Docket No. 52-003
(formerly Project No. 676

September 16, 1992

Mr. Nicholas J. Liparulo
Nuclear Safety and Regulatory Activities
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P.O. Box 355
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Dear Mr. Liparulo:

SUBJECT: TRANSMITTAL OF DOCUMENTS RELATED TO THE STANDARD SAFETY ANALYSIS REPORT (SSAR) CHAPTER 18

Enclosed are two staff documents that are related to the review of Chapter 18 for evolutionary and passive reactors:

1. "Advanced Control Room Design Review Guideline," Volumes 1 and 2, May 1992.

2. "HFE Program Review Model and Acceptance Criteria for Evolutionary Reactors," July 10, 1992

Enclosure 1 is transmitted for information only. This document is being finalized and will be published as guidance in the near future. Although your comments are not being requested on this document, they are welcomed.

Enclosure 2 contains the approach and acceptance criteria used by the staff to evaluate SSAR Chapter 18 submittals. This document will serve as the basis for revising applicable portions of the standard review plan. The staff requests your comments on this document within 30 days of receipt of this letter.

Sincerely,
(Original signed by)
Frederick W. Hasselberg
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Office of Nuclear Reactor Regulation

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ENCLOSURE 1

Advanced Control Room Design Review Guideline: Technical Development

Volume I

Brookhaven National Laboratory
Department of Nuclear Energy
Human Factors & Performance Analysis Group
Upton, New York 11973

May 1992

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Advanced Control Room Design Review Guideline: Technical Development

Volume I

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Upton, New York 11973

May 1992

NOTICE

Volume I contains draft material that was written to provide an overview of the technical basis of the overall guideline development project that resulted in the guidelines contained in Volume II. Volume I is not a formal report or a complete document. A formal report will be completed later this year and copies of it will be sent to all workshop participants.

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1. INTRODUCTION

1.1 Background

The importance of a well-designed human-system interface (HSI) to reliable human performance and nuclear safety is widely acknowledged. A report of the National Academy of Sciences (Moray & Huey, 1988) indicated that one of the first insights from studies of the Three Mile Island (TMI) accident was that errors caused by operators in the control room (CR) are a significant contributing factor to nuclear power plant (NPP) incidents and accidents. The errors at TMI were due to several factors including a poorly designed CR and inadequate provisions for monitoring of the basic safety parameters of plant functioning. The International Nuclear Safety Advisory Group (INSAG, 1988) of the International Atomic Energy Agency (IAEA) in their internationally recognized basic safety principles indicated that "one of the most important lessons of abnormal events, ranging from minor incidents to serious accidents is that they have so often been the result of incorrect human action." Further, "continued knowledge and understanding of the status of the plant on the part of operating staff is a vital component of defense in depth." This conclusion led to the following safety principle that plants should ensure that: "Parameters to be monitored in the CR are selected, and their displays are arranged to ensure that operators have clear and unambiguous indications of the status of plant conditions important to safety, especially for the purpose of identifying and diagnosing the automatic actuation and operation of a safety system or the degradation of defense in depth."

In the U.S., the Nuclear Regulatory Commission (NRC) reviews the human engineering aspects of CRs to ensure that they are designed to good human factors engineering (HFE) principles and that operator performance and reliability are appropriately supported. In response to the investigations following TMI, the U.S. NRC developed an action plan (U.S. NRC, 1980a and 1980b) to address safety-significant deficiencies in commercial NPPs. In addition, a formal human factors program was initiated in the NRC. With respect to HSI interface, there were two significant outgrowths of the post-TMI planning. First, all licensees and applicants for commercial NPP operating licenses were required to conduct a detailed CR design review (DCRDR) and including reviews of remote shutdown panels to identify and correct human factors design deficiencies. Extensive guidelines, published in NUREG-0700, "Guidelines for Control Room Design Review (U.S. NRC, 1981), were prepared for these evaluations. Second, all licensees and applicants were required to install a Plant Safety Parameters Display System (SPDS) to aid operators to rapidly and reliably determine the safety status of the plant, something they were unable to do during the accident at TMI. The minimum information required was reactivity control, reactor core cooling, and heat removal from the primary system, reactor coolant system integrity, radioactivity control, and containment conditions. The NRC provided guidance on SPDS design and implementation (U.S. NRC, 1980c, 1981). Analogous requirements for SPDS and human engineering of CRs were established for new plant designs in 10 CFR 50.34. In addition to requiring licensees to conduct DCRDRs and install SPDS consoles, the evaluation of licensees' compliance regarding these issues became part of the NRC's Standard Review Plan (SRP) (U.S. NRC, 1984), Sections 18.1 and 18.2, respectively. The SRP describes the review procedures and acceptance criteria that the NRC uses for each area covered.

The DCRDRs have produced a great deal of information regarding human engineering deficiencies (HEDs) that existed in NPPs. A recent study by the Electric Power Research Institute (EPRI) evaluated 25 DCRDRs performed in the 1980s in order to identify and categorize the identified problems based upon the categorization scheme provided in NUREG-0700 (Seminara, 1988). A total of 4,345 HEDs were evaluated in the EPRI study and a summary of the HEDs within each category is given in Table 1.1. It was found that there was a steady increase in the number of HEDs per CR reported between 1981 and 1986 as NUREG-0700 became increasingly applied to the DCRDRs. In general, the HSI issues associated with NPPs are broad and cover all aspects of CR design as can be seen in Table 1.1.

Table 1.1. Summary of Human Error Deficiencies Found in 25 DCRDRs

NUREG-0700 SECTION		HEDs	AVG. NO. PER NPP
6.1	Workspace	641	26
6.2	Communications	160	6
6.3	Annunciators	488	20
6.4	Controls	558	22
6.5	Displays	1085	43
6.6	Labels	638	26
6.7	Computer	335	13
6.8	Panel Layout	328	13
6.9	C/D Integration	112	4
	Summary:	4345	174

NOTE: From Seminara, 1988.

Problems have been reported following the review of SPDS interfaces as well (Liner, R., and DeBor, J., 1988). The main purpose of SPDS is to assist operators at detecting, interpreting, and tracking process disturbances by providing a concise display of key parameters and an ability to track changes. However, poor information displays which confuse or mislead operators have led to poor acceptance of these systems in some plants.

Following the completion of DCRDR- and SPDS-related reviews, attention was focussed on research areas for which scientific data were insufficient to support regulation. One such area was the introduction of advanced, computer-based HSI technology which was not utilized in TMI-era NPPs.

Advanced, computer-based HSI designs are emerging in NPPs as a result of several factors. These include: (1) incorporation of computer-based systems (such as SPDS), (2) backfitting of current CRs with new control and display technologies, when existing hardware is no longer supported by equipment vendors, and (3) development of advanced CR concepts as part of new (evolutionary and revolutionary) reactor designs. The first two activities result in a hybrid CR reflecting a mix of conventional and advanced technologies. Advanced CRs will be developed primarily with advanced instrumentation and controls based upon digital technology and will be substantially different from conventional and hybrid CRs. These developments may have significant implications for plant safety in that they will affect the operator's overall role (function) in the system, the method of information presentation, the ways in which the operator interacts with the system, and the requirements on the operator to understand and supervise an increasingly complex system.

To help assure that advanced technology is incorporated in both new and existing CRs in a way that emphasizes the potential safety benefits of the technology and minimizes the potential negative effects on performance and plant safety, the NRC reviews the design and implementation of significant changes to CRs and reviews the human engineering aspects of new CR designs. The principal guidance (NUREG-0700; U.S. NRC, 1981) available to the NRC, however, was developed more than ten years ago, well prior to these technological changes and was tailored to the technologies used in "conventional" CRs. Accordingly, the human factors guidance needs to be updated to serve as the basis for NRC review of these advanced designs.

While there is still much to be learned about the effects of advanced technology interfaces on human performance, there have been many government, and professional groups (e.g., NASA, DoD, Human Factors Society), which have initiated development of guidelines and evaluation methodologies for the incorporation of advanced technology into the HSI. Over the past ten years, the NRC has sponsored several studies addressing the evaluation of various aspects of advanced CR technologies (e.g., Gilmore, 1985; Rankin et al., 1985; U.S. NRC, 1984b). In addition, NRC has been a member of the Halden Project which has been very active in the testing and evaluation of computer-based CR technology and in developing evaluation criteria for such systems (see Kennedy, 1989 for an overview of this work). More recently, there has also been considerable activity within the nuclear industry to develop guidelines and standards for advanced technology interfaces (e.g., IEC, 1989; EPRI, 1990).

Several of the efforts to develop human factors guidance for advanced HSI have been based on multi-year studies incorporating peer review. While it is recognized that the HSI requirements in nuclear power plant CRs are unique in many ways, a critical review and incorporation of relevant portions of prior (and ongoing) efforts in other fields will maximize the speed of NRC's guideline development effort. Such an approach will enable the available resources to be specifically directed toward resolving those issues which are either unique to NPPs or which have not been adequately addressed by available guidelines and evaluation techniques. Further, there are many similarities between both advanced CRs and local HSIs in NPPs and other advanced workstation applications such as telecommunications network CRs, space-based workstations, advanced aircraft cockpits, and military "command, control, communications and intelligence" (C^3I) workstations. This trend toward increasing similarity of command and control complexes for diverse applications has been referred to as "convergent evolution" (Weiner, 1988) and is, in part, being brought about by digital technology. Thus, while there will remain many unique aspects to NPP operations, modern approaches to CR design share much in common with design of other types of control complexes, thus providing a further technology transfer benefit.

1.2 Project Objective and Overview

The overall purpose of this project is to develop human factors guidelines for the review of advanced human system interfaces in NPPs. Accordingly, several objectives have been identified:

1. To develop a general framework (or approach) for the evaluation of advanced HSI since such evaluations are likely to be influenced by different factors than NRC HSI reviews conducted in conventional control rooms.

2. To develop a "Guideline" document to support the review of advanced HSIs based upon accepted human factors engineering principles, standards, and guidance available from within and outside the nuclear energy community. In this document, the term "Guideline" (with a capitol "G") refers to the entire document, while the term "guideline" refers to the individual guidelines within the document.

3. To develop an interactive, computer-based document to facilitate guideline access and to provide user aids to support the conduct of reviews.

4. To perform tests and evaluations of the guideline in order to support its technical validity, scope, content, and functionality.

5. To identify areas that are important to performing reviews of advanced NPP HSIs for which available guidance is inadequate to support human factors reviews and develop approaches to closing the "gaps."

6. The project has an additional objective to utilize the results of this effort to support the NRC review of advanced control room designs. While this objective has been accomplished, it will not be discussed in this report due to the proprietary nature of the material.

The project is composed of five major tasks, each one corresponding to the five objectives listed above:

- Task 1 - General HFE Program Review Model Development
- Task 2 - Guideline Development
- Task 3 - Interactive Document Development
- Task 4 - Test, Evaluation, and Guideline Modification
- Task 5 - New Guidance Development

These general tasks are illustrated at the top of Figure 1.1. In the shaded boxes below, each task is broken into its major subtasks. At present, Tasks 1, 2, and 3 are completed and Task 4 is underway. While some effort toward Task 5 has been accomplished, the main effort will be conducted following the completion of Task 4. Figure 1.1 also shows the planned revisions to the Guideline (shown in the bold-outlined boxes). At present the Development Test has been completed and based upon the results the Guideline has been modified. Thus, Revision 2 of the Guideline is completed and appears in Volume 2 of the report. The first draft of the Guideline will be considered complete when Revision 3 of the Guideline is accomplished following modifications based upon User Test and Peer-Review Workshop evaluations.

A brief overview of these tasks follows (a more detailed description of these tasks is contained in this the remaining sections of this report).

As indicated above, the project is composed of a five primary tasks. The purpose of Task 1 - General HFE Program Review Model Development was to evaluate the issues that impact the performance of HFE reviews of advanced technology. These issues include specific factors that affect the NRC regulatory responsibility as well as general issues regarding the impact of advanced technology on operating crew performance in high-reliability and complex supervisory control systems.

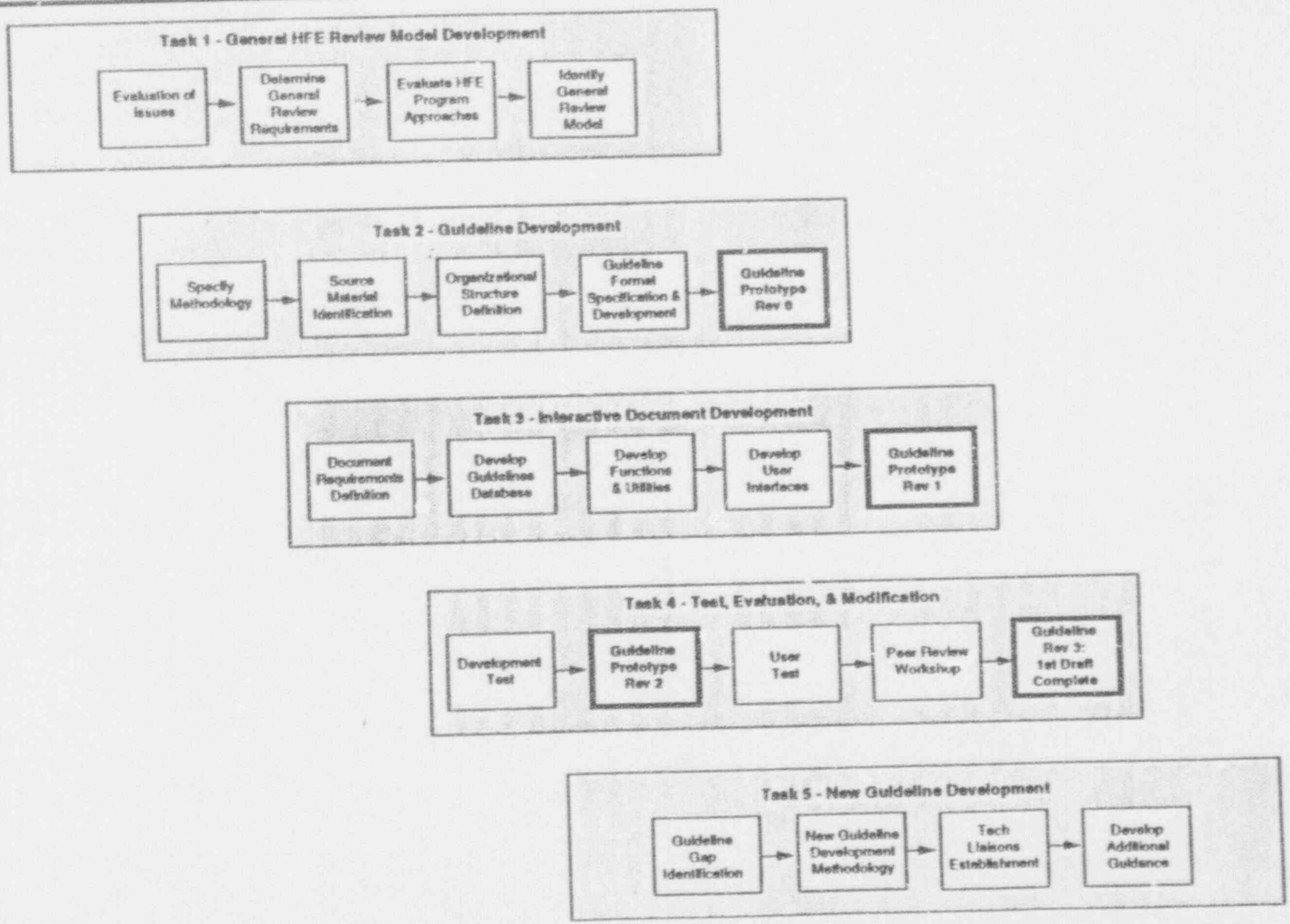

Figure 1.1 Guideline Project Task Structure

Based upon a analysis of these issues, a broad evaluation model was developed to encompass the issues that were identified. The model is expressed in fairly broad terms and will not be fully developed in this project. Instead one aspect of the model was selected for detailed development in Task 2 (Guideline Development) - HFE guideline for computer-based HSIs. As part of Task 2, a guideline development methodology was established and individual guidelines were assembled into an organizational structures and standardized.

In Task 3 - Interactive Document Development, the guidelines developed in Task 2 were assembled into an electronic database and an interactive document was created. The interactive document not only contains the guidelines, it provides reviewer aids to facilitate guideline utilization, evaluation, and report generation.

In Task 4 - Test, Evaluation, and Guideline Modification, the guideline is being evaluated for its technical content as well as its user interfaces and functionality. Three different types of evaluations are being conducted and the Guideline is being modified based upon the test/evaluation results. The guidelines are being tested by the developers (Development Test) and a selected group of representative users (User Tests). In addition, the Guideline will be evaluated in a peer-review workshop. Based upon the results of the User Test and Workshop, Revision 3 of the Guideline will be developed.

Task 5 will addresses new guideline development. Through the development, test and evaluation activities already accomplished, some gaps and deficiencies in the guidelines have already been identified. As testing proceeds additional deficiencies will be found. A methodology to address the development and incorporation of new guidelines in the Guideline will be developed.

