is required, have you observed any problems in turning over a job from the day shift crew to the swing shift crew for completion or vice versa? Are shift transitions accomplished smoothly?
59. During major outages is the maintenance work scheduled in an orderly manner or could planning be improved? What kinds of events have aborted outage schedules in the past? Have planning tools such as PLAN-A-LOG been helpful? Are computers used for outage planning and management?
60. Do you have a systematic preventive maintenance program with fixed dates that avoids unnecessary corrective maintenance? Does the program need to be improved? Are corrective and preventive maintenance schedules computerized? How is the Preventive Maintenance program managed?

EXHIBIT 4-8 (continued)

61. Is equipment servicing done on-line to the greatest extent possible as opposed to shut-down periods, e.g., lubrication, adjustments, filter replacement, etc.? How could this situation be improved?
62. Are there problems in monitoring equipment status through visual inspections, vibration testing, performing electrical/electronic checkout tests, etc.?
63. How do you estimate the time that it should take to do maintenance jobs and what controls are employed in ensuring maximum productivity of personnel? Do maintenance foremen and/or supervisors personally inspect maintenance work?
64. What failure rate data do you have available to help guide preventive maintenance or outage maintenance work? Are reliability analyses conducted? Are failure modes and effects analyses conducted?

EXHIBIT 4-8 (continued)

MANNING

65. During the normal work periods how many maintenance people including supervisors are there in your shop? _____ Is this number sufficient to handle normal work load?
66. During major outages how many people are added to the work force in your shop? _____ Where are these additional people obtained from?
67. How effective are these additional people who are added to your organization? In what ways could their effectiveness be improved?
68. If you did not add extra people to cope with major outages, how many additional in-house permanent employees would you have had to hire to get the necessary work accomplished?
69. During a major outage how many total additional maintenance people are hired? _____ What is the peak work force during the outage _____ as compared to your normal manning level? _____ How long do your major outages typically last? _____ Can you envision improvements that would reduce the duration of major outages? How much time would these improvements save? _____

ORGANIZATIONAL INTERFACES

70. Maintenance and I & C personnel rely on control room operators for diagnostic information, clearances to work on specific plant systems, etc. How could your interaction with operators be improved? How do you interact with auxiliary operators?

EXHIBIT 4-8 (continued)

71. Are there any problems in your relationships with the engineering organization? In what ways could your interface with engineering be improved?
72. Health physics provides important support to maintenance operations. Are any improvements needed in this relationship?
73. In what ways could plant management be more responsive to the needs of maintenance personnel in order to permit more efficient performance of maintenance activities?
74. In what ways could the union-management relationship be enhanced to permit more efficient maintenance operations?
75. What is the QC organization's contribution to effective maintenance? Can the relationship between maintenance and QC be improved to ensure the highest quality maintenance work?

EXHIBIT 4-8 (continued)

76. How good a job does the Plant Safety organization do in ensuring a safe work environment for maintenance personnel?
77. To what extent does the purchasing organization consult with maintenance personnel before buying system components, test equipment, etc., to ensure that maintenance requirements are being met? Are there any problems here?
78. To what extent are maintenance people consulted when your utility is planning or building a new plant? Are the mistakes of the past being avoided in new plants? To what extent must maintenance personnel reshape a plant when it is turned over to the utility to facilitate maintenance?
79. In general, how good a job are the A-Es doing in meeting the needs of maintenance people?
80. In general, how good a job are major system vendors doing in designing hardware so that it meets the needs of maintenance personnel?

EXHIBIT 4-8 (continued)

SELECTION, TRAINING

81. How good a job does your utility do in selecting the right people for maintenance (or I & C) jobs? What qualities and experience are sought?
82. What training programs does your utility provide for maintenance (or I & C) personnel? Is this training program adequate to provide the skills and knowledge needed for the job?

HOUSEKEEPING

83. Housekeeping is a necessary part of maintenance work. Are there adequate provisions available for conducting housekeeping chores?

CRITICAL INCIDENT

84. Based on your experience, cite one example of an error made by a maintenance man (or I & C technician) or an accident or near-accident with serious or potentially serious consequences. Describe the specifics of the case and indicate how the situation could have been averted either through improved facility design, better handling equipment, better procedures, special training, better equipment design, etc.

EXHIBIT 4-8
EXAMPLE OF SUMMARY OF
QUESTIONNAIRE RESPONSE DISTRIBUTION

Department/Functional Area:

Total Number of Respondents:

[illegible]

EXHIBIT 4-10
EXAMPLE OF AN HFE CRITERION CHECKLIST FORMAT

TOP 1-1-059

DESIGN CHECKLIST

1

LABELS, MANUALS, MARKINGS

Detailed Design Considerations	YES	NO	N/A	Comments	Location
1. Controls, displays, and other items of equipment are clearly marked and labeled except in cases where use is obvious to the operator. (5.5.1.1)					
2. Labels are on or near the item to be identified. (5.5.2.2)					
3. Labels do not cover any other information and are not located behind controls. They can be seen easily by the operator and are not obscured by the operator's hand activating a control. (5.5.2.2)					
4. Labels are located in the same manner throughout the equipment and system. (5.5.2.3)					
5. Labels are not covered by other equipment and are located on the flattest, least cluttered, and cleanest surface available.					
6. Labels are mounted so that they cannot be accidentally damaged or removed. (5.5.8.1.2)					
7. Where instructions are lettered on hinged door, lettering is set so that it can be read when the door is open. (5.9.9.3)					

YES = Adequate NO = Inadequate N/A = Not Applicable

EXHIBIT 4-8 (continued)

85. Based on your maintenance experience at this plant, cite one example of a plant system or unit of equipment that is not "human engineered" or is poorly designed from the maintenance man's standpoint and which has or could lead to an error, damage to equipment, or present a hazard to the man working the system.
86. Now think of a particular plant system or unit of equipment that is well "human engineered" or easy to maintain or monitor system status. Please describe the system or unit with emphasis on the features that make it especially good from the maintainer's standpoint.
87. This is the end of the interview. What questions have I neglected to ask you? Are there any major impediments or road blocks that keep you from doing the best possible maintenance job that we haven't covered?

EXHIBIT 4-11
EXAMPLE OF A PERFORMANCE SEQUENCE SCENARIO

(Source: Burgoyne, D. et al. (1983). Task analysis of nuclear power plant control room crews Volume 2 (NUREG/CR-3371). Washington, DC: U.S. Nuclear Regulatory Commission.)

Operating Sequence: Startup from Hot Shutdown

Initial Conditions: The plant has been shut down to correct an equipment malfunction. The process of restart has begun. Plant pre-starting checks have been completed and the estimated critical position (ECP) has been calculated. The reactor is subcritical. No measurable thermal power is being produced. Reactor coolant system (RCS) pressure is being controlled at 2155 psig. The turbine bypass valves are in automatic and controlling once-through steam generator (OTSG) pressure at 885 psig. OTSG level is being controlled at the startup operating level. Boron concentration is the proper concentration for startup. The rod groups are fully inserted. The Load Dispatcher has been notified of the plant condition.

Sequence Initiator: Permission has been received to take the reactor to 100% power.

Progression of Action: The crew withdraws the safety and regulating rod groups to take the reactor critical. Criticality is achieved within the limits specified in the ECP calculation. The crew proceeds to take the reactor to the hot standby condition. The crew then increases reactor power to 10%, notifies the Load Dispatcher that the plant is coming on the line, parallels the generator on the grid, and proceeds to 100% power.

Final Conditions: The plant is operating at 100% power in the normal full power lineup.

Major Systems: Electrical Generation and Distribution System, Plant AC Auxiliary System, Integrated Control System (ICS), Main Feedwater System (FWS), Reactor Protection System (RPS), Condenser System, Circulating Cooling Water System (CCWS), Power Conversion System (PCS), Control Rod Drive System (CRDS), Makeup and Purification System (M&P), Primary Sampling, Nuclear Instrumentation System (NIS), Auxiliary Feedwater (AFW), Main Turbine (MT), Generator and Exciter System, Reactor Coolant System (RCS), Pressurizer Level Control System (PZR-LCS), Condensate System, Extraction Steam and Heater Drain System, Heater Drains and Vents System.

EXHIBIT 4-13
EXAMPLE OF A TASK-DESCRIPTIVE DATA FORMAT

(Source: Paratore, B., Banks, W.W., Veneziano, C., Gilmore, R.D., & Coleman, S.R. (1983). A pilot task analyses of the Rockwell Size Reduction Facility, 234-52 Plutonium Finishing Plant. Richland, WA: Hanford Environmental Health Foundation.)

TASK ANALYSIS DATA FORM
DECONTAMINATION AND DECOMMISSIONING (D&D) OPERATIONS

PROCESS

1 Facility ID	2 Position ID	3 Sub- position	4 Task No.	5 Task Description	6 Task Purpose	7 Initiating Event	8 Plant Systems Affected

EXHIBIT 4-13 (continued)

TASK ANALYSIS DA FORM
(DAD) OPERATIONS
page 2

Task No.	9 Support Equipment	10 Person. Time	11 System Time	12 Task Diff.	13 Task Freq.	14 Feedback	15 Most Likely, Serious Potential Human Errors	16 Potential, Significant Error Consequences	17 Error P Rating	18 Error Severity Rating

TASK ANALYSIS DATA FORM
(OLD) OPERATIONS
page 3

A-89

EXHIBIT 4-13 (continued)

TASK ANALYSIS DATA FORM
(D&D) OPERATIONS
 page 4

Task No.	Knowledge Required To Perform this Task			28	29	30
	25 Academic Knowledge	26 Administrative Knowledge	27 System/Equip. Knowledge	Level of Supervision	Hazards	Performance Standards

A-90

EXHIBIT 4-14
EXAMPLE OF A BASIS FOR
WEIGHTING ERROR CONSEQUENCES USING THE RELATIVE
SAFETY SIGNIFICANCE OF SYSTEM FUNCTIONS

Function: Maintain Fuel Integrity

<u>Main Systems</u>	<u>Subsystem Examples</u>
High Pressure Safety Injection	Electrical supply, pump cooling water
Low Pressure Safety Injection	Electrical supply, first heat exchange system
Accumulator Safety Injection	--
Control Rod Drive	Cooling Water
Emergency Boration	Electrical Supply

Function: Maintain Reactor Coolant System Integrity

<u>Main Systems</u>	<u>Subsystem Examples</u>
Reactor Coolant Pumps	Electrical supply, cooling water, lubrication system
PORV, Pressurizer Spray	Electrical supply
Letdown System	Electrical supply
Auxiliary Feedwater	Steam, electrical supply
Main Steam	Valve control power

Function: Maintain Reactor Building Integrity

<u>Main Systems</u>	<u>Subsystem Examples</u>
Reactor Building Spray	Electrical supply, heat exchange system
Reactor Building Cooling Fans	Cooling water system
Passive Reactor Building Cooling (Icc)	--
Hydrogen Monitoring and Control Systems	Electrical supply
Containment Isolation	Electrical supply

Function: Prevent Unmonitored Radioactive Release

<u>Main Systems</u>	<u>Subsystem Examples</u>
Containment Purge	Electrical supply
Waste Gas	Electrical supply
Sump Systems	Electrical supply

EXHIBIT 4-14 (continued)

Function: Prevent a Forced Outage

<u>Main Systems</u>	<u>Subsystem Examples</u>
Most Equipment Protection Such as Oil Systems, Cooling Systems	Electrical, heat exchange systems
Alarm Systems	Electrical

Function: Prevent a Reactor or Turbine Trip or Reactor Runback

<u>Main Systems</u>	<u>Subsystem Examples</u>
Feedwater, Condensate Turbine Control System Reactor Control System Master Plant Controller	Steam supply, control oil Control oil Electrical power Electrical, instrument air system

Function: Prevent Limiting Conditions of Operation

Function: Prevent Long-Term Degradation of Equipment Misc. Systems

Function: Prevent Loss of Equipment Performance

(Source: Essex Corporation, Systems Operability and Design Group, 1984.)

Sheet _____ of _____

PLANT: _____ UNIT: _____

REVIEWER: _____ DATE: _____

ERG NAME: _____ NO.: _____
STEP NAME: _____ NO.: _____
TASK NAME: _____ NO.: _____
TASK OBJECTIVE: _____

INITIATING CUES:

TERMINATING CUES:

REMARKS:

NATURE OF TASK: Continuous _____ Discrete _____

[illegible]

EXHIBIT 4-15
EXAMPLE OF A CONSEQUENCE RATING SCHEME
FOR DECONTAMINATION AND DECOMMISSIONING OPERATIONS

(Source: Paramore, B., Banks, W.W., Veneziano, C., Gilmore, R.D., & Coleman, S.R. (1983). A pilot task analyses of the Rockwell Size Reduction Facility, 234-52 Plutonium Finishing Plant. Richland, WA: Hanford Environmental Health Foundation.)

- 1 = No consequence to personnel safety or contamination control.
- 2 = Very minor severity.
 - o Minor personal injury without contamination with no loss of time from work (e.g., pinch/bruise, contusion, strain).
 - o Airborne contamination or other significant spread or buildup of contamination in sectioning room.
 - o Significant contamination of anteroom (up to 3,000 dpm) requiring no more than 4-hour cleanup.
- 3 = Minor severity
 - o Personal injury resulting in loss of time from work but without contamination (e.g., broken finger or arm, sprained back muscle).
 - o Low-level skin contamination; no internal contamination.
 - o Dusting of contamination in clean area requiring no more than 2-day cleanup.
- 4 = Severe
 - o Slight internal deposition not requiring medical treatment.
 - o Wound with implantation requiring minor medical treatment.
 - o Contamination of clean area requiring up to 2 weeks cleanup.
 - o Controllable environmental release (up to 100 dpm).
 - o Injury resulting in long-term disability.
- 5 = Very severe
 - o Fatality.
 - o Heavy internal deposition or wound with implantation requiring extensive medical treatment.
 - o Spread of contamination requiring more than 2-week cleanup.
 - o Contamination of building, resulting in shutdown of building operations.
 - o Large or uncontrollable environmental release.

**FIGURE 4-1. DEFINITIONS OF TERMS IN SYSTEMS
ANALYSIS APPROACH TO HFE REVIEW**

System (Subsystem): A whole which functions as a whole by virtue of the interdependence of its parts. Also, especially of man-machine systems, an organization of hardware, software, and personnel that work together in a patterned manner to accomplish some purpose.

System(s) Analysis: Examination of a system and its constituents to define their relationships and the ways in which they interact to achieve goal states.

Function (Subfunction): An activity (or a static role) performed by one or more system constituents (people, hardware, software) to contribute to a larger activity or goal state.

Function/Functional Analysis: The examination of system goals to determine what functions they require. Also, examination of the required functions with respect to available manpower, technology, and other resources, to determine how the functions may be allocated and executed. In the context of HFE reviews, the identification of established functions and examination of how they are allocated and executed.

Task (Subtask): A set of human actions, related in time, that contributes to the accomplishment of a function.

Task Analysis: A process of identifying and describing units of work and analyzing the resources necessary for successful performance of those units of work.

Verification: The process of determining whether instrumentation, controls, and other equipment meet the specific requirements of the tasks performed by personnel.

Validation: The process of determining whether system functions can be accomplished given design, procedures, and allocation of task responsibilities.

FIGURE 4-2. EXAMPLE OF A FUNCTIONAL FLOW DIAGRAM

(Source: Geer, C.W. (1976). Analyst's guide for the analysis sections of MIL-H-46855 'D180-19476-1). Seattle, WA: Boeing Aerospace Company, Research and Engineering Division.)

FIGURE 4-3. EXAMPLE OF A DECISION-ACTION DIAGRAM

(Source: Seminara, J.L., et al. (1979). Human factors methods for nuclear control room design (EPRI-NP-1118-SY). Palo, Alto, CA: Electric Power Research Institute.)