1.3 Organization of the Report

The remainder of Volume 1 of the report is generally organized by the Tasks identified above and in Figure 1.1. Section 2 describes the development of a general model for the review of advanced NPP human factors and the factors and issues which were important in developing the approach. Developing the details of the entire model was beyond the scope or the project. Section 3 describes the development methodology of the aspect of the model to be addressed by the remainder of the project, i.e., HFE guidelines for the review of advanced HSI, and the overall scope of the guideline development effort. Section 4 describes the development of the interactive document and its present functions and user interfaces. Section 5 describes the tests and evaluations that have been performed to date. This work is presently underway, so only preliminary information is available. Task 5 on new guideline development has not fully begun, but some preliminary information of areas of advanced HSI for which available guidance is weak has been developed and is presented in Section 6. The references are not provided in this draft material.

The Guideline developed thus far is contained in Volume 2 of this report (bound separately).

2. DEVELOPMENT OF A GENERAL MODEL FOR THE REVIEW OF ADVANCED REACTOR HFE

2.1 Factors Affecting the Review of Advanced Reactor HFE

In order to develop an approach to the review of the human factors engineering of advanced NPPs, it was necessary to consider the factors which can be expected to impact such reviews. Several sources of information were reviewed to identify significant issues, including:

- Current NRC regulations governing the review of advanced reactors,
- Research reports and publications on advanced technology being developed for human system interfaces in process control application,
- Information available on advanced NPP control room designs,
- Advanced instrumentation and controls surveys conducted for the NRC (Carter and Urig, 1990), the IAEA (Neboyan and Kossilov, 1990), and the OECD (Kennedy, 1988),
- General human factors literature on human information processing and the effects of advanced technology on human performance, and
- Existing literature on human factors standards and guidelines for advanced HSI.

Based upon a review of the above material, many factors were identified which have implications for the development of an approach to the review of the human factors engineering of advanced HSI. These factors are organized into four categories: regulatory issues (Section 2.1.1), trends in NPP HSIs (Section 2.1.2), human information processing and performance factors (Section 2.1.3), and advanced HSI guidelines issues (Section 2.1.4). The implications of these factors and issues for the HFE review are summarized in Section 2.1.5.

2.1.1 Regulatory Considerations

Two factors are considered in this section:

- NRC review of standardized plant designs under 10 CFR Part 52,
- Scope of human factors reviews.

2.1.1.1 NRC Review of Standardized Plant Designs Under 10 CFR Part 52

NRC CR reviews have typically been directed toward existing CRs or existing systems (such as SPDS). However, the NRC and the utility industry have embarked on an effort to improve and standardize future commercial nuclear power plant designs. The NRC has issued 10 CFR 52 titled "Early site permits; standard design certifications; and combined licenses for nuclear power plants," in order to encourage standardization and to streamline the licensing process. Nuclear plant designers and vendors have begun the design of advanced standard plants, which are being submitted to the NRC for review and approval under Part 52. The General Electric (GE) Advanced BWR and Combustion Engineering (CE) 80+ are examples of designs undergoing this type of review.

The licensing process of Part 52 consists of a Final Design Approval by the NRC and the Advisory Committee for Reactor Safeguards (ACRS) followed by a standard design certification that is issued as an NRC Rule. This will require formal rule-making and include the opportunity for a public hearing before the Atomic Safety and Licensing Board (ASLB). The certification, when issued, would be valid for 15 years (renewable). During its tenure neither the NRC nor the designer can change or impose new requirements on the standard design certification without a new rule-making. Utilities would have the option of purchasing the standard design and utilizing it as already approved by the NRC.

In order to ensure that a plant, as built, conforms to the standard design certification, inspections, tests, analyses, and acceptance criteria (ITAAC) must be specified as part of the standard design certification. Then, a utility which is building the plant and the NRC will ensure that the ITAAC are performed and met.

A utility desiring to license and operate a nuclear power plant under Part 52, will obtain a Combined Operating License (COL), which authorizes both construction and operation in one step. The COL applicant may propose a new design or reference an existing standard design certification.

In order to obtain a standard design certification under Part 52, a designer must submit a Standard Safety Analysis Report (SSAR) to the NRC for review. The NRC's review of the SSAR is issued as a Final Safety Evaluation Report (FSER) which will form the basis for the Final Design Approval and the Standard Design Certification.

One of the major issues to emerge from the initial CR reviews under the certification process was that detailed HSI design information was not available for staff review as part of the design certification evaluation. For example, the ABWR control room analysis and design efforts have provided a list of key control room design features characterized at a general level (not a detailed specification). To address the issue of lack of design detail, the NRC has performed the design certification evaluation based partially on the preliminary design and partially on an implementation process plan which describes the HFE program elements required to develop the key features into an acceptable detailed design specification. Along with the design and implementation process, NRC will require GE to submit a form of ITAAC, now called Design Acceptance Criteria (DAC), which will ensure that the design and implementation process is properly executed by the COL applicant. The NRC specified that the design and implementation process should contain descriptions of all required human factors activities (elements) that are necessary and sufficient for the development and implementation of the HSIs. It should also include an identification of predetermined NRC conformance review points, the DAC, and ITAAC for the conformance reviews.

This process is very different from the typical HSI reviews conducted by the NRC. The present NRC review criteria presented in the Chapter 18 of the Standard Review Plan (SRP) and in NUREG-0700 provide little information to the reviewer for this type of evaluation. Since the review of a design and implementation process is unprecedented, the criteria for review are not addressed by current regulations and guidance documents. HFE reviews of advanced reactors must support the review of HSIs through the design and implementation design cycle and must be capable of supporting review of proposed standardized designs, as well as modifications to existing CRs.

2.1.1.2 Scope of Human Factors Reviews

While the focus of NUREG-0700 reviews was the CR (with reference to remote shutdown panels), the NRC has also been evaluating human factors characteristics of local panels in connection with Emergency Operating Procedures (EOP) and Appendix R (Safe Shutdown) reviews. In addition, the NRC is currently investigating the safety significance of local panels and components and to develop human factors guidance for them (see O'Hara et al., 1990; Ruger et al., 1991). Based on these studies, the review of advanced NPP human factors should encompass the HSIs outside as well as inside the main control room.

2.1.2 Trends in Advanced NPP

Two issues are considered in this section:

- Diversity of Advanced Reactor Technology
- CR Evolution and Major Trends in HSI Technology

2.1.2.1 Diversity of Advanced Reactor Technology

The current generation of commercial NPPs in the U.S., consisting of over 100 plants, is based upon light water reactor (LWR) technology. The LWR plants were either boiling water reactors (BWRs) or pressurized water reactors (PWRs). There were two gas-cooled commercial reactors, Peach Bottom-1 and Fort St. Vrain, but these were built in the 1960s and early 1970s and are now shut down.

Advanced reactors are being developed based upon a broader technology basis, including: Light Water Reactors (LWRs), Heavy Water Reactors (HWRs), Liquid Metal Reactors (LMRs), and gas-cooled reactors, such as the modular high-temperature gas reactor (MHTGR). Each of these reactor types is envisioned to be a standard plant design from which a number of reactors would be built. However, the diversity of reactor types raises new issues relative to the design and operation of the reactors. These issues include reactivity control and other reactor physics issues, core thermal hydraulics, natural cooling of the core, very different safety systems and safety system control and operation, smaller plants and multiple units (as many as nine per site), different dominant accident sequences, new hazards (e.g., sodium-water reactions and very high tritium levels), new equipment (liquid sodium pumps, gas circulators, and "passive" components), and advanced instrumentation and controls.

Thus, as these new reactor types are designed and built, there are new and different systems being incorporated and many new features to be addressed both from a reactor physics and plant engineering standpoint. One of the main design objectives of the next generation of reactors is to develop plants which are simpler, safer, and more reliable than the current generation. This objective is being addressed in several ways. One important design initiative to improve safety and reliability has been the move from active safety features toward more passive safety features, some of which utilize natural physical processes such as convection flow, radiational cooling, and gravity. If these designs are successful, there will be less opportunity for equipment failure or operator error to create hazardous situations. However, the operator's role in such systems and the means by which the operator will monitor and interact with such systems is not fully known.

The first advanced reactors to be proposed are extensions of current BWR and PWR technology and may be termed "evolutionary" advanced reactors (GE's ABWR and the CE's System 80+ PWR). These plants have incorporated technological improvements but still rely on primarily active safety systems. Beyond these are reactor designs utilizing "simplified passive" features (such as GE's simplified BWR and Westinghouse's AP-600 PWR) which have eliminated active pumps for emergency coolant injection but still have active components, i.e., valves. These designs use pressurized tanks and gravity flow to inject the coolant, but they still require various valves to actively cycle to permit the flows and to depressurize the reactor. Further along the spectrum toward actually passive design are the "revolutionary designs" (such as the PRISM liquid metal reactor and the PIUS LWR) which submerge the primary reactor systems in large pools of coolant that can provide natural circulation cooling in the event of an accident. The containment systems are also designed to provide natural circulation cooling to remove heat generated inside containment during accidents. The PIUS reactor has gone even further toward passive design, with the reactor internals directly in contact with the emergency shutdown and cooling pool and isolated only via density differences. These density locks are designed to immediately break on any overheating in the core.

These new passive features introduce new and different systems for operators to control, test, and monitor. They will require different types of instrumentation as well. There are questions as to how the reliable functioning of these passive systems can be verified (by the operators) during operation. Also, the role of the operator during transients and accidents changes considerably with these new passive systems. Important questions include:

- How do operators verify that these systems are ready during normal operation?
- How can proper operation be confirmed when the systems are called upon?
- What parameters should be monitored?
- What is the proper operator response when the passive systems do not function properly?

These will result in different operator roles and tasks, different CRs, and different operator-control interfaces. One implication of this diversity is that a prescriptive approach to interface design based upon known operator tasks is not acceptable in an NRC guideline which must be capable of enabling reviews of all acceptable designs and a great variety of operator functional roles in the system.

2.1.2.2 CR Evolution and Major Trends in HSI Technology

Several important trends emerged from the review of literature related to developments in advanced HSI in the nuclear industry. These include:

- The greater use of automation and corresponding shift of the operator's role in the system as monitor, supervisor, and back-up to automated systems.
- Greater centralization of controls and displays into "compact" digital workstations.
- Use of large display panels that can be seen from anywhere in the control room to present high-level information and critical parameters.
- Operators interfacing primarily with a data management system (DMS) with little interaction directly with components.
- Use of data integration and graphic displays.
- Use of information processing and decision-support aids.

With increased application of digital control technology comes an enhanced ability to automate tasks traditionally performed by an operator. It is generally presumed that automation will enhance overall system reliability by removing or reducing the need for human action. The operators' interaction with the system is believed to be improved by freeing them from tasks which are routine, tedious, physically demanding, or difficult. Thus, operators can better concentrate on supervising the overall performance and safety of the system.

The trends toward using a CR composed of a large display panels together with one or more "compact," computer-based workstations is characteristic of many new control room designs. The large overview display provides information such as high-level plant status, key parameter values (such as SPDS), major alarms, and status of important safety equipment. This display is designed to be seen from anywhere in the CR. The operator(s) is located at a workstation which serves as the locus of CR operations. Typically such workstations include elements such as centralized and integrated controls and displays, color graphics, high levels of data integration, display devices such as CRTs and flat panels, new input devices such as the mouse and touch screen, multifunction ("soft") controls, workstation flexibility, and an emphasis on information management and software-interface issues.

There is another trend toward the development of intelligent operator aids based on expert systems and other artificial intelligence-based technologies. These applications include aids for alarm processing, diagnostics, accident management, plant monitoring, and procedure tracking. In fact, many of the recently published articles on advances in NPP CR technology specifically address intelligent operator aids.

As the features become increasingly applied, an increase in CR types will result beyond the range with which the industry is presently familiar. CRs can generally be thought of as falling into four groups. Actually, the four groups reflect four points along an evolutionary continuum, but for the sake of discussion, four categories are identified:

Conventional CR - A CR containing analog and primarily hardwired controls (e.g., switches, knobs, handles) and displays (e.g., gauges, linear scales, indicator lights) typical of NPP CRs circa 1970s.

Hybrid CR - A conventional CR which has introduced digital technology for new systems and for replacement of selected analog systems. Thus, the CR represents a mixture of analog and digital technology. Increasingly, CRs in U.S. NPPs are evolving from conventional to hybrid CRs.

Advanced CR (ACR) - An ACR is based primarily on digital technology and computer-based interfaces. Some analog and hardwired interfaces may remain for safety critical or backup functions. Data processing functions are available to assist the operator with lower-level information processing. Computer-based decision aids may be available to the operator but will not be in the control loop.

Intelligent CR - The generation of CRs to be developed beyond advanced CRs will include various AI and related capabilities to further automate the operators' supervisory, control, and decision-making functions. Technologies to serve as the foundation for intelligent CRs are being developed and researched in many countries.

Related to CR evolution is the wide range of technological approaches to the implementation of HSI in computer-based CRs. In part, this is due to the tremendous flexibility offered by software-driven interfaces to provide for alternative data display and control. The options for display expand the hardware media choices (e.g., computer-driven displays which mimic conventional gauges and meters, video display units, and computer-driven large screen displays). Further, the formats in which to display data are nearly infinite (e.g., lists, tables, flow charts, graphs, iconic graphics, speech, etc.). Operator input to the system has seen similar expansion in diversity including, for example, conventional controls, miniature controls, keyboards, touch screens, mice, joy sticks, light pens, and voice controls. With the advent of interactive graphic displays, the traditional distinction between controls and displays becomes blurred. For example, an operator may open a valve or start a pump via computer graphic mimic of the system and touching the icon of the desired component. In addition, data processing and integration are more significant in advanced CRs providing the operator with higher-level displays.

The NRC will need guidance to review new CRs and modifications to existing CRs which reflect these industry trends.

2.1.3 Advanced Technology and Human Performance

In this section two issues will be considered:

- The human factors knowledge-base to support the understanding of the effects of advanced technology on human performance, and
- The effects of design on human performance and error.

A summary of the discussion is presented at the end of the section.

2.1.3.1 General State of Knowledge

The introduction of advanced instrumentation and control (I&C) and HSI technology promises to improve the safe operation of nuclear power plants. The potential advantages of advanced technology over conventional CR technologies include:

- Support for data access and presentation, e.g.,
    - Rapid, highly reliable, validated data transfer
    - Large amounts of data at the operator's fingertips
    - Precise digital data displays
    - Use of color graphic displays to facilitate the operator's assimilation of important information
- Support for the operator's processing of information, e.g.,
    - Data integration providing the operator with high-level, more meaningful information
    - Parameter trend displays
    - Computer-based procedures
    - Decision aids
- Support for process control, e.g.,
    - Hierarchical levels of control
    - Use of automation to lower operator workload

- Workstation design, e.g.,
  - HSI in a compact workstation
  - Flexibility in control and display operations

While the use of advanced technology is generally considered to enhance system performance, computer-based operator interfaces also have the potential to negatively impact human performance, spawn new types of human errors, and reduce human reliability (for examples see, Coblentz, 1988; Rasmussen, Duncan, and Leplat, 1987; and Wiener and Nagel, 1989; Woods et al., 1990). There has been a great deal of research over the past 20 years attempting identify the causes of error. The main conclusion from the work is that few human errors represent stochastic events. Instead, most human errors can be explained on the basis of a relatively small number of cognitive mechanisms (Reasons, 1988; Rasmussen, 1988). Therefore it is important to understand how operators perform their tasks from an information processing point of view and how human information processing relates to HSI design and human error. However, since the contributors to unreliability in an advanced CR (such as function allocation and automation, supervisory control, and human-software-computer interaction issues) are different from those which are familiar contributors to human error in conventional CRs, they are less obvious and generally less well understood (O'Hara and Hall, 1990, 1991). Cognitive and human information processing issues are emerging as more significant than the physical and ergonomic considerations which dominated the design of conventional HSIs. These issues are discussed further in the next section.

While these issues have been recognized for a long time, their full implication to human performance and system safety have only recently begun to be addressed in research, and there is not a long history of practical operational experience to draw upon. Thus, the National Academy of Sciences has identified areas such as automation, supervisory control, and human-computer interface as high priority research areas for the human factors community in general (Pew et al., 1983) and for the commercial nuclear industry in particular (Moray and Huey, 1988). Even more recently, issues which significantly impact the integration of human operators with advanced systems have been identified as high priority research topics in an effort to support safety improvement in the civilian aviation industry by the Federal Aviation Administration in their "National Plan for Aviation Human Factors" (FAA, 1990). The plan represents a major effort involving FAA, NASA, DOD, and industry.

Thus, there is broad consensus that the knowledge-base for understanding the effects of advanced HSI technology on human performance and system safety is weak and in need of further research (despite the rapidly increasing utilization of these technologies in complex, high-reliability systems such as NPPs and civilian aircraft). While information is sparse, some factors have been identified and these are summarized in the next section.