5.0 PROCEDURES REVIEW
REVIEW AIDS

4.0 HUMAN FACTORS ENGINEERING REVIEW

REFERENCES

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EXHIBIT 5-1
EXAMPLES OF PROCEDURE-RELATED PERSONNEL ERRORS

At Plant A, Unit 2, with the reactor critical, the boron injection tank (BIT) was not operated in accordance with the station's procedures for periods of time in February and March 1982, so that

- o Required BIT overpressure was not maintained and pressure control valve operability was not verified for the time periods noted.
- o Required overpressure was not verified and adjusted to normal on receipt of a low pressure alarm.
- o Operators and supervisors failed to identify abnormal trends in logged data and failed to take appropriate corrective action.
- o Required overpressure was reduced to zero on February 2, 1982, in accordance with a maintenance work request issued on January 24, 1982, without adequately determining the effect on plant operation.

At Plant B, the reactor was operated in violation of Technical Specification Limiting Conditions for Operation during the period from May 14, 1980, to February 26, 1982. A particular valve serves two functions, containment isolation and vacuum breaking (between the reactor building and the suppression pool). This valve was assembled incorrectly, so that it failed to properly perform either of its dual design functions. Inadequate maintenance procedures for reassembly and test of the valve caused the violation in the first place. Inadequate periodic functional test procedures allowed the condition to exist undetected for over 21 months.

At Plant C, from December 30, 1982, to September 26, 1983, Unit 2 was in violation of its Technical Specifications, because three successive quarterly tests for station battery operability had disclosed uncorrected violations of parameter limits. The licensee attributed the basic cause of the problem to inadequate procedures. The procedures included the limiting parameter values, but did not identify them as accept/reject values. Further, the procedures were vague about what was required of the tester if limits were exceeded.

EXHIBIT 5-2
EXAMPLE CHECKLIST FOR TECHNICAL VERIFICATION

Procedure Title: _____

Procedure Number: _____ Rev Number: _____

Date of Issue: _____ Rev Date: _____

Applicable Technical Documentation:

Evaluator(s): _____

Date Evaluation Completed: _____

EXHIBIT 5-2 (continued)

INSTRUCTION

Items 1 through 8 refer to information that should be provided in an introduction section, before the instructional steps. Check YES, NO or NA for each item. Make notes in the space below the item or on a copy of the procedure as necessary to explain a NO or NA check. Refer to the applicable technical documentation as necessary to ensure that the procedure is accurate and complete with respect to the requirements stated therein.

1. Does the procedure title clearly identify the situation to which the procedure applies?

_ YES _ NO _ NA

2. If the procedure is for scheduled maintenance, test, or calibration, does the title correctly specify the frequency (e.g., monthly)?

_ YES _ NO _ NA

3. If the procedure is for maintenance, test, or calibration, is the equipment to which it applies identified unmistakably in the title or in association with the title? (Unique identification number and/or nomenclature should be used. Location should be stated if necessary.)

_ YES _ NO _ NA

4. Is there a statement of purpose at the beginning, which clearly and correctly summarizes the actions detailed in the procedure and the final condition(s) to be accomplished?

_ YES _ NO _ NA

5. If the procedure is entered on the basis of plant/system/equipment symptoms, are the symptoms stated correctly, clearly, and completely?

_ YES _ NO _ NA

EXHIBIT 5-2 (continued)

6. Are all prerequisites for use of the procedure stated correctly and clearly? For example:
- 6.1 Other actions or procedures that must be completed before this procedure is used.
__ YES __ NO __ NA
- 6.2 Plant, system, or equipment conditions that must exist before this procedure is used.
__ YES __ NO __ NA
7. Does the procedure provide complete and correct job planning information? For example:
- 7.1 Other documents (e.g., other procedures, drawings, manuals) needed to perform the procedure.
__ YES __ NO __ NA
- 7.2 Tools, equipment, and materials needed to perform the procedure.
__ YES __ NO __ NA
- 7.3 Special requirements for personnel protective clothing and apparatus.
__ YES __ NO __ NA
8. Are general precautions which must be observed in performing the procedure stated correctly and completely?
__ YES __ NO __ NA

EXHIBIT 5-2 (continued)

INSTRUCTION

Items 9 - 46 are criteria that apply to the instructional steps of the procedure. Evaluate each step with respect to each of these criteria. Refer to the applicable technical documentation to verify the accuracy and completeness of the steps. If a step does not meet a criterion, make a note of what is wrong on the procedure. When all steps have been reviewed, complete the checklist item to show the findings, identifying the steps that do not meet a criterion.

9. Is provision made for documenting verification of symptoms actually observed?
__ YES __ NO __ NA
10. If this is an emergency procedure, are all required "immediate actions" stated in the first section of instructional steps?
__ YES __ NO __ NA
11. Are "immediate actions" clearly identified as such?
__ YES __ NO __ NA
12. Are the actions required by the steps correct?
__ YES __ NO __ NA
13. Are the actions required by the steps subject to misinterpretation?
__ YES __ NO __ NA
14. Is the sequence of steps correct/appropriate?
__ YES __ NO __ NA

Procedure Number:
Revision Number:

EXHIBIT 5-2 (continued)

15. Are steps that must be performed in a particular sequence identified (e.g., by a note or a symbol such as an asterisk)?
__ YES __ NO __ NA
16. Do the steps include verification of automatic actions where necessary?
__ YES __ NO __ NA
17. Are equipment and components identified correctly by unique number and/or nomenclature?
__ YES __ NO __ NA
18. Are equipment and component identification consistent?
__ YES __ NO __ NA
19. Are equipment and component locations stated when there might be uncertainty?
__ YES __ NO __ NA
20. Are all parameters to be observed identified correctly?
__ YES __ NO __ NA
21. Is the terminology used to identify parameters consistent?
__ YES __ NO __ NA

Procedure Number:
Revision Number:

EXHIBIT 5-2 (continued)

22. If performance of a step is conditional, are the conditions stated clearly and correctly?
__ YES __ NO __ NA
23. Are conditions of step performance stated quantitatively whenever possible?
__ YES __ NO __ NA
24. Are acceptance criteria and limits stated clearly and correctly?
__ YES __ NO __ NA
25. Are acceptance criteria and limits quantitative whenever possible?
__ YES __ NO __ NA
26. Are quantitative acceptance criteria and limits stated as ranges rather than point values whenever possible?
__ YES __ NO __ NA
27. Is the user told what to do if acceptance criteria and limits are not met?
__ YES __ NO __ NA
28. Are control and alignment positions specified correctly?
__ YES __ NO __ NA

EXHIBIT 5-2 (continued)

29. If there is a time criterion for starting or completing an action or series of actions is this stated clearly and correctly?
__ YES __ NO __ NA
30. If an action must be performed later or repeated at an interval, is this made clear
__ YES __ NO __ NA
31. Are all necessary cautions, warnings and notes that apply to individual steps or step series stated clearly and correctly?
__ YES __ NO __ NA
32. Do cautions, warnings, and notes immediately precede the steps to which they apply and appear on the same page?
__ YES __ NO __ NA
33. Are the steps to which cautions, warnings, and notes apply identified correctly?
__ YES __ NO __ NA
34. If calculations are necessary, is this stated?
__ YES __ NO __ NA
35. Are current, accurate formulas and references such as curves or lookup tables provided as necessary for calculations?
__ YES __ NO __ NA
36. Are instructions provided for all reasonable contingencies?
__ YES __ NO __ NA

Procedure Number:
Revision Number:

EXHIBIT 5-2 (continued)

37. Where decisions are required, are the decision factors identified correctly and completely?
__ YES __ NO __ NA
38. Where decisions are required, is the appropriate action path following each decision outcome identified?
__ YES __ NO __ NA
39. Are instructions to branch other procedures correct and complete?
- 39.1 Is the procedure correctly identified (by name, number, date of issue and Rev number and date as applicable)?
__ YES __ NO __ NA
- 39.2 Is the point of entry into the referenced procedure correctly stated?
__ YES __ NO __ NA
- 39.3 Are instructions given for return to the original procedure if necessary?
__ YES __ NO __ NA
- 39.4 Review the action path defined by branching instructions. Will this path accomplish the desired results?
__ YES __ NO __ NA
40. Are instructions to skip to another step within the same procedure correct and complete?
__ YES __ NO __ NA

Procedure Number:
Revision Number:

EXHIBIT 5-2 (continued)