2.1.3.2 Design Effects on Human Information Processing and Performance

In this section, issues related to the effects of selected design features on human performance and error are considered. These effects are discussed in terms of human cognitive processes. Therefore, the discussion is preceded by a brief overview of information processing and human error.

2.1.3.2.1 Human Information Processing

Human performance theories typically consider errors as one indicator of performance along with other measures, such as time, accuracy, and workload. However, error has special significance in the NPP domain due to its incorporation and quantification in risk models. Therefore, within the context of the present discussion, human errors are distinguished from other aspects of human performance. With respect to understanding the effects of ACRs on human performance, error, and safety, it is useful to consider the error event (whether omission or commission) to be the end product of an information processing sequence (see Figure 2.1). Then the focus of ACR effects on human performance can be directed to both errors themselves (which are infrequently observed in skilled operators) and to the information processing "precursors" that give rise to them (which are more readily measurable). To identify the effects of advanced technology on human error and performance it is useful to utilize a model of information processing with which to interpret the effects. A general model of information processing is described below.

Many models of information processing (IP) have been proposed (e.g., Broadbent, 1958; Atkinson and Shiffrin, 1968). These models differ in specificity with respect to the aspects of IP they attempt to explain as well as the type of studies used for validation. A general model frequently used in human engineering has been proposed by Wickens (1984). It is general in the sense that it borrows features which are common to many models of human cognition which have good empirical support. Figure 2.2 presents an adaptation of Wickens' model to a supervisory control task. A very brief overview of the model is provided below in order to identify those aspects of cognition which are important to HSI design and evaluation in supervisory control systems (where an automatic control system exerts an influence [generally the primary control] on the system).

The model in Figure 2.2 is simplified and not all interconnections between model elements are shown. While the model is organized to depict the flow of information through the system in left to right fashion, the complex interaction between cognitive elements renders a reading of information flow from "left to right" somewhat artificial.

During a typical monitoring task, information about the system is made available to the operator through the HSI (and through communications) via the operator's sensory organs. Each sense has a short-term storage capability (usually on the order of milliseconds) during which a large quantity of information is represented. Some of this information is "perceived" which implies (1) that a stimulus pattern was associated which a meaningful pattern based upon information stored in the knowledge base or "long-term memory" (LTM) (see path from LTM to perception in model) or (2) the stimulus had such energy-intense properties (such as very loud noise or very bright flash) that attentional resources were drawn to it through the "orienting response." The pattern recognition process is quite robust in that to make a perceptual identification, a stimulus pattern need not be an exact match in the knowledge base. Instead, knowledge is represented in prototypical or schematic form. The specific information available to the operator is evaluated in terms of the probability that it represents an exemplar of a known pattern in LTM. The task of pattern recognition becomes more difficult when the number of dimensions that are required to make the recognition increases.

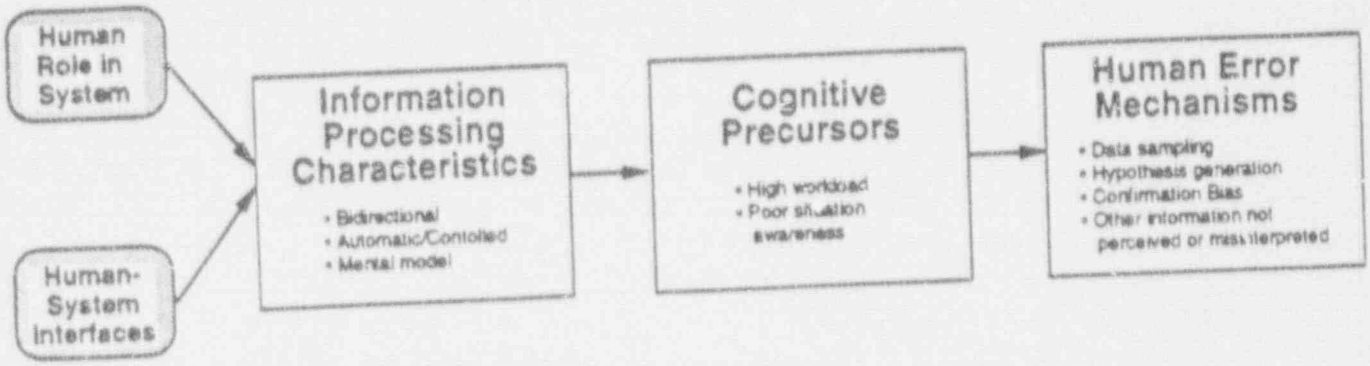

Figure 2.1 Human Error Mediators

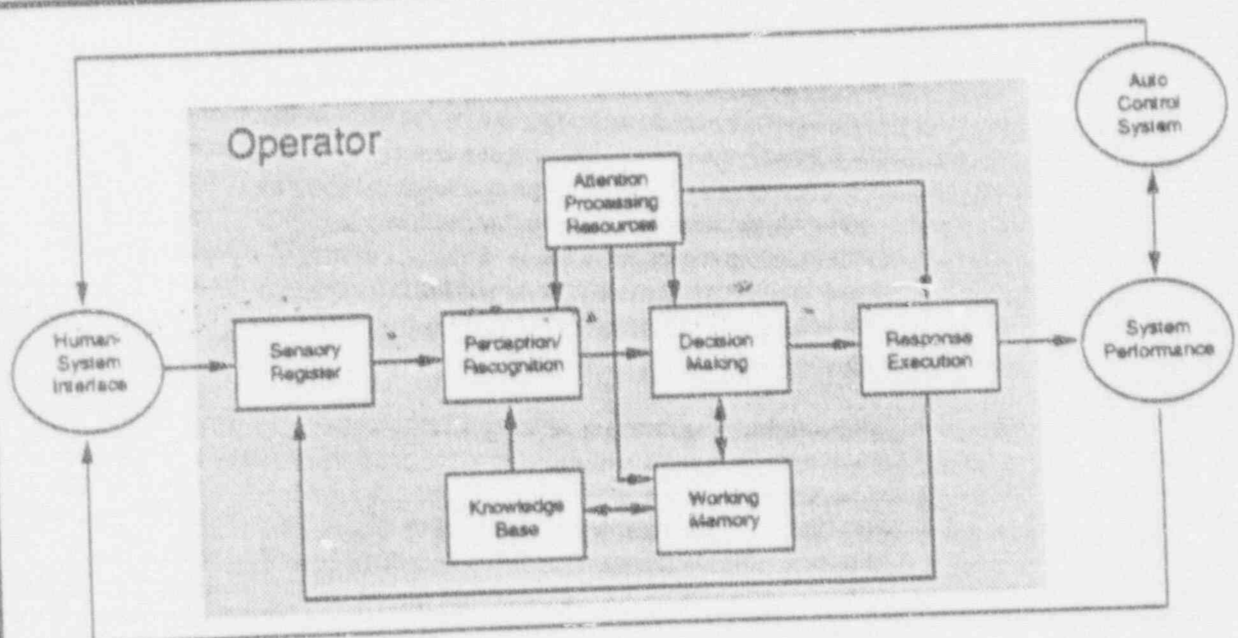

Figure 2.2 Simplified Supervisory Control Information Processing Model
(Adapted from Wickens, 1984)

The knowledge base is relatively permanent, has a large capacity, and can process information in parallel. There are many theories as to how information is stored in the knowledge base. One of the most widely held is that information is stored in knowledge structures which have traditionally been called schemas (Bartlett, 1932), and more recently, "frames" (Schank and Abelson, 1977). A schema, in its most classic sense, is an abstract representation containing the general properties, identifying characteristics, actions, and rules associated with a group of related concepts or events (Bartlett, 1932). Schemas are themselves organized by the meaning ascribed to them, and they constitute our understanding of the events that are perceived. Schemas tend to organize actions and behavior through either their direct activation based upon perceptual data (skill-based action) or through their identification in the decision-making process (rule- and knowledge-based process). At the point of correct schema identification and actuation, the operator can be said to understand the situation and its appropriate goal states. The schema also defines the actions required to achieve the goal state and initiate their execution.

One network of schemas related to skilled behavior is commonly referred to as the "mental model" of the operator. It is the group of schemas which define the operator's internal representation of the physical and functional characteristics of the system and its operation. The mental model is built up through formal education, system specific training, and experience. An accurate mental model is considered the defining characteristic of skilled performance in general (e.g., Wickens, 1984) and for NPP operations (e.g., Moray, et al., 1986; Bainbridge, 1986; Rasmussen, 1983; Sheridan, 1986). The mental model is thought to directly drive skill-based processing, control rule-based activity through the mediation of the operator's conscious effort in working memory, and provide the substantive capability to reason and predict future plant states required of knowledge-based processing (Rasmussen, 1983). Moray (1986) has argued that a well-developed mental model enables the operator's performance to become more "open-loop" and thus, system control to become smoother. The mental model allows prediction and expectancy to guide control responses; however, expectancy can also make the detection of subtle system failures difficult (Wickens and Kessel, 1981). Similarly, Bainbridge (1974) has stated that the operator of a NPP uses the mental model to predict the near-term future state of the plant and then uses this inference to guide the sampling of indicators to confirm the inference.

The mental model is quite complex and contains a vast amount of technical information and experience, but it is not directly represented in the operator's consciousness. This occurs in "working memory" (WM) which has a very limited capacity relative to the knowledge base. Information in working memory remains for only a brief period and is processed serially. An operator's current interpretation of a system's status as represented in working memory has been referred to as "situation awareness" (SA) (Fraker, 1988). SA is the degree of correlation between the operator's understanding of the plant's condition and its actual condition at any given point in time. An operator can have a good mental model (e.g., knowledge of how the plant functions) but poor situation awareness (understanding of its current status). SA has also been identified at an Air Force Symposium as the single most important factor in improving mission effectiveness (Endsley, 1988).

Under normal conditions, monitoring is accomplished by scanning information presented by the HSI and comparing the information to the mental model. If no discrepancies are identified, monitoring continues. The operator's SA represents the outcome of the comparison represented in WM. SA of normal conditions is the default condition if no discrepancy to the mental model is detected. For skilled operators this comparison is relatively effortless and requires little attention. If no deviation from what is expected is detected, the operator may not be aware of the comparison process.

Information processing during off-normal conditions is considerably more complex. The first step in detecting that conditions are not normal is to detect a discrepancy between the mental model of the information pattern representing normality and the information patten detected on the HSI. In a NPP this process is facilitated by the alarm system which directs the operator's attention to an off-normal situation.

Monitoring has been described in terms of signal detection theory (SDT) (Green and Swets, 1966, 1974). The early stages of the operator's detection of alarms and off-normal situations are basically signal detection issue. Process control operators are in a monitoring environment that has been described in SDT terms as an "alerted-monitor system" (Sorkin et al., 1985 and 1988). Such a system is composed of an automated monitor and a human monitor. The automated monitor in a NPP is the alarm system which monitors the system to detect off-normal conditions. When a plant parameter exceeds the criterion of the automated monitor, the human monitor is alerted and must then detect, analyze, and interpret the signal as a false alarm or a true indication of a plant upset. The human monitor can also assess plant parameters independent from the automated monitor (the alarm system). Both the human and automated monitors have their own specific signal detection parameter values for sensitivity (d') and response criterion. The response criterion refers to the amount of evidence that is needed before an operator will conclude that a signalled event is actually present. This is sometimes referred to as "response bias" since it describes an operator's degree of conservatism. Sensitivity refers to the resolution of the system which determines the ease with which signals (represented as a statistical distribution) can be distinguished from signals and noise (also represented as a distribution).

SDT research has many implications for the understanding of how operators process alarm system data. First, the response criterion is affected by expectancy, i.e., the expected probability that an event will occur and the payoff structure (the rewards and penalties for making correct and incorrect detections, respectively). Off-normal events in NPPs typically have a low probability of occurring and therefore, operators have low expectancy concerning their actual occurrence. The low expectancy creates a conflict between the cost to productivity for falsely taking an action that brings the plant down versus the cost for failing to take an action when one is warranted. Since in the real-world system disturbances have a low probability, operators need redundant information to confirm the alarmed condition. Upon verification of several consistent indicators, the operator can accept the alarm information as indicating an actual off-normal condition (as compared with a spurious condition).

In general, expectancy reflects "top-down" processing. Information processing is a synthesis of both "top-down" and "bottom-up" processing which occur simultaneously (Neisser, 1969). For example, during an off-normal situation, an operator monitors the HSI and processes data from the interface to determine what is wrong. This is bottom-up processing. At the same time, these data are used to formulate hypotheses or expectations about the status of the plant. These hypotheses or expectations serve to structure the perceptual process and data gathering occurring at lower levels. This is top-down processing. Both contribute to the operator's interpretation of the situation. While the situation remains normal, much of the operator's information processing occurs "automatically," i.e., with very little attention and conscious effort. As an off-normal situation becomes detected, information processing becomes more "controlled." In contrast to automatic information processing, controlled information processing demands a relatively great deal of attentional resources and effort. This is an important distinction which is explained below.

Once a situation is detected and perceived the operator must decide what to do. The operator must define a goal state and the transformations required to achieve that state. The goal state may be varied, such as to identify the proper procedure, to assess the status of back-up systems, or to diagnose a problem (Rasmussen, 1981). Decision-making is a burden and draws heavily upon WM, the knowledge base, and attentional resources. Information in consciously manipulated in WM. The ability to manipulate information in WM is a direct function of attentional resources available. Data to be manipulated may come from sensory input or information recalled from long-term memory, or some combination of the two. As indicated above, WM has very limited capacity and without sustained attentional resources (or transfer of the information to LTM), information decays rapidly. To be useful in decision making, information has to be in WM. Information can be lost due to (1) loss of attentional resources to keep it active, (2) overload of WMs limited capacity, (3) interference from other information in WM. If greater attentional resources are required by the operator to interact with the system, less will be available for decision making and situation analysis in WM. To increase the capacity of WM, operators use various memory heuristics such as chunking. This enables operators to organize various bits of information into higher-level meaningful units. Once this is accomplished, the higher-level units are stored in WM, not the individual elements.

For an experienced, well-trained operator, when the HSI can provide information to activate appropriate schemas in the operator's mental model, the load on WM and attention are greatly reduced. To the extent that such is not the case or the operator is less experienced, more WM and attention are required. Since the processing capacity of WM and attentional resources are limited, it will be very difficult to maintain good SA.

Attention is currently viewed as a finite limited resource that is distributed across the elements of cognition associated with perceptual mechanisms, WM, decision making, and response execution (see Figure 3.2). These aspects of cognition compete for this limited resource, and any process that requires a high amount of attention will be executed at the expense of other processes. Attention is also generally associated with the experience of mental effort (Kahneman, 1973) and is, therefore, frequently associated with cognitive workload.

While attention tends to be conceptualized as a single resource (Kahneman, 1973), human performance research on divided attention tasks (where operators perform more than one task at a time) suggests that this is not the case (Navon and Gopher, 1979; Wickens, 1984, 1987). Wickens (1984) has proposed a multiple resource model with attentional processing resources divided along three dimensions: (1) Processing Stage, i.e., perceptual and central processes require different resources than response processes; (2) Input Modality, i.e., visual processes require different resources from auditory processes; and (3) Information Code Type, i.e., spatial and analog mental representations require different resources from linguistic information. A secondary task competing for the same resources as the primary task will be performed less well than one requiring separate resources.

A secondary task requiring different resources will be performed better. Secondary task approaches to cognitive workload assessment, for example, assume that the primary task and the secondary task draw from the same attentional resources and that if the primary task performance is maintained, the secondary task is performed with the spare attentional processing capacity. The logic of the secondary task approach is simple. Assume that total capacity is equal to one and that the operator's primary task will utilize "x" amount of the total capacity. The spare capacity (1-x) is left in reserve and can be applied to the secondary task. The capacity limits of WM can largely be tied to limitations in attentional resources since it is largely these resources that keep information active in WM.

Research on selective attention (summarized by Moray, 1986, and Wickens, 1987) suggests the following. First, two tasks competing for the same resources will be performed less well than if they required separate resources. Thus, for example, it is easier to drive a car and hold a conversation with a passenger than it is to drive and manually tune an analog radio. While both involve doing two tasks simultaneously, the former situation involves less competition for common processing resources than the latter. Second, the allocation of attentional resources to sampling data from the environment is guided by the operator's mental model which contain expectations regarding the "statistical properties" of the environment, i.e., expected probability and correlation. Third, as cognitive workload increases, failure detection capability decreases (Ephrath and Young, 1981).

During the early stages of an off-normal condition the operator is likely to have poor situation awareness, i.e., the operator knows something is wrong but may not know what. The HSI is scanned to identify a pattern of alarms and displays which, as a result of training and experience, match a known failure pattern in the mental model. Assuming a successful match is found the activated schema will provide the operator with the knowledge as to the appropriate course of action and accurate situation awareness is established.

Response execution is the carrying out of actions that were decided upon and guided by either operating procedures or an operator generated plan to get from the current plant state to the goal state. The results of responses are monitored through feedback loops. In a slowly responding, supervisory control system, this is more difficult than in direct, rapid-response systems such as aircraft where responses can be better guided by feedback. In a NPP, as in other slowly responding systems, the operator's ability to predict future states ("feed forward") can be more significant in controlling responses than is feedback.

Response execution also draws attentional resources and depends on information code types. When the response demands are incompatible with information code types, operator performance can be impaired. An good example of this problem comes from research on telerobotics (human control of remote manipulator systems). One of the most demanding aspects of telerobot operation is the simultaneous control of manipulator arms and cameras in environments such as space where the entire system may be operated by a single person. Efforts have been made to use advances in computer-based voice recognition technology to enable operators to control cameras through voice commands rather than manual operations. The operator can control the manipulator arms by hand and cameras by voice; thus, overall system performance would be improved in terms of faster task completion and fewer errors. However, research has indicated that task time and errors increase when voice operations were introduced (Bejczy et al., 1982; O'Hara, 1986; Bierschwale, et al., 1989).

These findings can be understood in terms of two aspects of the multiple resource theory of attention. The first is competition for processing resources. Operators cannot make judgements concerning the spatial displacement of manipulator arms at the same time as they make judgements about camera positioning. Both tasks draw on the same cognitive processing resources: perceptual/central processes of visual information requiring spatial/analog mental representations. While it is true that the response modality is different, operators perform the tasks serially. Second, there was also a poor match between the task demands and the response modality which increased the error rate. Voice commands are not well suited to continuous spatial control tasks. Controlling a camera with voice is like trying to tell someone how to tie their shoes - easy to do manually but difficult to do verbally. The amount of language required to accurately position cameras was excessive, making the response execution workload very high. Language is much better suited to discrete rather than continuous control.

Operator tasks should be structured to take into account the cognitive processing resources required and to assure that tasks expected to be performed in parallel have minimal competition for common resources. The HSI should support maximum utilization of cognitive processing resources.

2.1.3.2.2 Human Error Mechanisms

As indicated in the beginning of this section, most human errors can be explained on the basis of a relatively small number of cognitive mechanisms (Reasons, 1988; Rasmussen, 1988). An identification of these mechanisms can contribute to specification of design principles that will help reduce the probability of error and make the system more error tolerant.

While error data can be collected in studies evaluating the effects of HSI on operating crew performance, it is not practical with the context of any one experiment to collect enough data to confidently estimate long-term, low likelihood errors under the myriad of conditions representing possible plant conditions. However, the cognitive prerequisites of human error can be measured to determine whether HSI design characteristics differ in error "likelihood." Noteworthy in the specification of human error mechanisms has been the work of Norman, Rasmussen, and Reasons. Their work can be interpreted within the general information processing model described above.

Norman (1979, 1981) classified errors into three categories, based upon the cognitive mechanisms involved. "Description errors" result from the operator's characterization of a situation at too high a level of abstraction. This occurs because it takes less mental effort than constructing a detailed characterization. At such a high level of description, the operator may not have enough detail to select the appropriate actions. Premature diagnosis of a problem is an example of this type of error. The second type is "activation" or "trigger errors," which occur when an intention leads to the activation of a schema, but the operator does not keep track of the resulting actions or the automated sequence is interrupted to perform another required action. Failure to restore a valve to its proper position after maintenance is an example of this type of error. The third type is "capture errors." The capture error occurs when the environment cues are similar to those associated with a well-developed schema and that schema is inappropriately activated. Equipment or procedural changes in the control room make an operator susceptible to this type of error, if well-learned responses in the old control room are inappropriate in the new control room. Also, similarity in the display of information patterns between two plant states can lead to capture errors.

Like Norman, Rasmussen (1988) has noted that errors are a function of the "cognitive control of behavior" and further that they are "manifestations of the efficient human adaptation to system characteristics." Four categories of error and their importance in system design have been defined. The first error category is the result of random human variability. However, these are few in number and have lower safety significance because they are single events and not correlated to other activities. The second category is errors related to inadequate processing resources. This is most important in knowledge-based processing since it is the most resource dependent mode of processing. However, even rule-based activity requires attentional resources, and when there are not enough resources available, errors become more probable. Therefore, this category of error is related to workload. Workload's association with error has frequently been noted in the error literature (Sheridan, 1981; Wickens, 1987). The third category of error is associated with interference between internal control structures or schemas. Thus, this category is similar to the capture errors described by Norman.

The final category is related to human learning mechanisms. These reflect the operators' adaptation to the system and, Rasmussen argues, probably no attempt should be made to eliminate them. Instead, HSI design should be made error tolerant, i.e., the system should make errors observable so their consequences can be mitigated by operator (or system) intervention. The use of human error models to design interfaces which minimize certain types of errors and make the system tolerant to other types of errors has been recommended by several researchers (e.g., Thompson, 1981; Rouse, 1985; Rouse and

Morris, 1987). Rouse and Morris (1987) has argued that "attempts to eliminate human errors yet retain innovation are tantamount to trying to obtain cost-free benefits, a strategy that is rarely successful in any endeavor." Indeed, one of the major purposes for having operators in the system is to respond to unanticipated events through adaptation and innovation.

Reasons (1987 and 1988) has presented a fairly well-defined model of human error which, in its current version, embodies most of the main points of Norman's and Rasmussen's work. The central thesis is that error is predictable and based upon a tendency to over utilize cognitive processes which serve to simplify complex information tasks through the application of previously established heuristics. Two heuristics (called "computational primitives") used by operators to retrieve information from the knowledge base are assumed to exert a strong influence on human performance and, therefore, human errors. They are "similarity matching" and "frequency gambling." These heuristics are used because of the high operator workload that results from the demands on and limitations of WM and when data are insufficient to clearly identify appropriate schemas. Similarity matching reflects the tendency for WM to attempt to match a perceived information pattern (such as a pattern of indicators) with an already existing knowledge structure (schema) in the knowledge base. The operator cognitively tries to establish a link with a stored knowledge structure since it contains a previously identified successful action sequence. This saves the operator the effort of knowledge-based reasoning which is resource intensive. When the perceived information partially activates more than one schema, the discrepancy is resolved by selection of the schema most frequently used in the past. This is the "frequency-gambling" heuristic.

According to Reasons, these computational primitives give rise to a number of "basic error tendencies" in human performance which account for most human errors. They are: (1) similarity bias - errors reflecting undue influence of salient features of the current situation (resulting in premature situation identification) or the intention/expectation of the operator (resulting in a bias to "see" only confirmatory data), (2) frequency bias - in ill-defined situations, the most frequently performed action will be selected, (3) bounded rationality - the processing limitations of WM cause information to be lost, (4) imperfect rationality - IP will favor heuristics over knowledge- based processing, (5) reluctant rationality - IP acts to minimize cognitive effort and strain, (6) incomplete/incorrect knowledge - schemas rarely contain highly accurate models of the system.

Reasons has developed a Generic Error Modelling System (GEMS) to account for performance errors (fully described in ref. 1987 and revised in ref. 1988). It need not be detailed here since it is structurally similar to the WM and the knowledge base elements of the information processing model presented earlier. Reasons postulates that the search for problem identification and solution occurs in parallel between automatic matching in the knowledge base and conscious search in WM. The model varies somewhat based upon problem configuration. The NPP operator is confronted with what Reasons refers to as a "complex multiple-dynamic configuration" which is a situation where the problem configuration changes as a result of both the operator's actions and the system's own actions which can come from many different sources and create a great deal of variability in the problem. This is the most difficult problem solving situation and the one in which the information processing system is most likely to rely on heuristics. In such a situation, like a NPP emergency, a typical problem solving sequence assumes the following structure: (1) initial scanning is initiated by signals from the alarm system and the operator's attention is split between a variety of data gathering activities, (2) the operator "homes in" on a specific group of indicators and makes an initial diagnosis, (3) the operator now structures his attentional resources to seek data confirming the hypothesis, and (4) the operator becomes fixated on the hypothesis and can fail to notice changes in the plant's state or subsequent new developments. The operator does eventually become aware of subsequent changes, but the process is hampered by focal attention being directed toward the current hypothesis and the overall processing limitations of WM.

The model provided by Reasons accounts for many of the error tendencies identified by other researchers such as "cognitive tunnel vision" (Sheridan, 1981), operator failure to effectively utilize information about what has not failed (Rouse, 1981), description errors (Norman), capture errors (Norman), activation (Norman)/interference (Rasmussen) errors, and inadequate processing resources errors (Rasmussen and Wickens).

In summary, human errors are not typically stochastic but are the result of basic characteristics and limitations of the human information processing system. Aspects of information processing that have been identified as especially significant to error are attention, WM limitations, situation awareness, and cognitive workload. Many errors reflect the system's response to high information/high complexity situations which result in high demands on attentional resources and working memory. The information processing system attempts to handle these high workload situations through the application of heuristics, such as those described by Norman, Rasmussen, and Reasons. These heuristics reduce overall load on the IP system but can also lead to error. The HSI should help prevent heuristic-initiated errors which often reflect incomplete processing and tunnel vision. For example, operator decision-support aids which indicate when (1) "unexpected" events (based upon the current pattern) occur, and (2) when "expected" events (based upon the current pattern) do not occur, would call the operator's attention to plant conditions which are likely to be missed due to the information processing bias toward "capture" errors.

The implications of these characteristics of human cognition and error for advanced HSI are discussed in the next section.

2.1.3.2.3 Design-Related Factors Impacting Performance

In Section 2.1.3.1 it was stated that the knowledge-base pertaining to the effects of advanced technology on human performance was limited. While this is the case, there have been many issues identified in the human factors literature. In this section, these issues are considered with respect to the model of human cognitive processes and error discussed above. The issues briefly considered are:

- Automation and Allocation of Function
- System Complexity and Operator Skills
- Display Design
- DMS Design and Data Access
- Workstation Flexibility and Interface Management

Automation and Allocation of Function

One of the major trends in ACR design is an increase in automation of tasks traditionally performed by the operator. Increases in automation result in a shift of the operator's function in the system from that of a direct manual controller to a supervisory controller and system monitor who is largely removed from direct control. This type of role change is typically viewed as positive from a reliability standpoint, since the human operator is considered one of the more unpredictable components in the system. It is generally presumed that automation will enhance overall system reliability by removing or reducing the need for human action. The operator's performance in the system is believed to be improved by freeing him from tasks which are routine, tedious, physically demanding, or difficult. Thus, the operator can better concentrate on supervising the overall performance and safety of the system.

However, functions are often allocated to automated systems based largely on the capability of available technology to reliably and safety execute the function. This allocation of function strategy does not consider whether a function should be automated with respect to the human operator's ability to perform as part of the overall system, even though the human factors problems associated with automation to been known for some time (Edwards, 1977) and the emergence of new types of human and system errors has been noted (Wiener and Curry, 1980). For example, over the past 20 years, there has been a great increase in automation of functions in the cockpits of civilian aircraft. However, it did not take long for the problems associated with automation to become known (Edwards, 1977). As more of the pilot's tasks were automated, new types of human and system errors emerged. Wiener grouped these problems into six categories: (1) failures of automatic equipment, such as autopilot; (2) automation-induced errors compounded by crew error, such as an error occurring following the crew's attempt to recover from the failure of an automated system; (3) crew error in the set up of automated systems, such as keying the wrong information/data into an automated system, (4) crew action taken in response to a false alarm, (5) failure of the crew to pay attention to an automatic alarm, and (6) failure to properly monitor the automated system (Wiener and Curry, 1980). With respect to automation in civil aviation, Sexton (1988) observed that if "decisions are automatically made without providing the rationale to the pilot, the ability to stay ahead of the aircraft is lost. Complacency and inability to take timely and proper action result." In general, increases in automation have been associated with loss of operator vigilance and an increase in vigilance-associated human errors (Warm and Parasuraman, 1987). Similar concerns have been raised in the nuclear industry (IAEA, 1991).

The problems with operator intervention in an automated system have been associated with poor SA (Kibble, 1988). Maintaining SA is difficult when the operator is largely removed from the control loop, i.e., shifting the operator's role from an active, in-the-loop, manual controller to an out-of-the-loop supervisor and monitor (Wickens and Kessell, 1981; Ephrath and Young, 1981).

The shift in roles has other significant effects on the operator as well, such as a shift from high physical to high cognitive workload (rather than the expected reduction in overall workload), workload transition effects when the situation shifts from normal to off-normal (i.e., going from a low activity monitoring period to a highly active, more uncertain time at the beginning of a process disturbance), and the potential erosion of the skills to perform the task in the event of automated system failure. Since many advanced NPP designs still require the operator to assume control in the event of a severe transient and to act as the last line of defense, the consequences of poor integration of the operator in the plant design can be quite serious.

Generally, allocation of system functions should not be based upon technological capability alone but also on the goal of maintaining the degree of operator involvement in the functions required to support accurate SA. Toward this end, it has been frequently argued that allocation of function need not be simply a binary process of operator versus automated system selection. Rather, there are functions where a combination of human and system task allocation best serve the overall productivity and safety of the system (Price, 1985).

<u>System Complexity and Operator Skills</u>

There is a somewhat paradoxical relationship between the skills an operator will require to successfully understand and supervise a complex, technologically advanced and the day-to-day monitoring tasks the operator performs in a highly-automated plant. Monitoring is typically considered very boring and not something people do particularly well (e.g., vigilance is difficult to maintain). Yet the skills required of operators to evaluate the performance of advanced systems, to know the limitations of those systems, and to assume manual control when appropriate, will require very capable individuals and extensive training. Operators will be required to understand reactor physics and the functioning of system hardware (as they are required to do now). The advanced reactor goal of plant and system simplification may help operators in this regard. However, as plants become increasingly automated and increasingly utilize intelligent systems, operators will be required to understand the complex and abstract software routines (in order to be an effective supervisory controller). Operator selection considerations and training program development will have to reflect these demands. Yet, there is a risk that the carefully selected and highly trained operators will be required to perform a boring and monotonous job.

Display Design

Human performance and reliability are especially influenced by the design of the human-computer interface and the information displays in particular. With respect to computer-based interfaces, "even slight changes in both the nature of the information available and the manner in which it is represented might have serious effects on performance" (Patrick, 1987). Therefore, computer-based HSI design requires, to a far greater extent than traditional control room designs, the specification of cognitive requirements and processing resources that the operator must utilize in task performance, i.e., cognitive task analysis. The variety of ways that data/information can be processed and displayed is vast. Information may be presented in "processed" form, i.e., raw data parameters are processed and integrated into a higher level of information, thus potentially obscuring their meaning. Poorly designed displays will be ignored or, worse, will mislead and/or confuse the operator. Thus the design of the interfaces can have very significant effects on human performance. These types of problems have been observed in reviews of SPDS interfaces (Liner and DeBor, 1986). In some SPDS implementations, poor information displays have led to poor operator acceptance.

DMS Design and Data Access

Second, the operator typically has much more information available to him which, if not properly organized and presented, can lead to excessively high cognitive workload, or worse, can be overwhelming. Information in an advanced control room will typically be resident in a "virtual" workspace, rather than in dedicated spatial locations spread out across control stations. Information is located somewhere in the computer system but the operator has only a glimpse of its contents (through a display device) at any one time. This is sometimes referred to as the keyhole effect (Woods et al., 1990). A poorly designed interface can make location of information and navigation through data difficult.

Workstation Flexibility and Interface Management

The flexibility of software-driven interfaces often allows information to be displayed in a variety of formats and locations. Sometimes this flexibility is offered as a positive feature, allowing operators to customize the interface. However, it can also increase the operator's workload associated with managing the interface, which competes with the operator's primary task of monitoring and supervising the system for cognitive processing resources. Interface management workload should be minimized in advanced CRs. Cook et al (1990) found that operators of a computer-based surgical operating room information system often used the flexibility of an interface to "convert the device to a static, spatially dedicated display."

2.1.3.3 Summary of the Human Performance Considerations

While advanced technology may provide the potential to improve operator performance, the literature indicated that numerous problems have been observed in advanced systems associated with failure to properly integrate operators into the system and to provide interfaces to the system that support performance. The major issues include:

- Increase in the cognitive workload associated with information management
- Inability to use the type of well-learned scanning patterns associated with analog displays
- Difficulty understanding how a complex system works (poor mental model)
- Confusion over the meaning of high-level displays
- Loss of vigilance and boredom from prolonged monitoring
- Loss of situation awareness in supervisory control situations
- Workload transition when automated systems fail
- Loss of skill proficiency
- Emergence of heuristics and error mechanisms to cope with an overloaded information processing system
- Increase in the secondary task "interface management" workload with workstation flexibility which competes with the primary task
- Navigation difficulties

An NRC advanced HSI review guideline should identify these potential problem design features when they exist

2.1.4 Advanced HSI Guidelines Issues

Two issues were considered in this section:

- Hardware vs. Software Interface Review Guideline,
- Suitability of Human Factors Engineering Guidelines for Evaluation

2.1.4.1 Hardware vs. Software Interface Review Guideline

NUREG-0700 is primarily concerned with human interfaces for the hardware characteristics of conventional CRs. The development of guidelines for the review of advanced and primarily computer-based, human-system interfaces is not a straightforward extension of the guidelines applied to more conventional interfaces. In a conventional CR, the design of the HSI is readily apparent from the physical layout of the controls and displays. In an advanced CR, the physical layout of the VDUs and computer input devices is significantly less important than the design of the human-software interface; i.e., the information management system and the methods by which information is displayed to the operator. This information can be displayed in a complex network of thousands of computer displays and flexible, operator-defined display formats. This difference in focus creates a whole new set of problems for the operator (O'Hara and Hall, 1990; Woods et al., 1990) and for the reviewer.