41. Are essential communications specified? ☐ YES ☐ NO ☐ NA
42. If communication is required with personnel at a remote location, does the procedure correctly state where, with whom, and by what means? ☐ YES ☐ NO ☐ NA
43. If the procedure is performed by more than one person, do the instructional steps clearly and correctly indicate the division of responsibility? ☐ YES ☐ NO ☐ NA
44. Do the steps include hold points for independent quality control verifications where necessary and specify who is to perform the verifications (e.g., computations, alignments, tagouts)? ☐ YES ☐ NO ☐ NA
45. If steps require that the actions of two or more people must be coordinated, is there adequate guidance to ensure proper coordination? ☐ YES ☐ NO ☐ NA
46. Are any steps omitted from the procedure? ☐ YES ☐ NO ☐ NA
47. Are all aids (such as decision flow charts, worksheets, checklists) necessary for step performance provided? ☐ YES ☐ NO ☐ NA

Procedure Number:

Revision Number:

EXHIBIT 5-2 (continued)

48. Review any aids. Are they technically correct and useful? ☐ YES ☐ NO ☐ NA
49. Are all references to other documents correct and appropriate? ☐ YES ☐ NO ☐ NA
50. Is the level of detail in instructional steps sufficient for all personnel who may use the procedure? * ☐ YES ☐ NO ☐ NA
51. Are provisions for independent verification and signoff of accurate step completion adequate to prevent errors that could have significant consequences from going unnoticed? ☐ YES ☐ NO ☐ NA
52. Does the procedure or a related document (e.g., work request) identify any required follow-up actions such as a test, notifications, implementation of another procedure? ☐ YES ☐ NO ☐ NA

*A "specificity index" is provided at the end of this checklist which may be used to evaluate level of detail more precisely.

Procedure Number:
Revision Number:

EXHIBIT 5-2 (continued)

53. Specificity Index*: The level of specificity of a procedure may be evaluated by determining the percentage of steps in a selected sample that meet all of the following criteria:

53.1 The action to be taken is specifically identified (open, close, torque, etc.).

53.2 Limits (if applicable) are expressed quantitatively (2 turns, 100 inch lbs., etc.).

53.3 The equipment or parts are identified completely (HPCI-MO-17, etc.).

Base the estimate on a sample of 20% of the steps in a given procedure or a minimum of 10 steps.

Do at least 90% of the steps evaluated meet the above criteria?

☐ YES ☐ NO ☐ NA

*Source: Brune & Weinstein (May 1981)

EXHIBIT 5-3

EXAMPLE CHECKLIST FOR PROCEDURE DESIGN VERIFICATION

Procedure Title: _____

Procedure Number: _____ Rev Number: _____

Date of Issue: _____ Rev Date: _____

Evaluator(s): _____

Date Evaluation Completed: _____

INSTRUCTIONS

The checklist is designed to address major parts of the procedure in turn: cover, title page, table of contents, instructions (steps), and attachments. Items 4 through 10, however, will require you to scan through all instruction and attachment pages to verify proper identification. Items 11 through 42 must be repeated for each instructional step or page of steps.

All items call for a "YES", "NO" or "NA" answer. "NO" indicates a discrepancy from a checklist criterion. Use the space below the item to identify the discrepancy (e.g., record the step number(s) and page number (s)) and describe it in more detail as necessary.

EXHIBIT 5-3 (continued)

Identification

1. Is there a cover page that shows all of the following information?
 - o Procedure title
 - o Procedure number
 - o Date of issue
 - o Revision number (if applicable)
 - o Revision date
 - o Approval signature and date

__ YES __ NO __ NA

2. Is there a table of contents that identifies and gives page references for the major sections of the procedure, as applicable (e.g., objective, prerequisites, job planning information, immediate actions, subprocedures, attachments)?

__ YES __ NO __ NA

3. Is indention used in the table of contents to show subordination of parts of the procedure?

__ YES __ NO __ NA

4. Is a descriptive title provided in the table of contents for all attachments?

__ YES __ NO __ NA

5. Do the headings/titles and page numbers listed in the table of contents match those in the procedure?

__ YES __ NO __ NA

Procedure Number:
Revision Number:

EXHIBIT 5-3 (continued)

6. Does the procedure title appear in all caps, centered near the top of the first page of the procedure?
__ YES __ NO __ NA
7. Is the title of each major section within the procedure highlighted (e.g., under-scored, with the first letter of each word capitalized)?
__ YES __ NO __ NA
8. For each page of the procedure, does the following identifying information appear in the upper right corner?
- o Procedure number
 - o Date of issue
 - o Revision number (if applicable)
 - o Revision date (if applicable)
- __ YES __ NO __ NA
9. If this is a temporary procedure, is this shown in the identifying information on each page, with the expiration date?
__ YES __ NO __ NA
10. For each page of the procedure, are the page number and total number of pages (page __ of __) shown at the bottom of the page?
__ YES __ NO __ NA
11. Is the end of the procedure identified by END or FINAL PAGE following the last instructional step?

Procedure Number:
Revision Number:

EXHIBIT 5-3 (continued)

12. For each page of each attachment, is the following identifying information in the upper right corner?
- o Procedure number
 - o Date of issue
 - o Revision number (if applicable)
 - o Revision date (if applicable)
- __ YES __ NO __ NA
13. For each attachment, are the page number and total number of pages shown at the bottom of the page? (page __ of __, referring to the pages in the particular attachment)
- __ YES __ NO __ NA
14. Do the attachments have the following information centered at the top of each page?
- o Attachment number
 - o Attachment title
 - o Appropriate highlighting (e.g., underscored, with the first letter of each word capitablized)?
- __ YES __ NO __ NA

Instructional Step Format and Style

15. Is there enough space between all numbered steps to separate them clearly?
- __ YES __ NO __ NA
16. Do all of the written words of a given step or substep appear on the same page?
- __ YES __ NO __ NA

Procedure Number:
Revision Number:

EXHIBIT 5-3 (continued)

17. Are steps typed in upper and lower case letters rather than all upper case letters?
("All caps" should be reserved for use as a highlighting or emphasis technique.)
__ YES __ NO __ NA
18. Are margins sufficient, so that no information will be lost when the page is copied?
__ YES __ NO __ NA
19. Is correct standard English spelling, grammar, and punctuation used?
__ YES __ NO __ NA
20. Are instructions written in short, concise, identifiable steps are opposed to multistep paragraphs?*
- __ YES __ NO __ NA
21. Are steps which have more than one action minimized?*
- __ YES __ NO __ NA
22. If a step has more than two objects of action (e.g., the operator/technician is directed to close four valves), are they listed on separate lines rather than presented as a string in a sentence?
- __ YES __ NO __ NA

*An index is provided at the end of this checklist which may be used to evaluate the complexity of the instructional steps more precisely.

Procedure Number:
Revision Number:

EXHIBIT 5-3 (continued)

23. Are first-level steps highlighted by a short horizontal line to the left of the step number, to assist the operator in place-keeping?
__ YES __ NO __ NA
24. Do acronyms and abbreviations conform to facility conventions?
__ YES __ NO __ NA
25. Do symbols, if used, conform to facility conventions?
__ YES __ NO __ NA
26. When a specific component is referred to, is it identified in all caps, followed by the engineering number in parentheses?
__ YES __ NO __ NA
27. When a specific annunciator is referred to, is it identified in all caps, followed by the alarm panel and window numbers in parentheses?
__ YES __ NO __ NA
28. Are conditional or contingency steps expressed such that the conditions are stated before the action which is to be performed? (For example, conditional/contingency instructions should be stated "IF __, THEN do __," not "do __ IF __.")
__ YES __ NO __ NA

EXHIBIT 5-3 (continued)

29. Are conditional or contingency instructions easy to understand? For example, if two or more conditions must be met before an action is performed are they:
- a. Listed separately?
 - b. Listed ahead of the action statement?
 - c. Clarified by the appropriate logic terms?
- __ YES __ NO __ NA
30. Are logic terms emphasized by using all capital letters and underscoring? (For example IF, THEN, AND, OR)
- __ YES __ NO __ NA
31. Are conditional steps written to avoid multiple combinations of logic terms?
- __ YES __ NO __ NA
32. If calculations are required, is adequate space provided to perform them?
- __ YES __ NO __ NA
33. Are formulas for calculations provided when needed?
- __ YES __ NO __ NA
34. When deviation from a setpoint is allowed, is it given as a range or limiting value rather than as a percentage?
- __ YES __ NO __ NA
35. Are cautions, warnings, and notes free of action instructions?
- __ YES __ NO __ NA