The difficulty of developing guidelines for human-software interfaces when compared with human-hardware interfaces has been elaborated by Smith (1988). Hardware guidelines are generally based upon human physiology, e.g., visual acuity, reach envelopes, etc., while software guidelines are generally based on cognition and information processing. Hardware design is limited by technology while software design is mainly limited by human understanding of the tasks to be performed. Software design is generally very flexible in terms of what and how information is presented while hardware is much less flexible. Finally, and perhaps most significant to the review of human-software interface is that the most important design features are often hidden (to the reviewer, transparent to the operator) while important hardware design features are usually readily observable. For example, the observable computer display may be an end product of integration and processing of data into higher-level displays (in contrast to the single sensor/single display characteristic of conventional CRs). As a result, while hardware guidelines tend to be relatively clear and specific, software guidelines tend to be stated in more general language. Thus, the review of human-software interfaces, one of the most important aspect of advanced CR design review, is more complex and difficult than the review of hardware interfaces.

The design of conventional CRs were based upon decades-old technology. When NUREG-0700 was developed, the available human factors guidance (such as MIL-STD-1472B) was long-standing and tested through many years of design experience. By contrast, hybrid, advanced, and intelligent CRs are based upon relatively new technology which is rapidly changing. Relative to the guidelines available for NUREG-0700, the guidelines available for advanced technology have a considerably weaker research base (Smith, 1988) and have not been tested and validated through many years of design application which provides valuable lessons learned. Thus, the human factors guidelines available for the review of advanced CR technology are less firm and typically stated in far less prescriptive terms (pending specification through research and design experience). Further, as indicated above, to the extent that the human software interface is critical to operator performance, the cognitive task requirements become significant and these are less familiar to designers and reviewers (Karat, 1989; Woods et al., 1990).

These characteristics of advanced technology guidelines can make the reviewers' job more difficult. A study by Reaux and Williges (1988) compared reviewers' ability to detect guideline violations in a computer display prototype as a function of guideline wording - concrete vs. abstract. It was found that almost twice as many concrete guideline violations were detected as compared with abstract guidelines. Further, reviewers were less confident in their evaluations using abstract guidelines. Similarly, it has been found that abstractly worded guidelines are less utilized by designers (Mosier and Smith, 1985).

2.1.4.2 Suitability of HFE Guidelines for Evaluation

Another issue related to the immature status of advanced technology guidelines is whether evaluations based only on conformance to human engineering guidelines provides a sufficient basis for review. Gould (1988) has indicated that due to the nature of advanced human-system interfaces (as discussed above), a good system cannot be designed by guidelines alone. A similar conclusion resulted from an effort to evaluate a computer-based system using only guidelines (Potter et al., 1990). Thus, ACR evaluations need to be broader and, in terms of final design at least, include dynamic testing under realistic operating conditions.

2.1.5 Implications for the Review of the Advanced NPP HFE

The issues discussed above have implications for the development of an approach to the safety review of the HFE aspects of advanced reactor designs. These implications are summarized below.

1. The evaluation methodology should provide guidance for reviews to be performed throughout the design life cycle, i.e., proposed/conceptual design to final designs. Important reasons for this include:

- The need for criteria for the review of advanced reactor certifications which may provide control room designed only to conceptual levels of detail.

- The finding that many significant human factors issues arise early in design, e.g., initial goals/objectives of the design and allocation of function.

2. Reviews of the final HSIs should extend beyond checklist-based, HFE guideline evaluations and should include validations of the fully integrated system under realistic, dynamic conditions using experienced operators performing the types of tasks the HSI has been design for (including various types of failures and transient conditions). The reasons for this include:

   - The state of knowledge concerning the effects of advanced technology on human performance is limited, therefore, the technical basis on which to develop valid HSI design review guidelines is limited.

   - Studies have shown that a comparison of a final design against HFE guidelines is necessary but not sufficient to ensure a safe, acceptable design.

3. The evaluation methodology will be used for reviews of advanced technology retrofits to existing plants as well as new HSI design concepts.

4. The evaluation methodology will have to provide for the review of a broad range of CR "types" and the diversity of approaches to advanced HSI technology. The Guideline should focus heavily on human-software interface since this is where some of the most significant human performance issues reside and this is where NRC review guidance is most deficient.

5. Violations of human-software guidelines have been found to be more difficult to detect than violations of hardware guidelines. This places greater burden on the judgement of the reviewer and the reviewer's ability to adapt and interpret the guidelines in the context of a particular review. Thus, for the near-term, HSI reviews of advanced systems will have to be performed by experienced human factors evaluations. Reasons for this include:

   - Available human factors guidelines for advanced HSI technology are relatively general and more abstract in comparison to guidelines for conventional technology.

   - Since the Guideline should be capable of addressing the wide variety of reactor designs and the diversity of operator tasks that result, it cannot be prescriptive concerning the design of HSIs developed to support those tasks.

2.2 Advanced NPP HFE Review Model

2.2.1 Rationale and Overview

General Rationale

The implications from the examination of the factors and issues impacting advanced NPP reviews lead to the conclusion that reviews of HSI will have to be broader than those traditionally conducted by the NRC. Therefore, a fairly broad review model will be required to achieve a safety finding with regard to advanced HSI.

The philosophy adopted for the purposes of this effort was that evaluating the safety of NPP HSIs is a relative assessment. That is, "safety" is a abstract concept that can only be assessed in relative terms. When reviewing a design in order to make a safety assessment, evidence is collected and weighted towards or against an acceptable finding. With respect to the advanced HSI evaluations, different types of evidence can be collected. Like any "measurement" process, each type of data has its overall correlation with safety and each has its strengths and weaknesses. The reviewer would like to collect as much data as possible in order to get a better picture of the "common factor variance"; i.e., to see if a consistent finding emerges across different types of data, each subject to its own sources of bias and error. The types of information that can provide partial assessments of HSI safety include:

- HFE Planning (including an HFE team, program plans and procedures),
- Design analyses and studies (including requirements/function/task analyses, technology assessments, trade-off studies, etc.),
- Design compliance with respect to accepted HFE guidelines, and
- Performance on the integrated system with operators performing the required tasks under actual (or simulated) conditions.

The four categories of "safety" evidence all have their strengths and weaknesses although they are probably listed in an order of increasing correlation with safety, i.e., greater reliance on full-mission testing will be made when compared with the make-up of an HFE Design team and program plan. It is tempting to view the fourth category as definitive, but it is also subject to error. Typically full mission evaluations cannot test all possible conditions of HSI usage and they will generally be performed using a simulator (since actual plants cannot be subject to the failures and transients for which the HSIs are mainly needed for to achieve their safety function) which create a somewhat artificial condition that can modify crew responses. Thus, the reviewer must infer the safety of a design from a variety of different pieces of evidence, each with their own bias and sources of error.

The greatest confidence in a finding that a design is "safe" can be placed in one which was (1) developed by a qualified HFE design team including all the skills required using an acceptable HFE program plan; (2) the result of appropriate HFE studies and analyses during the design development; (3) in compliance with accepted HFE standards and guidelines and which justified exceptions, and (4) validated in full-mission testing.

Overview

The scope of the general HFE Program Review Model was limited to HSIs including human interfaces with hardware, software, and procedures. Training and personnel qualifications were not considered as part of this model development. The first step in formulating the review and evaluation process was to identify which aspects of the HSI design process are required to assure that safety goals are achieved and to identify the general review criteria by which each element can be assessed. Review criteria are required to assure that the design reflects currently acceptable human factors engineering practices. Thus, a technical basis for review of a design process was developed and is described in this section. The specific objectives of this effort were:

1. To develop HFE program review model to serve as a technical basis for the review of the development and design of ACRs. The model requirements were that it be: (1) based upon currently accepted practices, (2) well-defined, and (3) validated through experience with the development of complex, high-reliability systems.

2. To identify the HFE elements in a system development, design, and evaluation process that are necessary and sufficient requisites to successful integration of the human component in complex systems.

3. To identify which aspects of each HFE element are key to a safety review and are requires to monitor the process.

4. To identify the types of acceptance criteria that would have to be developed for each HFE element in order that it can be evaluated.

2.2.2 Development Method

A technical review of current HFE guidance and practices was conducted to identify important human factors program plan elements relevant to a design process review. Sources reviewed included a wide range of nuclear industry and non-nuclear industry documents, including those currently under development as part of the Department of Defense (DoD) MANPRINT program (Booher, 1990, DoD, 1989; DoD, 1990a). From this review a generic system development, design, and evaluation process was defined. Once specified, key HFE elements were identified, general criteria by which they are assessed (based upon a review of current literature and accepted practices in the field of human factors engineering) were developed.

The generic HFE Program Review Model was developed based largely on applied general systems theory (Bailey, 1982; DeGreen, 1970; Gagne, et al., 1988; VanCott et al.,; Woodson, 1981) and the Department of Defense (DoD) system development process which is rooted in systems theory DoD, 1979a; DoD, 1990b; Kockler et al., 1990). Other DoD documents were utilized as well (DoD 1979b; DoD 1981; DoD 1983; DoD 1985; DoD 1986; DoD 1989a; DoD 1989b; DoD 1991a; DoD 1991b; DoD 1991c).

Applied general systems theory provides a broad approach to system design and development, based on a series of clearly defined developmental steps, each with clearly defined and goals, and with specific management processes to attain them. System engineering has been defined as "...the management function which controls the total system development effort for the purpose of achieving an optimum balance of all system elements. It is a process which transforms an operational need into a description of system parameters and integrates those parameters to optimize the overall system effectiveness" (Kockler et al., 1990).

Utilization of the DoD system development as an input to the development of the Generic HFE Program Model was based on several factors. DoD policy identifies the human as a specific element of the total system (DoD, 1990a). A system approach implies that all system components (hardware, software, personnel, support, procedures, and training) are given adequate consideration in the developmental process. A basic assumption is that the personnel element receives serious consideration from the very beginning of the design process. In addition, the military has applied HFE for the longest period of time (as compared with industrial/commercial system developers), thus the process is more highly evolved and formalized and represents the most highly developed model available. Finally, since military system development and acquisition is tightly regulated by federal, DoD, and military branch laws, regulations, requirements, and standards, the model provides the most finely grained, specifically defined HFE process available.

Within the DoD system, the development of a complex system begins with the mission or purpose of the system, and the capability requirements needed to satisfy mission objectives. Systems engineering is essential in the earliest planning period to develop the system concept and to define the system requirements. During the detailed design of the system, systems engineering assures:

- balanced influence of all required design specialties,
- resolution of interface problems,
- the effective conduct of trade-off analyses,
- the effective conduct of design reviews, and
- the verification of system performance.

The effective integration of HFE considerations into the design is accomplished by: (1) providing a structured top-down approach to system development which is iterative, integrative, interdisciplinary and requirements driven and (2) providing a management structure which details the HFE considerations in each step of the overall process. A structured top-down approach to NPP HFE is consistent with the approach to new control room design as described in Appendix B of NUREG-0700 (U.S. NRC, 1981) and the more recent international standard, IEC 964 (IEC, 1989) for advanced control room design. The approach is also consistent with the recognition that human factors issues and problems emerge throughout the NPP design and evaluation process and therefore, human factors issues are best addressed with a comprehensive top-down program.

The systems engineering approach was expanded to develop a HFE Program Review Model to be used for the ACR design and implementation process review by the incorporation of NRC HFE requirements.

2.2.3 General Model Description

In this section an overview of the model is presented to generally describe the HFE elements, products reviewed for each element, and the acceptance criteria used to evaluate the element. A more detailed description of the elements are presented in O'Hara and Higgins, 1992).

The model is intended as the programmatic approach to achieving a design commitment to HFE. The overall commitment and scope of the HFE effort can be stated as follows: Human-system interfaces (HSI) should be provided for the operation, maintenance, test, and inspection of the NPP that reflect "state-of-the-art human factors principles" (10 CFR 50.34(f)(2)(iii)) as required by 10 CFR 52.47(a)(1)(ii). For the purposes of model development "state of the art" human factors principles was defined as those principles currently accepted by human factors practitioners. "Current" is defined with reference to the time at which an HSI is developed. "Accepted" is defined as a practice, method, or guide which is (1) documented in the human factors literature within a standard or guidance document that has undergone a peer-review process, and/or (2) justified through scientific/industry research practices.

The model developed to achieve this commitment contains eight elements divided into four review stages:

<u>HFE Planning Review</u>

- Element 1 - Human Factors Engineering Program Management

Analysis Results Review

- Element 2 - Operating Experience Review
- Element 3 - System Functional Requirements Analysis
- Element 4 - Allocation of Function
- Element 5 - Task Analysis

Design Development Review

- Element 6 - Human-System Interface Design
- Element 7 - Plant and Emergency Operating Procedure Development

Verification and Validation

- Element 8 - Human Factors Verification and Validation.

The elements and their interrelationships are illustrated in Figure 2.3. Also illustrated are the minimal set of items submitted to the NRC for review of the developers' HFE efforts. The materials reviewed at each stage are shown in Figure 2.4 (either an Implementation Plan, Analysis Report, and HFE Design Team Review Report). Each element contains an element objective and the factors that must be considered in the review process. More detailed acceptance criteria have been described elsewhere (O'Hara and Higgins, 1992).

A brief description of each element follows.

2.2.4 Review Elements

2.2.4.1 Element 1 - Human Factors Engineering Program Management

As stated above, this element reflects the general design commitment: Human-system interfaces (HSI) should be provided for the operation, maintenance, test, and inspection of the HSI that reflect "state-of-the-art human factors principles" (10 CFR 50.34(f)(2)(iii)) as required by 10 CFR 52.47(a)(1)(ii). All aspects of HSI should be developed, designed, and evaluated based upon a structured top-down system analysis using accepted human factors engineering (HFE) principles based upon current HFE practices. HSI is used here in the broad sense and should include all operations, maintenance, test, and inspection interfaces, procedures, and training needs of the main control room and remote shutdown system functions and equipment.

To assure the integration of HFE into system development and the achievement of the goals of the HFE program, an HFE Design Team and an HFE Program Plan should be established to assure the proper development, execution, oversight, and documentation of the program. As part of the program plan an HFE issues tracking system (to document and track HFE related problems/concerns/ issues and their solutions throughout the HFE program) should be established.

Considerations for the review of this element include (organized by the topics to which the considerations apply: General, HFE Team, Issue Tracking System, and HFE Program plan):

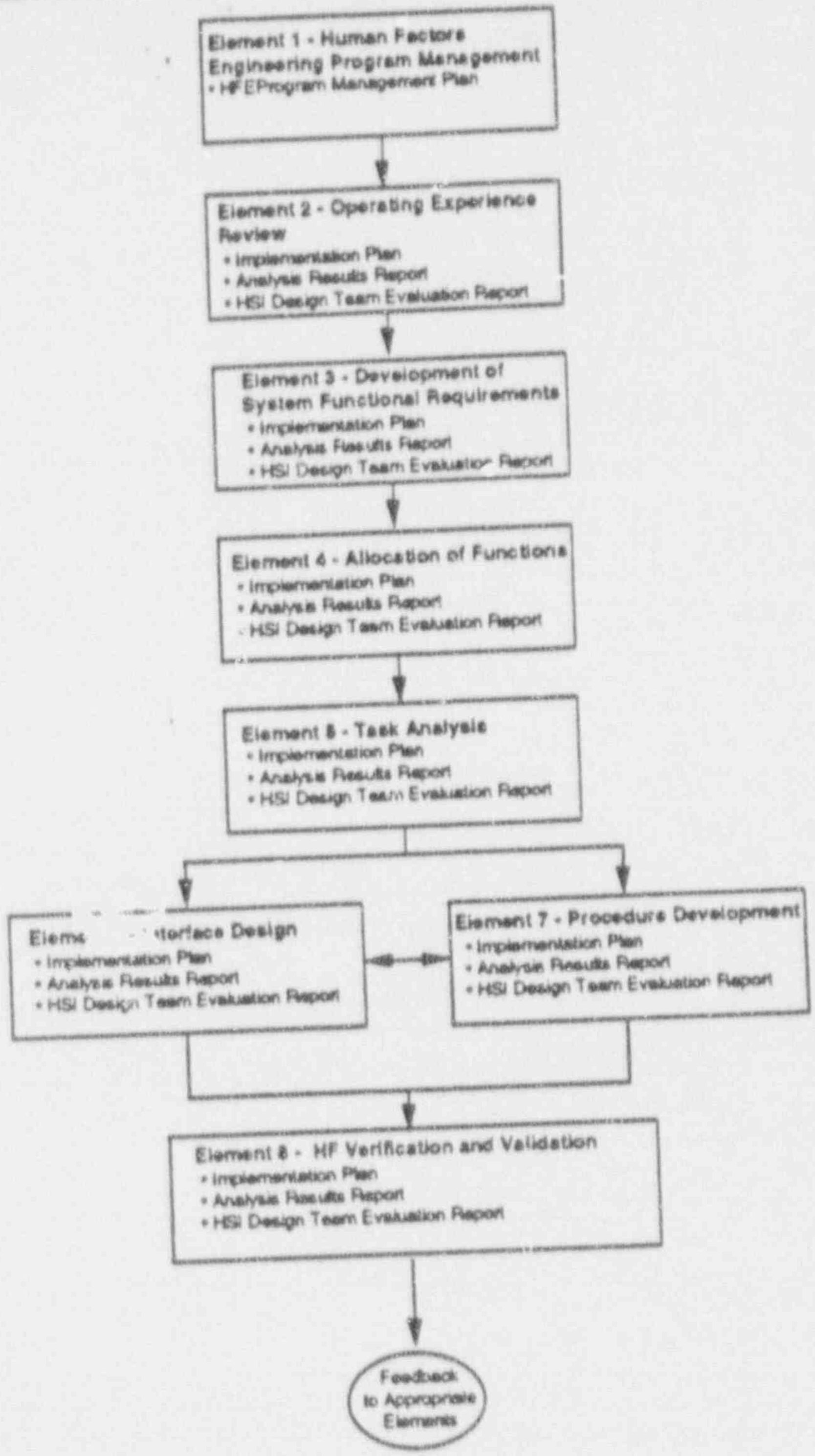

Figure 2.3 HFE Program Review Model Elements

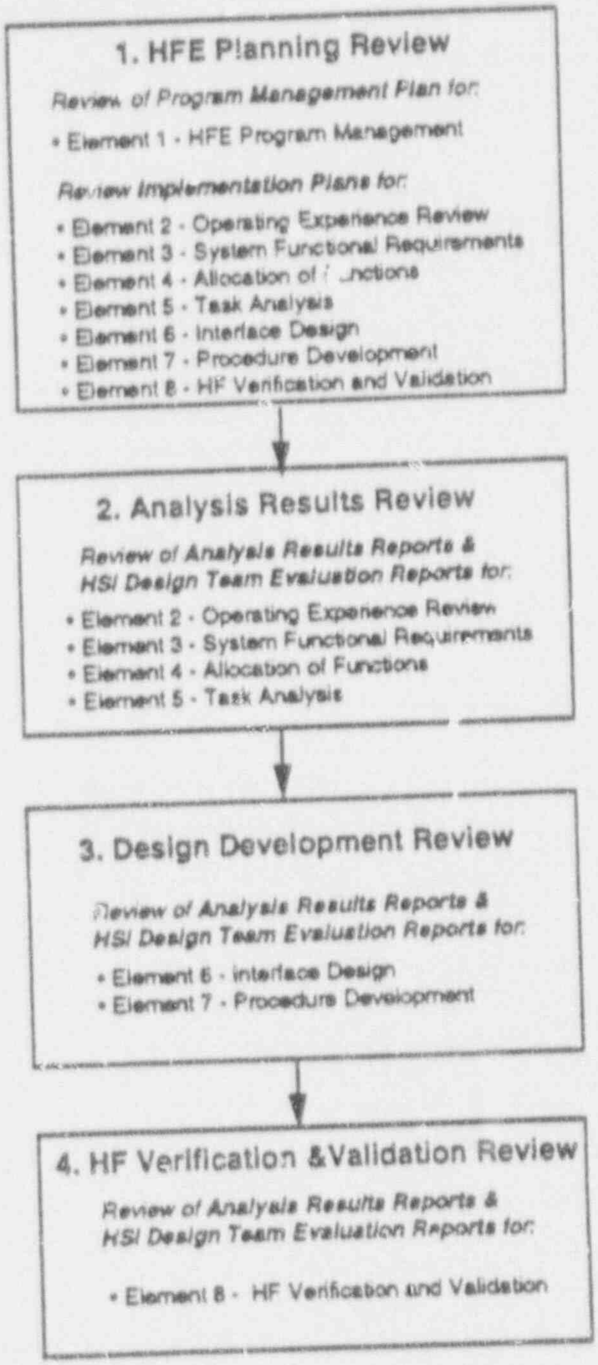

Figure 2.4 Review Stages

General

1. The primary goal of the HFE program should be to developing an HSI which makes possible safe, efficient, and reliable operator performance and which satisfy all regulatory requirements. The general objectives of this program should include the high-level cognitive goals (identified in Section 3 of this report) which, as the HFE program develops, should be objectively defined and should serve as criteria for test and evaluation activities.

HFE Team

1. An HFE Design Team should have the responsibility, authority and placement within the organization (as defined below) to ensure that the design commitment is achieved.

2. The team should be responsible for (1) the development of all HFE plans and procedures; (2) the oversight and review of all HFE design, development, test, and evaluation activities; (3) the initiation, recommendation, and provision of solutions through designated channels for problems identified in the implementation of the HFE activities; (4) verification of implementation of team recommendations, (5) assurance that all HFE activities comply to the HFE plans and procedures, and (7) scheduling of activities and milestones.

3. The Team should have the authority and organizational freedom to ensure that all its areas of responsibility are accomplished and to identify problems in the implementation of the HSI design. The team should have the authority to determine where its input is required, access work areas, design documentation. The Team should have the authority to control further processing, delivery, installation or use of HFE/HSI products until the disposition of a non-conformance, deficiency or unsatisfactory condition has been achieved.

4. The HFE Team should be placed at the level in the organization required to execute its responsibilities and authorities. The team should report to a level of management such that required authority and organizational freedom are provided, including sufficient independence from cost and schedule considerations.

5. The HFE design team should include the following expertise:

- Technical Project Management
- Systems Engineering
- Nuclear Engineering
- Control and Instrumentation Engineering
- Architect Engineering
- Human Factors
- Plant Operations
- Computer Systems Engineering
- Plant Procedure Development
- Personnel Training
- Safety Engineering
- Reliability/Availability/Maintainability/Inspectability (RAMI) Engineering

HFE Issue Tacking System

1. The tracking system should address human factors issues that are (1) known to the industry (such as TMI related HF issues and other NRC, industry and generic human factors issues), (2) identified in the operating experience review (see Element 2), and (3) those identified throughout the life cycle of the system design, development and evaluation.

2. The method should document and track human factors engineering issues and concerns, from identification until elimination or reduction to a level acceptable to the review team.

3. Each issue/concern that meets or exceeds the threshold effects established by the review team should be entered on the log when first identified, and each action taken to eliminate or reduce the issue/concern should be thoroughly documented. The final resolution of the issue/concern, as accepted by the review team, should be documented in detail, along with information regarding review team acceptance (e.g., person accepting, date, etc.)

4. The tracking procedures should carefully spell out individual responsibilities when an issue/concern is identified, identify who should log it, who is responsible for tracking the resolution efforts, who is responsible for acceptance of a resolution, and who should enter closeout data.

HFE Program and Management Plan

1. An HFE Program Management plan should be developed to describe how the human factors program should be accomplished, i.e., the plan should describe the HFE Team's organization and composition and which lays out the effort to be undertaken and provides a technical approach, schedule, and management control structure and technical interfaces to achieve the HFE program objectives. The plan is the single document which describes the designer's entire HFE program, identifies its elements, and explains how the elements will be managed. Generally, it should address:

   - The scope of the HFE Design Team's authority within the broader scope of the organization responsible for plant construction. Included within this scope should be the authority to suspend from delivery, installation, or operation any equipment which is determined by the Team to be deficient in regard to established human factors design practices and evaluation criteria.

   - The process through which the Team will execute its responsibilities.

   - The processes through which findings of the Team are resolved and how equipment design changes that may be necessary for resolution are incorporated into the actual equipment ultimately used in the plant.

   - The qualifications of the team members.

   - The process through which the Team activities will be assigned to individual team members, the responsibilities of each team member and the procedures that will govern the internal management of the team.

- The procedures and documentation requirements of the HFE Issues Tracking System

2.2.4.2 Element 2 - Operating Experience Review

The accident at Three Mile Island in 1979 and other reactor incidents have illustrated significant problems in the actual design and the design philosophy of NPP HSIs. There have been many studies as a result of these accidents/incidents. Utilities have implemented both NRC mandated changes and additional improvements on their own initiative. However, the changes were formed based on the constraints associated with backfits to existing control rooms (CRs) using early 1980s technology which limited the scope of corrective actions that might have been considered, i.e., more effective fixes could be used in the case of a designing a new CR with the modern technology typical of advanced CRs. Problems and issues encountered in similar systems of previous designs should be identified and analyzed so that they are avoided in the development of the current system or, in the case of positive features, to ensure their retention.

Considerations for the review of this element include:

1. Problems and issues encountered in similar systems of previous designs should be identified and analyzed:

   - Human performance issues, problems and sources of human error should be identified.

   - Design elements which support and enhance human performance should be identified.

2. The review should include both a review of literature pertaining the human factors issues related to similar systems and operator interviews.

3. The following sources both industry wide and plant or subsystem relevant should be investigated at a minimum:

   - Government and Industry Studies of Similar Systems
   - Licensee Event Reports
   - Outage Analysis Reports
   - Final Safety Analysis Reports and Safety Evaluation Reports
   - Human Engineering Deficiencies identified in DCRDRs
   - Modifications of the Technical Specifications for Operation
   - Internal Memoranda/Reports as Available

4. The following topics should be included in interviews as a minimum:

   - Screen Design Issues
   - Data Presentation Formats
   - Data Entry and Control Requirements
   - Situational Awareness, Workload, and Vigilance Issues
   - Communications
   - Procedures
   - Job Design

2.2.4.3 Element 3 - System Functional Requirements Analysis

System requirements should be analyzed to identify those functions which must be performed to satisfy the objectives of each functional area. System function analysis should: (1) determine the objective, performance requirements, and constraints of the design; and (2) establish the functions which must be accomplished to meet the objectives and required performance.

Considerations for the review of this element include:

1. System requirements should determine system functions and the function should determine the performance necessary to carry out its objective.

2. Critical functions should be defined (i.e., those functions required to achieve major system performance requirements; or those functions which, if failed, could degrade system or equipment performance or pose a safety hazard to plant personnel or to the general public)

3. Safety functions should be identified and any functional interrelationship with non-safety systems should be identified.

4. Functions should be defined as the most general, yet differentiable means whereby the system requirements are met, discharged, or satisfied. Functions should be arranged in a logical sequence so that any specified operational usage of the system can be traced in an end-to-end path.

5. Function diagramming should be done at several levels, starting at a "top level" where a very gross picture of major functions is described, and continuing to decompose major functions to several lower levels until a specific critical end-item requirement will emerge, e.g., a piece of equipment, software, or an operator.

6. Detailed narrative descriptions should be developed for each of the identified functions and for the overall system configuration design itself. Each function should be identified and described in terms of inputs (observable parameters which will indicate system status), functional processing (control process and performance measures required to achieve the function), outputs, feedback (how to determine correct discharge of function), and interface requirements from the top down so that subfunctions are recognized as part of larger functional areas.

7. Functional operations or activities should include:

   - detecting signals
   - measuring information
   - comparing one measurement with another
   - processing information
   - acting upon decisions to produce a desired condition or result on the system or environment (e.g., system and component operation, actuation, and trips)

8. The function analysis should be kept current over the life cycle of design development.

9. Evaluation of the analysis should be performed to assure that:

- All the functions necessary for the achievement of operational and safety goals are identified.

- All requirements of each function are identified.

2.2.4.4 Element 4 - Allocation of Function

The allocation of functions should take advantage of human strengths and avoids allocating functions which would be impacted by human limitations. To assure that the allocation of function is conducted according to accepted HFE principles, a structured and well-documented methodology of allocating functions to personnel, system elements, and personnel-system combinations should be developed.

Considerations for the review of this element include:

1. All aspects of system and functions definition must be analyzed in terms of resulting human performance requirements based on the expected user population.

2. The allocation of functions to personnel, system elements, and personnel-system combinations should be made reflect (1) sensitivity, precision, time, and safety requirements, (2) required reliability of system performance, and (3) the number and level of skills of personnel required to operate and maintain the system.

3. The allocation criteria, rational, analyses, and procedures should be documented.

4. As alternative allocation concepts are developed, analyses and trade-off studies should be conducted to determine optimum configurations of personnel- and system- performed functions. Analyses should confirm that the personnel elements can properly perform tasks allocated to them while maintaining operator situation awareness, workload, and vigilance. Proposed function assignment should take the maximum advantage of the capabilities of human and machine without imposing unfavorable requirements on either.

5. Functions should be re-allocated in an iterative manner, in response to developing design specifics and the outcomes of on-going analyses and trade studies.

6. Function assignment should be evaluated.

2.2.4.5 Element 5 - Task Analysis

Task analysis should provide the systematic study of the behavioral requirements of the tasks the personnel subsystem is required to perform in order to achieve the functions allocated to them. The task analysis should:

- form the basis for specifying the requirements for the displays, data processing and controls needed to carry out tasks,

- provide one of the bases for making design decisions; e.g., determining before hardware fabrication, to the extent practicable, whether system performance requirements can be met by combinations of anticipated equipment, software, and personnel,

- assure that human performance requirements do not exceed human capabilities,

- be used as basic information for developing procedures, and

- be used as basic information for developing manning, skill, training, and communication requirements of the system.

Considerations for the review of this element include:

1. The scope of the task analysis should include all operations, maintenance, test and inspection tasks. The analyses should be directed to the full range of plant operating modes, including start-up, normal operations, abnormal operations, transient conditions, low power and shutdown conditions. The analyses should include tasks performed in the control room as well as outside of the control room.

2. The analysis should link the identified and described tasks in operational sequence diagrams. A review of the descriptions and operational sequence diagrams should identify which tasks can be considered "critical" in terms of importance for function achievement, potential for human error, and impact of task failure. Human actions which are found to affect plant risk in PRA sensitivity analyses should also be considered "critical." Where critical functions are automated, the analyses should consider all human tasks including monitoring of an automated safety system and back-up actions if it fails.

3. Task analysis should begin on a gross level and involve the development of detailed narrative descriptions of what personnel must do. Task analyses should define the nature of the input, process, and output required by and of personnel. Detailed task descriptions should address (as appropriate):

   - Information Requirements

     - Information required, including cues for task initiation
     - Information available

   - Decision-Making Requirements

     - Description of the decisions to be made (relative, absolute, probabilistic)
     - Evaluations to be performed
     - Decisions that are probable based on the evaluation (opportunities for cognitive errors, such as capture error, will be identified and carefully analyzed)

   - Response Requirements

     - Action to be taken
     - Overlap of task requirements (serial vs. parallel task elements)
     - Frequency
     - Speed/Time line requirements
     - Tolerance/accuracy
     - Operational limits of personnel performance

- Operational limits of machine and software
- Body movements required by action taken

- Feedback Requirements

  - Feedback required to indicate adequacy of actions taken

- Workload

  - Cognitive
  - Physical
  - Estimation of difficulty level

- Task Support Requirements

  - Special/protective clothing
  - Job aids or reference materials required
  - Tools and equipment required
  - Computer processing support aids

- Workplace Factors

  - Workspace envelope required by action taken
  - Workspace conditions
  - Location and condition of the work
  - Environment

- Staffing and Communication Requirements

  - number of personnel, their technical specialty, and specific skills
  - Communications required, including type
  - Personnel interaction when more than one person is involved

- Hazard Identification

  - Identification of Hazards involved

4. The task analysis should be iterative and become progressively more detailed over the design cycle. The task analysis should be detailed enough to identify information and control requirements to enable specification of detailed requirements for alarms, displays, data processing, and controls for human task accomplishment.

5. The task analysis results should provide input to the personnel training programs.

2.2.4.6 Element 6 - Human-System Interface Design

Human engineering principles and criteria should be applied along with all other design requirements to identify, select, and design the particular equipment to be operated/maintained/controlled by plant personnel.

Considerations for the review of this element include:

1. The design configuration should satisfy the functional and technical design requirements and insure that the HSI will meet the appropriate HFE guidance and criteria.

2. The HFE effort should be applied to HSI both inside and outside of the control room (local HSI).

3. HSI design should utilize the results of the task analysis to assure the adequa[illegible] of the HSI.

4. The HSI and working environment should be adequate for the human performance requirements it supports. The HSI should be capable of supporting critical operations under the worst credible environmental conditions.

5. The HSI should be free of elements which are not required for the accomplishment of any task.

6. The selection and design of HSI hardware and software approaches should be based upon demonstrated criteria that support the achievement of human task performance requirements. Criteria can be based upon test results, demonstrated experience, and trade studies of identified options.