EXHIBIT 5-3 (continued)

36. Are cautions, warnings, and notes separate and easily distinguishable from instructional steps? (e.g., by headings and boxing)
__ YES __ NO __ NA
37. Are cautions, warnings, and notes easily distinguishable from each other? (e.g., by headings and different boxing techniques such as asterisks, dashed lines, solid lines)
__ YES __ NO __ NA
38. Do alignment instructions (e.g. valve alignment lists, electrical alignment lists) meet the following criteria?
a. Each item individually specified.
b. Each item identified with a unique number or nomenclature.
c. Position specified.
__ YES __ NO __ NA
39. Are the titles and numbers of all referenced documents accurately identified, with procedure number given first, followed by title in all caps?
__ YES __ NO __ NA
40. Is the operator/technician told where to enter and exit the referenced procedure?
__ YES __ NO __ NA
41. Is the operator/technician told whether it is necessary to reenter this procedure and, if so, when/under what conditions, and where?
__ YES __ NO __ NA

Procedure Number:

Revision Number:

EXHIBIT 5-3 (continued)

42. Examine referenced material. Is the referenced material to have been easily incorporated into the procedure being verified?

☐ YES ☐ NO ☐ NA

43. If a graphic attachment or other attachment is cited in a step, does it appear at the end of the procedure, with the correct numerical identification and title, and in the correct order relative to other attachments? (They should be numbered and appear in the order in which they are cited.)

☐ YES ☐ NO ☐ NA

44. Are all graphics identified as attachments?

☐ YES ☐ NO ☐ NA

45. Are all attachments. . .

a. Descriptively titled?

b. Clearly labeled?

c. Readable?

☐ YES ☐ NO ☐ NA

EXHIBIT 5-3 (continued)

46. For all flow charts. . .

- a. Is the direction of yes/no paths consistent?
- b. Are path and loop logic complete so there is no ambiguity about how to proceed?

47. Complexity index*: Evaluate the complexity of the instructions by determining the average number of actions per step that the user is directed to perform. Use all steps to calculate the average.

Is the average number of actions per step 1.5 or less?

☐ YES ☐ NO ☐ NA

*Source: Brune & Weinstein (1957)

EXHIBIT 5-4
EXAMPLE CHECKLIST FOR PROCEDURE VALIDATION EXERCISES

Procedure Title: _____

Procedure Number: _____ Rev Number: _____

Date of Issue: _____ Rev Date: _____

Observer: _____

Date of Validation: _____

INSTRUCTIONS

Answer "YES", "NO", or "NA" to each criterion statement. Use the space below each criterion statement to explain any "NO" answers. Identify the part(s) or step(s) of the procedure that are involved.

Procedure Number:
Revision Number:

EXHIBIT 5-4 (continued)

1. Do the symptoms observable in the work station agree with what is said in the procedure?
☐ YES ☐ NO ☐ NA

2. Can the instructional steps be performed in the sequence indicated by the procedure?
☐ YES ☐ NO ☐ NA

3. Can personnel readily locate all components referred to in the procedure?
☐ YES ☐ NO ☐ NA

4. Are system/equipment responses and parameter values consistent with what is said in the procedure?
☐ YES ☐ NO ☐ NA

5. Do personnel omit any procedural steps?
☐ YES ☐ NO ☐ NA

6. Do personnel perform steps that are not specified in the procedure?
☐ YES ☐ NO ☐ NA

Procedure Number:
Revision Number:

EXHIBIT 5-4 (continued)

7. Can personnel perform the procedure without getting additional information from sources not identified in the procedure?

☐ YES ☐ NO ☐ NA

8. Can personnel perform the procedure without getting help from others not identified in the procedure?

☐ YES ☐ NO ☐ NA

9. If the procedure is performed by more than one person. . .

- 9.1 Can they communicate without difficulty?

☐ YES ☐ NO ☐ NA

- 9.2 Are essential communications specified in the procedure?

☐ YES ☐ NO ☐ NA

- 9.3 Can their actions be coordinated without difficulty?

☐ YES ☐ NO ☐ NA

- 9.4 Do they get in each others' way?

☐ YES ☐ NO ☐ NA

Procedure Number:
Revision Number:

EXHIBIT 5-4 (continued)

10. Can personnel perform the procedure effectively while wearing protective gear (if required)?
__ YES __ NO __ NA
11. Do the physical characteristics of the procedure (e.g., size, binding, mounting) allow it to be used conveniently in the work setting?
__ YES __ NO __ NA
12. Can other documentation, tools, and materials required by the procedure be used conveniently in the work setting?
__ YES __ NO __ NA

EXHIBIT 5-6

SUMMARY OF REGULATORY GUIDANCE CONCERNING NEEDS FOR WRITTEN PROCEDURES

- o Title 10 of the Code of Federal Regulations, Part 50, Appendix B ("Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants") states that "Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures or drawings. (They) shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished" (10 CFR 50, revised as of January 1, 1983, p. 456).
- o For nonreactor facilities handling sufficient amounts of materials with criticality potential - DOE Order 5480.1 (8-13-81), page V-9) requires that contractors shall "prepare and utilize written procedures for the handling of fissionable materials, including storage, transfer and processing." More description of the activities and concerns to be covered by these procedures is given in Section V.9C of the Order.
- o For reactor facilities - DOE Order 5480.1 (8-13-81, page VI-22) refers to "procedures, i.e., administrative, operating (normal and abnormal), maintenance repair, testing, quality assurance, and emergency", in the context of requirements for the "Contractor Independent Review and Appraisal System." (Independent and objective review of these procedures, and of changes thereto, is required.)
- o For both nuclear and non nuclear facilities - DOE Order 5500.2 requires written plans and procedures for operational emergencies. The order identifies items that "should be considered in the preparation of emergency procedures." (It is noted that the list is not considered all-inclusive):
 - Personnel evacuation and accountability
 - Emergency notification
 - Readiness actions
 - Personnel monitoring and decontamination
 - Medical emergency requirements
 - Damage control
 - Reentry planning
 - Damage assessment.

Somewhat more specific guidance concerning procedural coverage at licensed reactor facilities is available in American National Standard N18.7-1976.⁵ This standard for NRC-licensed reactors specifies that written procedures shall be provided for the following activities:

EXHIBIT 5-5 (continued)

- o System operations (i.e., instructions for operation of individual systems related to the safety of the plant, including energizing, filling, venting, draining, starting up and shutting down, etc.)
- o Integrated plant operations, including
 - Startup
 - Shutdown
 - Power operation and load change
 - Process monitoring
 - Fuel handling (Specific procedures should be prepared for each receipt and shipment of fuel and for each refueling outage. General fuel handling procedures should prescribe preplanning and safety measures and should identify the specific procedures to be prepared for each outage.)
- o Maintenance, including
 - Preparation
 - Performance
 - Post-maintenance checkout and return to service.
- o Calibration and test
- o Radiation control
- o Chemical-radio chemical control
- o Emergency operations
- o Emergency Plan implementation and restoration to normal conditions following an emergency
- o Test and inspection

EXHIBIT 5-6
EXAMPLE OF A CRITERION CHECKLIST FOR ASSESSING
NEEDS FOR ADDITIONAL PROCEDURES

Functional Area/Department

Activity

Reviewer(s):

Date:

INSTRUCTIONS

Check YES or NO for each item. YES checks indicate potential reasons why a written procedure may be needed. The mix of results for each activity should be weighed on a case-by-case basis. As a rule of thumb, if three or more items are checked YES, a written procedure should usually be recommended.

EXHIBIT 5-6 (continued)

1. The activity is long in terms of number of steps that must be performed.
☐ YES ☐ NO

2. The activity requires relatively complex decision-making or diagnosis.
☐ YES ☐ NO

3. The activity is not performed very often (e.g., it is performed no more than four times a year).
☐ YES ☐ NO

4. It could be necessary to perform this activity under conditions of high physiological or psychological stress.
☐ YES ☐ NO

5. Proper execution of the activity is not self-evident from the equipment configuration.
☐ YES ☐ NO

6. In error could occur in this activity that would be difficult to detect or recover.
☐ YES ☐ NO

5.0 PROCEDURES REVIEW

REFERENCES

1. Brune, R.L. & Weinstein, M. (1981, May). Development of a checklist for evaluating emergency procedures used in nuclear power plants (NUREG/CR-1970, SAND81-7070). Washington, DC: U.S. Nuclear Regulatory Commission.
2. Brune, R.L. & Weinstein, M. (1980, May). Development of a checklist for evaluating maintenance, test, and calibration procedures used in nuclear power plants (NUREG/CR-1368, SAND80-7053). Washington, DC: U.S. Nuclear Regulatory Commission.
3. Serendipity, Inc. (1969). Project PIMO final report, Volume I: summary (AD-852 101). Alexandria, VA: Defense Logistics Agency, Defense Technical Information Center.

Sources of Procedures Evaluation Methods/Checklists

- Brune, R.L. & Weinstein, M. (1981, May). Checklist for evaluating emergency procedures used in nuclear power plants (NUREG/CR-2005, SAND81-7074). Washington, DC: U.S. Nuclear Regulatory Commission.
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- Fuchs, F., Engelschall, J. & Imlay, G. (1981). Human Engineering Guidelines for Use in Preparing Emergency Operating Procedures for Nuclear Power Plants (NUREG/CR-1999) Washington, D.C.: U.S. Nuclear Regulatory Commission.
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Sources of Procedure Development Guidance

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- Morgenstern, M.H. et al. (1981). Guidelines for preparing emergency operating procedures (NUREG/CR-1977, PNL-3713). Washington, DC: U.S. Nuclear Regulatory Commission.
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- Serendipity, Inc. (1969). Project PIMO final report, Volumes IV-VII (AD-852 104, 105, 106, 107). Alexandria, VA: Defense Logistics Agency Defense Technical Information Center.
- Taylor, D.F. & Voss, T.J. (1982). A pilot evaluation of three alternative formats for emergency control room procedures. Transactions of the American Nuclear Society, 43, 235-236.
- U.S Nuclear Regulatory Commission. (1982). Guidelines for the preparation of emergency operating procedures (NUREG-0899). Washington, DC: Author.

EXHIBIT 5-6 (continued)

7. There could be significant consequences of an error made in performing this activity.

☐ YES ☐ NO

8. Personnel may perform this activity who do not have a high level of skill/experience.

☐ YES ☐ NO

9. Personnel may perform this activity without close supervision or verification of correct performance.

☐ YES ☐ NO

6.0 ORGANIZATIONAL INTERFACE REVIEW
REVIEW AIDS

EXHIBIT 6-2
ORGANIZATIONAL COMMUNICATION SURVEY QUESTIONNAIRE

This questionnaire is presented as an example of a comprehensive survey instrument that addresses many aspects of organizational interfaces that are relevant to the DOE facilities. Scoring of this survey is discussed in Section 6.0 of this Review Plan and Exhibit 6-1 of the Appendix provides the listing of communication indices and related questionnaire items to be used for scoring the questionnaire.

EXHIBIT 6-2

Plant _____

ORGANIZATIONAL COMMUNICATION SURVEY

Date: _____

1. What department do you work in?

- 1. ☐ Operations
- 2. ☐ Maintenance
- 3. ☐ I&C
- 4. ☐ Quality Assurance
- 5. ☐ Health/Physics
- 6. ☐ Plant Management
- 7. ☐ Other (Please specify):

2. What is your current job category?

- 1. ☐ Auxiliary Reactor Operator
- 2. ☐ Licensed Operator (RO)
- 3. ☐ Senior Licensed Operator (SRO)
- 4. ☐ Technician
- 5. ☐ Mechanic
- 6. ☐ First Line Supervisor (e.g., shift supervisor, chief mechanic)
- 7. ☐ Second Line Supervisor
- 8. ☐ Third Line Supervisor
- 9. ☐ Top Level Manager
- 10. ☐ SRO and First Line Supervisor
- 11. ☐ SRO and Second Line Supervisor
- 12. ☐ Professional/Technical Staff
- 13. ☐ Management Staff
- 14. ☐ Other (Please specify):

This is a series of questions about how people communicate at work. Imagine a typical week at work on your current job, and answer the questions accordingly. Please attempt to answer all the questions.

Most questions have seven point scales on which to answer. On these questions, please check the point that represents most closely how you feel. Read each question and scale carefully. For instance, to the question, "How rich do you want to be?" you might answer:

- 1 ☐ Very Poor
- 2 ☐
- 3 ☐
- 4 ☐
- 5 ☐
- 6 ☐
- 7 ☐ Very rich

Answer each question for routine conditions except where outages are noted.

EXHIBIT G-2

3. Do you have subordinates working for you? No ____ Yes ____ How many? ____
4. How free do you feel to discuss with your immediate superior (the person who most frequently gives you orders and directions) the problems and difficulties you have in your job without jeopardizing your position or having it "held against" you later?
- 1 ____ Completely free
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Very cautious
5. Immediate superiors at times must make decision which seem to be against the interests of their subordinates. When this happens to you as a subordinate, how much trust do you have that your immediate superior's decision was justified by other considerations?
- 1 ____ Trust completely
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Feel very distrustful
6. In general, how much do you feel that your immediate superior can do to further your career in the utility?
- 1 ____ Much
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Little
7. How much importance would your immediate superior's recommendation have in any decision which would affect your standing in the utility such as promotions, transfers, etc.?
- 1 ____ Important
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Unimportant
8. As part of your present job plans, do you want a promotion to a higher position at some point in the future?
- 1 ____ Content as I am
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Very much want a promotion

EXHIBIT 6-2

9. How important is it for you to progress upward in the utility?

- 1 ☐ Not important
 2 ☐
 3 ☐
 4 ☐
 5 ☐
 6 ☐
 7 ☐ Very important

10. To what extent do you have confidence in your immediate superior regarding his general fairness?

- 1 ☐ Have little confidence or trust
 2 ☐
 3 ☐
 4 ☐
 5 ☐
 6 ☐
 7 ☐ Have complete confidence and trust

While working, what percentage of time do you spend interacting with the following individuals in your department?

<u>Under Normal Conditions:</u>		<u>Under Outage Conditions:</u>	
11. Immediate superiors	☐ %	14. Immediate Superiors	☐ %
12. Subordinates	☐ %	15. Subordinates	☐ %
13. Peers—others at your job level	☐ %	16. Peers—others at your job level	☐ %
Total = ☐ %		Total = ☐ %	
100%		100%	

While working, what percentage of time do you spend interacting with individuals from the following departments (including your own)?

<u>Under Normal Conditions:</u>		<u>Under Outage Conditions:</u>	
17. Operations	☐ %	22. Operations	☐ %
18. Maintenance	☐ %	23. Maintenance	☐ %
19. I&C	☐ %	24. I&C	☐ %
20. Quality Assurance	☐ %	25. Quality Assurance	☐ %
21. Health/Physics	☐ %	26. Health/Physics	☐ %
Total = ☐ %		Total = ☐ %	
100%		100%	

Of the total time you engage in communication while on the job, about what percentage of the time do you use the following methods to communicate?