7. HFE standards should be employed in HSI selection and design. Human engineering guidance regarding the design particulars should be developed by the HSI designer to (1) insure that the human-system interfaces are designed to currently accepted HFE guidelines and (2) insure proper consideration of human capabilities and limitations in the developing system. This guidance should be derived from sources such as expert judgement, design guidelines and standards, and quantitative (e.g., anthropometric) and qualitative (e.g., relative effectiveness of differing types of displays for different conditions) data. Procedures should be employed to ensure HSI adherence with the developed design standards.

8. HFE/HSI problems should be resolved using studies, experiments, and laboratory tests, e.g.,

   - Mockups and models may be used to resolve access, workspace and related HFE problems and incorporating these solutions into system design
   - Dynamic simulation and HSI prototypes should be evaluated for use to evaluate design details of equipment requiring critical human performance
   - The rationale for selection of design/evaluation tools should be documented

9. HFE should be applied to the design of equipment and software for maintainability, testing and inspection.

2.2.4.7 Element 7 - Plant and Emergency Operating Procedure Development

Plant and Emergency Operating Procedures should be developed to support and guide human interaction with plant systems and to control plant-related events and activities. Human engineering principles and criteria should be applied along with all other design requirements to develop procedures that are technically accurate, comprehensive, explicit, easy to utilize, and validated. The types of procedures covered in the element are:

- plant and system operations (including start-up, power, and shutdown operations),
- abnormal and emergency operations,
- preoperational, start-up, and surveillance tests, and
- alarm response.

Considerations for the review of this element include:

1. The task analysis should be used to specify the procedures for operations (normal, abnormal, and emergency), test, maintenance and inspection.

2. The basis for procedure development should include:

   - Plant design bases
   - system-based technical requirements and specifications
   - the task analyses for operations (normal, abnormal, and emergency)
   - significant human actions identified in the HRA/PRA
   - initiating events to be considered in the EOPs should include those events present in the design bases.

3. A Writer's Guide should be developed to establish the process for developing technical procedures that are complete, accurate, consistent, and easy to understand and follow. The Guide should contain sufficiently objective criteria so that procedures developed in accordance with the Guide should be consistent in organization, style, and content. The Guide should be used for all procedures within the scope of this Element. The Writer's Guide should provide instructions for procedure content and format (including the writing of action steps and the specification of acceptable acronym lists and acceptable terms to be used).

4. The content of the procedures should incorporate the following elements:

   - Title
   - Statement of Applicability
   - References
   - Prerequisites
   - Precautions (including warnings, cautions, and notes)
   - Limitations and Actions
   - Required Human Actions
   - Acceptance Criteria
   - Checkoff Lists

5. All procedures should be verified and validated. A review should be conducted to assure procedures are correct and can be performed. Final validation of operating procedures should be performed in a simulation of the integrated system as part of V&V activities described in Element 8.

6. An analysis should be conducted to determine the impact of providing computer-based procedures and to specify where such an approach would improve procedure utilization and reduce operating crew errors related to procedure use.

2.2.4.8 Element 8 - Human Factors Verification and Validation

The successful incorporation of human factors engineering into the final HSI design and the acceptability of the resulting HSI should be thoroughly evaluated as an integrated system using HFE evaluation procedures, guidelines, standards, and principles.

Considerations for the review of this element include:

1. The evaluation should verify that the performance of the HSI, when all elements are fully integrated into a system, meets (1) all HFE design goals as established in the program plan; and (2) all system functional requirements and support human operations, maintenance, test, and inspection task accomplishment.

2. The evaluation should address:

   - Human-Hardware interfaces
   - Human-software interfaces
   - Procedures
   - Workstation and console configurations
   - Control room design
   - Remote shutdown system and location control station
   - Design of the overall work environment

3. Individual HSI design elements should be evaluated in a static and/or "part-task" mode to assure that all controls, displays, and data processing that are required are available and that they are designed according to accepted HFE guidelines, standards, and principles.

4. The integration of HSI elements with each other and with personnel should be evaluated and validated through dynamic task performance evaluation using evaluation tools which are appropriate to the accomplishment of this objective. A fully functional HSI prototype and plant simulator should be used as part of these evaluations. If an alternative to a HSI prototype is proposed its acceptability should be documented in the implementation plan. The evaluations should have as their objectives:

   - Adequacy of entire HSI configuration for achievement of safety goals
   - Confirm allocation of function and the structure of tasks assigned to personnel
   - Adequacy of staffing and the HSI to support staff to accomplish their tasks.
   - Adequacy of Procedures
   - Confirm the adequacy of the dynamic aspects of all interfaces for task accomplishment
   - Evaluation and demonstration of error tolerance to human and system failures

5. Dynamic evaluations should evaluate HSI under a range of operational conditions and upsets, and should include:

   - Normal plant evolutions (e.g., start-up, full power, and shutdown operations)

- Instrument Failures (e.g., logic and control units, fault tolerant controllers, local "field Units" for multiplex (MUX) system, MUX controller)
- HSI equipment and processing failure (e.g., loss of VDUs, loss of data processing, loss of large overview display)
- Transients (e.g., Turbine Trip, Loss of Offsite Power, Station Blackout and Loss of all FW)
- Accidents (e.g., Main steam line break, Positive Reactivity Addition, Control Rod Insertion at power, Control Rod Ejection, ATWS, and various-sized LOCAs)

6. Performance measures for dynamic evaluations should be adequate to test the achievement off all objectives, design goals, and performance requirements and should include at a minimum:

   - System performance measures relevant to safety
   - Crew Primary Task Performance (e.g., task times, procedure violations)
   - Crew Errors
   - Situation Awareness
   - Workload
   - Crew communications and coordination
   - Anthropometry evaluations
   - Physical positioning and interactions

7. A verification should be made that all issues documented in the Human Factors Issue Tracking System have been addressed.

8. A verification should be made that all critical human actions as defined by the task analysis and PRA/HRA have be adequately supported in the design. The design of tests and evaluations to be performed as part of HFE V&V activities should specifically examine these actions.

3. HSI REVIEW GUIDELINE DEVELOPMENT

3.1 General Methodology and General Design Principles

3.1.1 Overview

While a very broad general model for the review of advanced reactor HFE was developed, the development of guidelines for the review of advanced HSI controls and room displays was identified as the part of the model to be developed. The general methodology for this part of the effort is illustrated in Figure 3.1.

The most important aspect of design evaluation is knowing what tasks the operator must perform and what the information, data processing, and control requirements are for each task transaction. This information must be developed for each unique design and cannot be specified in advance. There are several reasons for this including:

- The great diversity of plant types under development incorporating reactor technologies beyond LWRs,
- The evolutionary continuum in active to passive safety systems which greatly impacts the operator's safety functions, and
- The varying degree of automation available in present advanced reactor designs.

Thus, while a knowledge of operator tasks is the single most important aspect of safety evaluation, the state of the industry does not permit the specification of these tasks in enough detail to enable the development of a guidance document that would be generic enough to be applicable the all ACR design. Therefore, access to detailed task information will be required for each evaluation - whether it is made available to evaluators through secondary sources (such as documentation or operators) or whether it is developed by evaluators.

It is possible to identify some high-level operator cognitive goals based upon what is understood about human information processing and the cognitive precursors to human error (as was discussed in Section 2). Based upon the discussion in Section 2, a relatively small number of high-level cognitive goals can be identified:

Information Perception and Detection

Information Processing Requirements - Signal detection and event recognition requirements should be kept within the operators' information processing limits.

Rapid Information Assimilation - HSI information should be displayed in a form that can be easily assimilated and understood by the user.

Maximize Primary Task Performance

Operator Primary Task Support - The HSI should be designed around the operator's primary tasks in terms of what has to be performed within a given time frame, i.e., the HSI should support the users to accomplish all assigned tasks within system-defined time and performance criteria.

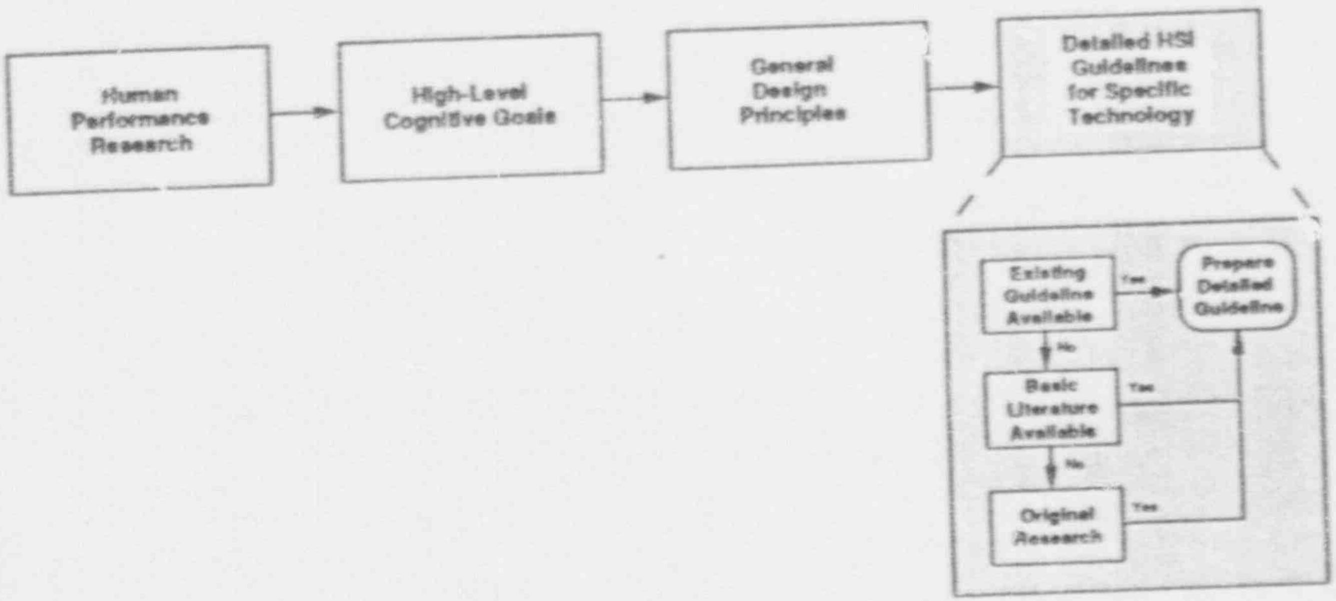

Figure 3.1 Guidance Development Approaches

Situation Awareness Support - The HSI should support a high degree of operating crew "situation awareness."

Appropriate Workload - The HSI should provide for a level of workload that does not negatively affect performance but which is sufficient to maintain vigilance.

Minimize Secondary Task Effects on Divided Attention

Minimize Unwanted Secondary Tasks - The HSI should minimize the competition for attentional processing resources of secondary tasks (tasks not directly involved with process control, such as the interface management).

Minimize Mental Computations and Transformations - The HSI design should minimize the need for operators to perform mental computations or to mentally transform data in order to make it usable.

Minimize Memory Load - The system will minimize operator memory load.

Minimize Errors

Feedback - The operator should be provided with feedback regarding the behavior of the system in response to control actions.

Error Tolerance - The operator interfaces should minimize operator error and provide for error detection and recovery capability. They should provide the cues required to activate the mental model which is appropriate to the situation (thus minimizing the higher-level processing and the information processing burden) and distinguish the information from other similar events.

The means of attaining these goals in the HSI is reflected in a set of General Design Principles that depict the generic HSI characteristics necessary to support optimal operator performance. Such general principles of human-interface design have been proposed in a number of sources (Smith and Mosier, 1986; Rarden and Johnson, 1989; Shneiderman, 1987; DoD, 1989). It should be noted that all of the cognitive goals do not all translate directly into clear-cut design review principles. However, most can be addressed as part of HSI evaluation. For the purposes of this report the General Design Principles are referred to as "Meta Guidelines." There are ten Meta Guidelines:

Efficient Screen Organization

All aspects of screen organization (placement of elements, sequencing of elements, spacing, etc.) should be based on user requirements and reflect the general principles of organization by importance, frequency of use, order of use, etc.

Logical Structure

All aspects of the system (formats, terminology, sequencing, grouping, etc.) should reflect an obvious logic, preferably based on task requirements, nuclear power conventions, or cultural conventions. In the absence of a logic based on one of these, another non-arbitrary logic, such as alphabetical, chronological, size, etc., should be employed.

Consistency

All aspects of the system should be expressed consistently, including formats, terminology (labels, prompts, menu items, commands, etc.), abbreviations, coding, control actions, sequences of actions, etc.

Familiarity/Meaningfulness

All aspects of the system should be expressed in customary, commonplace, useful and functional terms, rather than abstract, unusual or arbitrary forms, or in forms requiring interpretation prior to use.

Task Compatibility

The system should support task accomplishment and not force the user to conform to system processing requirements and limitations. Required data should be available in forms and formats appropriate to the task, and control options should encompass the range of potential desired actions.

Minimal Memory Load

The system should minimize the user's cognitive load by not requiring users to perform mental calculations, mental transformations, or to remember lengthy lists of codes, complex syntactic command strings, information from one screen to another, lengthy action sequences, etc.

Minimal Required Actions

The system should require the minimum number of actions necessary to accomplish an action; e.g., single vs. command keying, menu selection vs multiple command entry, single input mode (keyboard, mouse, etc.) vs. mixed mode, etc. In addition, the system should not require the entry of redundant data. The user should not be required to re-enter information already resident in the system, or information the system can generate through operating on already resident data.

Flexibility

The system should provide the user with multiple means to carry out actions and permit the user to format display/control in a configuration most convenient for the task at hand. Flexibility is sometimes a trade-off with consistency and should not impose interface management workload which distracts the user from plant monitoring and operations tasks.

Effective Feedback

The system should provide useful information regarding system status, permissible operations, errors and error recovery, dangerous operations, data parameters, etc. The system should provide an effective HELP function.

Effective Error Handling

The system should generally be designed such that the user can not make a serious error. If an error is made, the negative effects should be controlled and minimized, the system should offer simple, comprehensible notification of the error, including guidance for error recovery, and should provide simple, effective methods for recovering from the error.

Since the principles are generic and stated at a fairly general level, they must be made more application specific through the development of detailed design review guidance. The general HSI principles are then made more technology dependent and to a level of detail sufficient to support HSI review and evaluations. The general HSI principles must be translated into terms that can be applied to specific applications of advanced technology for NPPs, i.e., by developing guidelines for the review of the specific types technology (e.g., graphic displays, touch screens, and expert systems).

The detailed guidelines can be derived from many sources as illustrated in Figure 3.1. The most cost-effective means of developing guidance is to adapt validated guidelines already developed for similar complex, high-technology systems. For areas where no guidance is available, the scientific literature and industry experience related to the area can be reviewed to determine whether a sufficient knowledge-base exists to support guideline development. If the knowledge basis is weak, specific research projects can be developed to provide a foundation for guideline development.

Revision 2 of the Guideline (described in this document) reflects the results of the first method of guideline development. While a preliminary list of areas in need of further development have been identified, no effort was made in this project to review the literature (beyond that defined in the first method).

The purpose of this section is to describe the derivation of the detailed guidelines contained in Revision 2 of the Guideline.

3.2 Identification of Available Guidance for Advanced HSI

3.2.1 Document Search

Human factors guidelines for the types of advanced HSI technology being used in NPPs (as discussed in Section 2) were sought. The search process was composed of: (1) a search of the human factors literature including journal articles, conference papers, special interest group newsletters, and announcements of recent publications for books, manuals, etc.; and (2) direct contact with organizations which sponsor such research as well as individuals in the field of advanced human factors technology.

Three general criteria were used to facilitate the identification of guidelines projects for consideration in this project. First, no effort was made to identify documents developed before 1980. The reasons for this restriction included (1) significant guidelines were absorbed in later documents developed in the 1980s, and (2) HSI and computer technology have so dramatically changed over the 1980s that many of the guidelines published in the 1970s are not applicable to today's technology. Second, for this stage of the project, very specialized documents were not included because their validity could not be judged and they typically contain guidelines drawn from more well-known guidelines. Third, a "finer net" was used to identify applicable documents in the nuclear industry. That is, almost any nuclear industry document suggesting recommendations or guidelines for advanced HSI was sought and included while such a fine resolution search was not performed in other areas. For example, NUREG/CR-3987 on computerized annunciator systems contains general guidelines for such systems and was identified in the search process. Similar documents from outside of the nuclear industry would not have been included in the search process.

Information on each effort was entered into a computerized database containing information such as: authors, document title, document number, publication date, performing organization, sponsoring organization, publisher, status (completed, draft report, or work-in-progress), availability (available or not available for release), and a synopsis of the document's contents. The available documents for all projects were solicited and obtained where available.

Over 75 guideline efforts were identified. The great emphasis is on HCI with the more recent emphasis specifically on human-software interfaces. Many of the hardware aspects of HCI were elaborated in earlier guidelines, although there are some exceptions to this as well (such as in the area of computer input devices like the mouse and touch screen). It was also observed that a large number of books have been published in recent years on HCI guidelines. These texts, however, generally are limited in terms of the research justification audit trail provided for individual guidelines (i.e., individual guidelines are not linked with references validating their use). Government sponsored documents such as Smith and Mosier (1986) and DoD-HDBK-761A are much stronger in this regard. The latter are also much stronger in terms of the peer/industry review the guidelines received.