27. Written ☐ %
 28. Face-to-face ☐ %
 29. Telephone ☐ %
- Total = 100%

How would you rate the quality of the following in providing you the information you need to effectively perform your job:

30. Work Request/Job Order Forms	31. Policies	32. Procedures
1 ☐ Very poor	1 ☐ Very poor	1 ☐ Very poor
2 ☐	2 ☐	2 ☐
3 ☐	3 ☐	3 ☐
4 ☐	4 ☐	4 ☐
5 ☐	5 ☐	5 ☐
6 ☐	6 ☐	6 ☐
7 ☐ Outstanding	7 ☐ Outstanding	7 ☐ Outstanding

EXHIBIT 6-2

When receiving information from the sources listed below, how accurate would you estimate it usually is under normal plant conditions:

33. Immediate Superiors	34. Subordinates	35. Peers--Others at your Job Level
1 ___ Completely Accurate	1 ___ Completely Accurate	1 ___ Completely Accurate
2 ___	2 ___	2 ___
3 ___	3 ___	3 ___
4 ___	4 ___	4 ___
5 ___	5 ___	5 ___
6 ___	6 ___	6 ___
7 ___ Completely Inaccurate	7 ___ Completely Inaccurate	7 ___ Completely Inaccurate
	8 ___ Not Applicable	

When receiving information from the sources listed below, how accurate would you estimate it usually is during a plant outage:

36. Immediate Superiors	37. Subordinates	38. Peers--Others at your Job Level
1 ___ Completely Accurate	1 ___ Completely Accurate	1 ___ Completely Accurate
2 ___	2 ___	2 ___
3 ___	3 ___	3 ___
4 ___	4 ___	4 ___
5 ___	5 ___	5 ___
6 ___	6 ___	6 ___
7 ___ Completely Inaccurate	7 ___ Completely Inaccurate	7 ___ Completely Inaccurate
	8 ___ Not Applicable	

39. Do you ever feel that you receive more information than you can efficiently use?

- 1 ___ Never
 2 ___
 3 ___
 4 ___
 5 ___
 6 ___
 7 ___ Always

Of the total time you spend receiving information at work, what percentage is from:

40. Immediate superiors	___%	} Total = 100%
41. Subordinates	___%	
42. Peers--others at your job level	___%	
43. Other Sources (please specify _____)	___%	

Of the total time you spend sending information, what percentage goes to:

44. Immediate superiors	___%	} Total = 100%
45. Subordinates	___%	
46. Peers--others at your job level	___%	
47. Other Sources (please specify _____)	___%	

EXHIBIT 6-2

When transmitting information to the following people in your department, how often do you summarize by emphasizing those aspects which are important and minimize those aspects which are unimportant?

48. Immediate Superiors

- 1 ☐ Always
2 ☐
3 ☐
4 ☐
5 ☐
6 ☐
7 ☐ Never

49. Subordinates

- 1 ☐ Always
2 ☐
3 ☐
4 ☐
5 ☐
6 ☐
7 ☐ Never
8 ☐ Not Applicable

50. Peers—Others at Your Job Level

- 1 ☐ Always
2 ☐
3 ☐
4 ☐
5 ☐
6 ☐
7 ☐ Never

When transmitting information to the following departments, how often do you summarize by emphasizing those aspects which are important and minimizing those aspects which are unimportant?

	Always						Never
	1	2	3	4	5	6	7
51. Operations	☐	☐	☐	☐	☐	☐	☐
52. Maintenance	☐	☐	☐	☐	☐	☐	☐
53. I&C	☐	☐	☐	☐	☐	☐	☐
54. Quality Assurance	☐	☐	☐	☐	☐	☐	☐
55. Health/Physics	☐	☐	☐	☐	☐	☐	☐
56. Plant Management	☐	☐	☐	☐	☐	☐	☐

57. In a typical work week, approximately how often do you have less than the amount of information you could consistently handle for making the best possible work-related decisions?

- 1 ☐ Very often
2 ☐
3 ☐
4 ☐
5 ☐
6 ☐
7 ☐ Not often

58. Sometimes at work you may receive more information than you can efficiently use. Other times, however, you may feel that you are not receiving all the information you need. How often during a week would you say this lack of information arises?

- 1 ☐ Very often
2 ☐
3 ☐
4 ☐
5 ☐
6 ☐
7 ☐ Not often

59. Is the total amount of information you receive in a typical work week enough to meet the information requirements of your job?

- 1 ☐ Not enough at all
2 ☐
3 ☐
4 ☐
5 ☐
6 ☐
7 ☐ Too much

EXHIBIT 6-2

When transmitting information to the following people in your department, how often do you expand it by discussing in greater detail some aspects of the information?

60. To Immediate Superiors

- 1 ___ Never
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ Always

61. To Subordinates

- 1 ___ Never
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ Always
8 ___ Not Applicable

62. To Peers—Others at Your Job Level

- 1 ___ Never
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ Always

When transmitting information to the following departments, how often do you expand it by discussing in greater detail some aspects of the information?

	Never						Always
	1	2	3	4	5	6	7
63. Operations	☐	☐	☐	☐	☐	☐	☐
64. Maintenance	☐	☐	☐	☐	☐	☐	☐
65. I&C	☐	☐	☐	☐	☐	☐	☐
66. Quality Assurance	☐	☐	☐	☐	☐	☐	☐
67. Health/Physics	☐	☐	☐	☐	☐	☐	☐
68. Plant Management	☐	☐	☐	☐	☐	☐	☐

Of the total amount of information you receive at work, how much do you pass on to:

69. Immediate Superiors

- 1 ___ All
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ None

70. Subordinates

- 1 ___ All
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ None
8 ___ Not Applicable

71. Peers—Others at Your Job Level

- 1 ___ All
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ None

How desirable do you feel it is in your work group to interact frequently with:

72. Immediate Superiors

- 1 ___ Very Desirable
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ Completely Undesirable

73. Subordinates

- 1 ___ Very Desirable
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ Completely Undesirable
8 ___ Not Applicable

74. Peers—Others at Your Job Level

- 1 ___ Very Desirable
2 ___
3 ___
4 ___
5 ___
6 ___
7 ___ Completely Undesirable

EXHIBIT 6-2

75. While at work, we often receive the same information (such as directives, statements of policy, changes in regulations, requests for reports, etc.) more than once. How often do you estimate the information you receive on the job is received more than once?

1 ____ Never
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Often

It is often necessary in our jobs not to pass to others some of the information which comes to us. About how often during a typical week do you withhold from the following people information which might be useful to them?

76. Immediate Superiors

1 ____ Frequently
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Infrequently

77. Subordinates

1 ____ Frequently
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Infrequently
8 ____ Not Applicable

78. Peers—Others at Your Job Level

1 ____ Frequently
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ Infrequently

It is often necessary in our jobs not to pass to others some of the information which comes to us. About how often during a typical week do you withhold from the following departments information which might be useful to them?

	Frequently					Infrequently	
	1	2	3	4	5	6	7
79. Operations	☐	☐	☐	☐	☐	☐	☐
80. Maintenance	☐	☐	☐	☐	☐	☐	☐
81. I&C	☐	☐	☐	☐	☐	☐	☐
82. Quality Assurance	☐	☐	☐	☐	☐	☐	☐
83. Health/Physics	☐	☐	☐	☐	☐	☐	☐
84. Plant Management	☐	☐	☐	☐	☐	☐	☐

We often find it necessary to change the nature of information (e.g., use different words, shift emphasis, simplify, etc.) we pass on to others in our organizations. Of the total amount of information you receive, how much of it must you actively change in some way before you pass it on to the following people in your department:

85. Immediate Superiors

1 ____ A Small Amount
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ A Large Amount

86. Subordinates

1 ____ A Small Amount
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ A Large Amount
8 ____ Not Applicable

87. Peers—Others at Your Job Level

1 ____ A Small Amount
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____ A Large Amount

EXHIBIT 6-1
ORGANIZATIONAL COMMUNICATION INDICES AND THEIR
COMPONENT QUESTIONNAIRE ITEMS

Listed below are the set of communication indices taken from the Organizational Communication Questionnaire^{4,5} and the related questionnaire items that make up each index. Questionnaire item numbers correspond to those numbers shown in Exhibit 6-2 of the Appendix.

INDEX	QUESTIONNAIRE ITEM NUMBERS
Trust	4, 5, 10
Influence	6, 7
Mobility	8, 9
Upward Directionality	11, 14, 41, 44
Downward Directionality	12, 15, 40, 45
Lateral Directionality	13, 16, 42, 46
Quality of Work-Related Documentation	27, 28, 29, 30, 31, 32
Accuracy	33, 34, 35, 36, 37, 38
Summarization	48, 49, 50, 51, 52, 53, 54, 55, 56
Expansion	60, 61, 62, 63, 64, 65, 66, 67, 68
Gatekeeping/Withholding Information	69, 70, 71, 76, 77, 78, 79, 80, 81, 82, 83, 84
Desire for Interaction	72, 73, 74
Redundancy	75
Changing Information	85, 86, 87, 88, 89, 90, 91, 92, 93
Satisfaction	94
Information Amount	57, 58, 59, 95, 96, 97, 98, 99
Timeliness	100-110
Feedback	111-120

EXHIBIT 6-2

Of the total amount of information you receive, how much of it must you actively change in some way before you pass it on to the following departments:

	A Small Amount					A Large Amount	
	1	2	3	4	5	6	7
88. Operations	☐	☐	☐	☐	☐	☐	☐
89. Maintenance	☐	☐	☐	☐	☐	☐	☐
90. I&C	☐	☐	☐	☐	☐	☐	☐
91. Quality Assurance	☐	☐	☐	☐	☐	☐	☐
92. Health/Physics	☐	☐	☐	☐	☐	☐	☐
93. Plant Management	☐	☐	☐	☐	☐	☐	☐

94. Put a check under the face that expresses how you feel about communications in general, including the amount of information you receive, contacts with your immediate superior and others, the accuracy of information available, etc.

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>

All organizations have reporting requirements. Please rate your satisfaction with the amount of information you give/send to others regarding the areas listed below.

	Too Little			About Right		Too Much	
	1	2	3	4	5	6	7
95. Reporting job-related problems	☐	☐	☐	☐	☐	☐	☐
96. Reporting poor working conditions	☐	☐	☐	☐	☐	☐	☐
97. Documenting my work	☐	☐	☐	☐	☐	☐	☐
98. Requesting information needed to do my job	☐	☐	☐	☐	☐	☐	☐
99. Requesting clarification of work requests	☐	☐	☐	☐	☐	☐	☐

EXHIBIT 6-3

CANDIDATE INTERVIEW QUESTIONS FOR THE ORGANIZATIONAL COMMUNICATION SURVEY

This set of interview questions was developed to tap critical incidents or real world examples of communication problems that employees have in their organization. The topic areas of the interview questions correspond to the major areas covered in the Organizational Communication Survey (Exhibit 6-2). These questions should be asked to a cross section of DOE facility personnel on an individual and confidential basis. The interview responses should be reviewed to verify the questionnaire data findings and to provide examples of specific events where problems have occurred.

EXHIBIT 6-3

1. Do communication problems between functional areas lead to conflicting priorities for your facility or problems with advanced planning?
2. Do the official lines of communication in your facility allow for effective transfer of information up and down the chain of command? Why do you feel this is true?
3. Do the official lines of communications break down? If so, where and when?
4. Do you sometimes receive inadequate information from other functional areas? Which areas do you have the most problems with?
 - a. How is the information received from other functional areas inadequate?
 - (1) Incomplete
 - (2) Inaccurate
 - (3) Untimely
 - (4) Poorly written/transmitted
 - b. What type of information, in particular, is most inadequate from other functional areas? (e.g., general letters of transmittal; work requests, forecasts, etc.)
 - c. What suggestions do you have to help other functional areas improve on the adequacy of information which they provide to you?
 - d. Do you ever experience work delays that are caused by poor communication between functional areas?

What types of delays? Please give an example.

EXHIBIT 6-3

Are the activities in your functional areas sensibly organized?

IF YES:

- a. What factor(s) do you believe contribute most to the sensible organization of your functional area's work activities?

IF NO:

- b. What is an example of work activities not being sensibly organized?
 - c. What factor(s) do you believe contribute most to the lack of sensible organization of work activities?
 - d. What suggestions do you have to organize work activities more sensibly?
6. Does your supervisor provide support to help get work done on time?
- a. What are some examples of when your supervisor has provided support to help you get your work done on time?

What are some examples of when your supervisor has not provided support?

- b. What factor(s) do you believe contribute most to your supervisor's lack of support in getting your job done on time.
- c. What suggestions do you have that might help your supervisor to provide you with the support you need to get your work done on time?

EXHIBIT 6-3

7. Can you think of any specific problems with work procedures and/or documentation that cause confusion or increase the chance of performance errors? What are these?

EXHIBIT 6-4
SAMPLE INTERVIEW TALLY SHEET

INTERVIEW QUESTION: _____

[illegible]

EXHIBIT 6-5
SUMMARY EVALUATION OF CANDIDATE
ORGANIZATIONAL INTERFACE SOLUTIONS

	RELEVANCE TO ORGANIZATIONAL INTERFACE ISSUES	PAYOFF TO FACILITY	EVIDENCE OF EFFECTIVENESS	EASE OF IMPLEMENTATION	
SOLUTION 1:					
SOLUTION 2:					
SOLUTION 3:					
SOLUTION 4:					

MAKE RATINGS FOR EACH
CRITERION ON A FIVE-POINT
RATING SCALE (1 = LOW; 5 = HIGH).

**FIGURE 6-1
MANAGEMENT/PLANT INTERFACE**

% WHO HAVE PROBLEMS INTERFACING WITH:

TABLE 6-1
TYPICAL CROSS SECTION OF DOE FACILITY PERSONNEL
SELECTED FOR AN ORGANIZATIONAL COMMUNICATIONS SURVEY

<u>Functional Area</u>	<u>Operator/ Technician/ Mechanic</u>	<u>Line Supervisors</u>	<u>Department Managers</u>	<u>Top-Level Manager</u>
Operations	4	1	1	
Maintenance	4	1	1	1
I&C	2	1	1	
Health and Safety	2	1	1	
Quality Control/ Quality Assurance	<u>2</u>	<u>1</u>	<u>1</u>	-
Subtotals	14	5	5	1

Total: 25 personnel per facility receiving questionnaires.

TABLE 6-2
DEPARTMENTAL COMMUNICATION PROBLEMS* BY FACILITY

COMMUNICATION						
	OPERATIONS	MAINTEN- ANCE	I&C	HEALTH & SAFETY	QA/QC	MANAGE- MENT
FACILITY	GATEK (3.6) REDUND (3.7)	AMOUNT (3.0) REDUND (3.3) TIMELIN (3.7) MODAL (3.7)	REDUND (3.3) MODAL (3.3)	MODAL (3.1) REDUND (3.3) AMOUNT (3.7) TIMELIN (3.7) FEEDBACK (3.8)	GATEKEEP (3.3) AMOUNT (3.9)	OVERLOAD (2.0) TIMELIN (3.0) REDUND (3.0) MOBIL (3.0) GATEK (3.3) EXPANS (3.8)
FACILITY	REDUND (3.0) INFLUEN (3.3) UNDERL (3.4) CHANG (3.6) FEEDBACK (3.6) TIMELIN (3.7) MODAL (3.8)	REDUND (2.7) MODAL (3.8) OVERL (3.8) UNDERL (3.8) TIMELIN (3.8) AMOUNT (3.9)	FEEDBACK (3.3) TIMELIN (3.4) UNDERL (3.7) REDUND (3.7) AMOUNT (3.7)	MODAL (3.9)	REDUND (3.5) GATEK (3.9)	(TECH STAT) OVERLOAD (3.0) UNDERL (3.5) REDUND (3.5) AMOUNT (3.8)
FACILITY	AMOUNT (3.9)	REDUND (2.8) EXPANS (3.2) AMOUNT (3.5) MODAL (3.9) MAINT (3.9)	REDUND (3.7) AMOUNT (3.7)	UNDERL (2.9) TIMELIN (3.3) FEEDBACK (3.6) MODAL (3.7)	AMOUNT (3.7) MODAL (3.8) FEEDBACK (3.9)	REDUND (2.5) AMOUNT (3.7) INFLUEN (5.8)

*Indices shown have mean scores less than 4.0 on a 7-point (low to high) rating scale.

TABLE 6-3
JOB COORDINATION MEETING AGENDA/SUMMARY INFORMATION FORM

Work Request Process Functions	Needs Follow-Up	Missing Job-Relevant Information	Takes Too Long	Information Withheld	Too Little Feedback	Redundant Information	Duplication of Effort	Affected Departments/ Comments
A) WORK ORDERS IN PROGRESS 1. Problem recognition/reporting/description 2. Approvals/Authorizations 3. Assignment of work/priority setting 4. Equipment tagging/out-of-service procedure 5. Notification to interfacing departments 6. QA/Health Physics review 7. Availability of tools, equipment, spare parts. 8. Performance of work; functional tests B) UPCOMING WORK ORDERS 9. Notification, planning and scheduling C) COMPLETED WORK ORDERS 10. Feedback on completed work 11. Resolution of planning problems								

6.0 ORGANIZATIONAL INTERFACE REVIEW

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REVIEW AIDS

7.0 TRAINING REVIEW
REVIEW AIDS

7.0 TRAINING REVIEW

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