3.2.2 Document Selection of Primary Source Documents

Once advanced HSI documents were identified, the selection of those documents to serve as the basis for the initial set of guidelines to be incorporated in the Guideline document had to be made. Although many documents were identified and included in the database, no attempt was made to include all of them in the development of the Guideline for two reasons. First, the sheer volume of documents would have been too resource intensive to permit a detailed evaluation of each. Second, there was great diversity in the "validity" of individual documents. Therefore, a strategy was developed to classify the documents into primary (those to be used in the Guidelines development) and secondary sources. The classification process is explained below.

In the selection of primary source documents and in the subsequent selection of individual guidelines, a high priority was given to assuring the "validity" of the guidelines. Validity is not used here in the classic scientific sense of the term, instead an attempt was made to assure that the guidelines were based upon empirical research and/or accepted human engineering practice. Validity was defined in terms of two aspects of potential source document development which loosely correspond to the empirical research support and conformance with accepted human engineering practice. "Internal" validity was evaluated by the degree to which the individual guidelines within a document were based upon empirical research and an audit trail maintained from each guideline back to the research upon which it was based. Thus, if an individual guideline seemed questionable, it would be possible to go back to the original source documents to evaluate the appropriateness of the guideline's technical basis. "External" validity was evaluated as a function of the degree to which the document has been subjected to peer review. A document which had undergone extensive peer review was considered to have external validity. Such a review process was considered a good method of screening guidelines for conformance to accepted human engineering practices. Internal and external validity were evaluated at the document level and not at the level of individual guidelines.

In general, documents which had both good internal and external validity were considered the best primary source documents. Documents which had neither internal or external validity were considered secondary sources. This classification was used to specify the use of the documents in the guidelines compilation process.

While internal validity (research basis) and external validity (peer review) are important factors, there are additional factors which affect a document's priority within a class. Thus, a more fine-grained prioritization procedure was developed that included three additional factors:

- Authorship - A document was considered higher priority than another if it was developed by a panel of experts under the auspices of a recognized institution (such as the Human Factors Society) than if it was developed by a small group of authors.

- Recency - A document was considered higher priority than another if it was developed recently (1985-Present) than if it was developed prior to that (1980-1984).

- Industry - A document was considered higher priority than another if it was developed for the nuclear industry than if it was developed for another industry.

When these three factors are combined with the first two factors, a 32-level prioritization system results. Each of the documents in the database was rated by priority and that information was coded in the database. The priority rating was used to guide the order of document utilization and to facilitate the resolution of conflicting guidance that may appear between documents. The general classification used to establish document priority is illustrated in Table 3.1.

Table 3.1. Guideline Document Prioritization Scheme

REVIEW	PEER REVIEW																NO PEER REVIEW															
RESEARCH BASIS	YES								NO								YES								NO							
AUTHORSHIP	PANEL				NO				PANEL				NO				PANEL				NO				PANEL				NO			
RECENCY	REC		OLD		REC		OLD		REC		OLD		REC		OLD		REC		OLD		REC		OLD		REC		OLD		REC		OLD	
INDUSTRY	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O
PRIORITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Notes:
For Recency: REC= Recent (1985-Present) and OLD = 1980-1984
For Industry: N = Nuclear Industry and O = Other Industry

Table 3.2. Guideline Primary Source Documents

ORGANIZATION	DOC. NUMBER	YEAR	TITLE
DoD	MIL-STD-1472D	1989	Human Engineering Design Criteria for Military Systems
DoD	DOD-HDBK-761A	1990	Human engineering Guideline for Management Information Systems
U.S. Air Force	ESD-TR-86-278	1986	Guidelines for Designing User-Interface Software (Smith and Mosier)
NASA	NASA-STD-3000	1987	Man-System Integration Standards
NASA	NASA-USE-HCIG-1000	1988	Space Station Freedom Human-Computer Interface Guidelines
HFS	ANSI-STD-HFS-100	1988	American National Standard for Human Factors Engineers of Visual Display Terminals Workstations
U.S. NRC	NUREG-0800	1984	Standard Review Plan
INEL	ISBN 0-12-283965-X	1989	User-Computer Interface in Process Control: A Human Factors Engineering Handbook

The primary source documents used for the NRC Guideline are indicated in Table 3.2.

While all of the documents are the products of U.S. Government-sponsored efforts, the last document listed is a published book (Gilmore et al., 1989). It was based in part upon work performed at the Idaho National Engineering Laboratory (INEL) for the NRC and reported in NUREG/CR-4227 (Gilmore, 1985). The work is significant because it (1) is specifically directed toward process control applications, (2) provides an excellent research basis for the guidelines presented, and (3) draws heavily from source material developed in the nuclear industry. It differs from the other documents in that it did not receive the extent of peer review received by the other documents. However, its positive features were considered significant enough to warrant its inclusion as a primary source.

Another slightly different document was the Space Station Freedom Guidelines. Since these guidelines were developed for the Space Station they were much more prescriptive than the other documents. This source was used, however, because it had an excellent research base and peer review. It also provided a number of new HCI guidelines. When used as a source for the NRC Guideline, these guidelines were modified to present a general principle rather than an equipment-specific requirement.

3.3 Organizational Structure

Before developing an organizational structure for the Guideline, the approaches used in other documents that provide advanced human factors guidelines were examined. The structure should remain fairly flexible at this point to allow for the diversity of technology implementations, the growth of emerging technology, and to provide for an expansion of document scope to other types of interfaces.

A computer-based document can provide the flexibility needed at this stage of the Guideline development.

The organizational structure of the primary source documents was reviewed. Typically these documents used a generic function-based approach, that is, the guidelines were organized by high-level functions the operator performs with the system, such as data entry, data display, dialogue, communication, and data protection. In addition, a section on integration of these functional elements is usually provided. Several of these documents address the human interface issues peculiar to computer systems. The more general documents, such as MIL-STD-1472D and NASA-STD-3000, also include guidelines for the hardware required to perform computer functions (e.g., keyboards, CRTs). NUREG-0700 follows a similar approach; the list of interface guidelines are organized into the following sections. Control Room Workspace, Communications, Annunciator Warning Systems, Controls, Visual Displays, Labels and Location Aids, Process Computers, Panel Layout, and Control-Display Integration.

The Guideline's organizational structure is similar to other documents that focus heavily on the human-computer interface. However, the organizational structure was influenced by the results of the scoping task which indicated major trends in the use of relatively "compact" computer-based workstations and intelligent operator aids. Thus, the proposed structure represents a blend of current guideline approaches and the anticipated needs of the NRC inspector or reviewer. The seven major sections of the draft document are presented in Table 3.3. Each of these is broken into several subsections. A more detailed breakdown of the sections is presented at the beginning of Volume II of this report.

Of the seven sections, the first six tend to be human-software/human-information oriented. The last section provides the majority of the guidelines pertaining to hardware and workplace layout. Note that no effort is being made in this project to incorporate guidelines for "traditional" technology (e.g., rotating knobs or sound-powered phones) already addressed by NUREG-0700, although there are plans to do so in the future since these will be needed to review advanced CRs.

Information Display

This section deals primarily with the formatting of visual displays, both text- and graphics-based. Guidance is provided in top-down fashion beginning with broad display design issues and then proceeding to finer levels of display details. The first four major sections include overall organization & layout, type of display, display elements, and finally coding. The fifth subsection pertains the display of safety critical parameters.

Screen organization guidelines include general organizing principles, establishment of functional areas on the display (e.g., command, message areas), methods of presenting information on multiple pages, techniques for grouping displayed items, and the use of "windows." Guidelines for types of displays address the use of various methods of presenting information such as by tables, lists, data forms, mimics, and graphics (including flow charts, graphics, map displays, diagrams, etc.).

Guidelines for display elements treat the appearance of the cursor and text characters, graphical and textual methods of data presentation, and the content and format of labels used in such presentations.

Table 3.3. Guideline Table of Contents

1.0 INFORMATION DISPLAY	1.1 Screen Organization and Layout 1.2 Types of Displays 1.3 Display Elements 1.4 Coding 1.5 Display of Safety Parameters
2.0 OPERATOR INPUT AND CONTROL	2.1 Entering Information 2.2 Operator Dialogue 2.3 Display Control 2.4 Information Manipulation 2.5 System Response Time
3.0 ALARMS	
4.0 OPERATOR AIDS	4.1 Routine System Messages and Guidance 4.2 Decision Aids
5.0 INTER-PERSONNEL COMMUNICATION	5.1 General 5.2 Preparing Messages 5.3 Addressing Messages 5.4 Initiating Transmission 5.5 Controlling Transmission 5.6 Receiving Messages
6.0 INFORMATION PROTECTION	6.1 General 6.2 User Identification 6.3 Data Access 6.4 Data Transmission
7.0 WORKSTATION DESIGN	7.1 Display Devices 7.2 Control and Input Devices 7.3 Control Room Configuration

Coding is used to distinguish among types of displayed data (e.g., normal/out-of-range, labels/values). Coding guidelines consider text codes and methods of highlighting text displays, generally applicable codes based on visual attributes (e.g., brightness, color, size, shape, etc.), and auditory codes. The guidance centers on the consistent application of codes, and the appropriateness of their use in connection with various types of tasks.

Operator Input and Control

This section addresses entering information, operator dialogue, display control, information manipulation, and system response time. Thus, considerations of display-control integration are included here.

Information entry comprises any circumstance in which the operator provides data to a computer-based system. Modes of information input considered include text entry, tabular and form entry, graphical entry, and entry via speech.

Operator dialogue refers to the issuing of sequence control commands to the system. Sequence control refers to operator inputs that initiate or interrupt transactions (i.e., functions of the system). The specific means by which such command inputs are made is the transaction dialogue. The types of dialogue considered are: command language, direct manipulation, menu selection, form-filling, function keys, query language, question and answer, and constrained natural language.

Command Language - A command language dialogue requires the operator to specify the functions to be performed without prompting; the operator is assumed to be aware of the available options, the proper command syntax, etc.). A command language dialogue is appropriate when a great deal of flexibility is required regarding the sequencing and content of operator inputs, and the operator is very familiar with the system.

Direct Manipulation - A direct manipulation or graphic user interface (GUI) typically displays pictographic icons to represent control actions and options; actions and options not easily represented in pictographic form are presented in menus. Icons or menu items are "selected" by positioning a cursor, usually by means of a pointing device (i.e., a mouse or trackball). GUIs often present different modes of interaction or types of information in separate, selectable "windows" on the display.

Menu Selection - A menu selection dialogue presents the operator with a number of options from which the desired action is chosen any of a variety of means (e.g., positioning of the cursor, entering a keystroke code, etc.). This style of dialogue is appropriate when the number of options is limited and speed and accuracy are critical.

Form-Filling - A form-filling dialogue requires the operator to enter data in predefined fields presented on the display. This style of interaction is, therefore, appropriate to situations in which the categories of data to be input can be specified, but flexibility is required with respect to the data to be input. It is the obvious choice for entry of into a computer system of information that already exists on hardcopy forms.

Function Keys - Function keys are dedicated to a single option or action and are therefore best used to in order to select from among a small number of frequently-used options that are available at any point in the operator/system interaction (i.e., functions that are available only in certain modes of system operation are typically not assigned to function keys).

Query Language - Query language is a specialized type of command language used to retrieve information from a system.

Question and Answer - In a question and answer dialogue, the system poses questions for the operator to answer. This style of interaction is appropriate when the types of information to be input are specified, and the order in which the data are to be input is predefined.

Constrained Natural Language - A natural language interface allows instructions or requests to be entered using "everyday" vocabulary with few requirements as to syntax.

A well-designed operator dialogue will allow operators to interact with the system without imposing unnecessary constraints on the selection or sequencing of actions, and move efficiently from one task to the next.

Display Control guidelines comprise a variety of display interactions and modes (e.g., selection, freezing, updating, paging, scrolling). The objective of the design of display control functions is to allow the operator to access the specific information required for the task at hand while maintaining awareness of the ongoing process and the display/control context.

System Response Time address the necessity of the system to respond promptly to operator input. Guidelines address the speed the systems's response to user inputs of various kinds, and control by the operator of the display of information.

Alarms

Alarms have historically been problematic in NPP CRs. Recent advanced technology-based efforts to improve alarms have not been completely successful (see O'Hara et al., 1991), thus, the NRC has specifically identified alarms (annunciators) as a generic issue and initiated research to develop review guidance in the area of advanced alarm systems (FIN A-3967). This section is essentially a place holder for the results of the NRC project identified above.

Operator Aids

Areas covered by guidelines in this section are prompts (including routine messages), operator guidance (feedback and on-line help), and decision aids (i.e., expert systems). Well-designed prompts indicate not only that input is expected, but also the proper format and means of performing the entry. Useful error messages clearly convey the nature of the problem and facilitate its correction. The overall goal of prompting and user guidance is to ensure that operators, at any point in the interaction, are aware of what type of action is appropriate, what their options are, how they should proceed, and how they can request help.

Inter-Personnel Communication

This section contains guidelines for activities related to computer-mediated communication among the plant personnel, e.g., preparing, addressing, transmitting and receiving messages. Many of the guidelines are concerned with minimizing the demands placed on the operators of the system while providing them with considerable flexibility in communications. It is especially important in the context of a CR that inter-operator communication functions be well-integrated into the larger computer-based control system, e.g., operators should not feel that communications require an interruption their ongoing tasks, the use of a unique command set or mode of interaction, recall of special syntax and addresses, etc.

Information Protection

This section contains guidelines pertaining to methods for ensuring the integrity of data used by the system. Guidance covers prevention of inadvertent change or deletion of data, minimization of data loss due to computer failure, and protection of data such as setpoints from unauthorized access. Measures taken to protect data will usually involve trade-offs between security and ease-of-use. The inconvenience introduced by the necessity to, e.g., verify potentially destructive actions, should be appropriate to the costs of such actions.

Workstation Design

This section is hardware-oriented and organized in bottom-up fashion beginning with guidelines on individual display and control devices, then continuing with the organization of those devices within an individual workstation, then finally treating the overall organization of the entire CR. The section contains many "placeholders," since guidelines do not currently exist for many aspects of advanced technology hardware to be used in advanced CRs (such as flat panel displays). The guidelines pertain to the design of display and control devices typically associated with human-computer interfaces: video display terminals, audio & voice displays, projection devices, printers, keyboards, and direct manipulation controls. More general considerations related to the design of the CR (i.e., equipment dimensions and anthropometrics, CR environment, etc.) are treated in NUREG-0700.

3.4 Guideline Tiers

Within each section of the Guideline, individual guidelines are arranged into three tiers. Tiering was accomplished to aid reviewers in performing more efficient, less time consuming evaluations. However, the current tiering is considered very preliminary and will be subject to further evaluation. The tiering is defined below followed by an explanation of how it might be used in the review process.

The first tier contains guidelines that address the appropriate use (or contraindication) of a particular technology, equipment, methodology, or approach. These are called the "appropriate use guidelines." Not every section in the Guideline contains Tier 1 guidelines. The remainder of the guidelines were divided in two tiers of importance with respect to design review. Tier 2, called "leading indicator guidelines," contains guidelines that are more general, directly observable to a reviewer (without special equipment), and considered more significant in terms of their potential effect on operating crew performance than the Tier 3 guidelines. Tier 2 contains guidelines that (1) represent technology specific applications of the meta guidelines or (2) were not clearly tied to a meta guideline but were judged by the project staff as important. Tier 3 guidelines, called "detailed guidelines", were considered slightly less important than the Tier 2 guidelines and often represented finer levels of detail of more general Tier 2 guidelines.

The logic of using the tiers as part of a design review is illustrated in Figure 3.2. Essentially the reviewer first evaluates the design feature for its acceptability with respect to Tier 1 - Appropriate Use. If the reviewer concludes that the design represents an inappropriate use of the design feature, then the evaluation of that particular feature is terminated. The rationale is that if a design feature is inappropriately applied, there is no purpose to evaluating the further specifics of the design. For example, if a table display format is used to show the trend relationship of two contiguous variables, the reviewer would find the display rejected on Tier 1 (due to an appropriate use of table displays). There is no need for the reviewer to establish whether it is a good or bad tabular display design.

If the display is acceptable at Tier 1, then the reviewer evaluates the design feature for Tier 2 guidelines. If the feature "passes" the Tier 2 guidelines, then the evaluation of the specific feature is terminated with an acceptable evaluation. Since Tier 2 are the more important guidelines, no further review at Tier 3 would be made. By similar logic, if the design feature "fails" the Tier 2 guidelines, no further evaluation need be made at Tier 3 unless the reviewer wishes to more specifically pinpoint the deficiencies. If the results at Tier 2 are equivocal, then the Tier 3 guidelines would be used to determine the ultimate acceptability of the design feature.

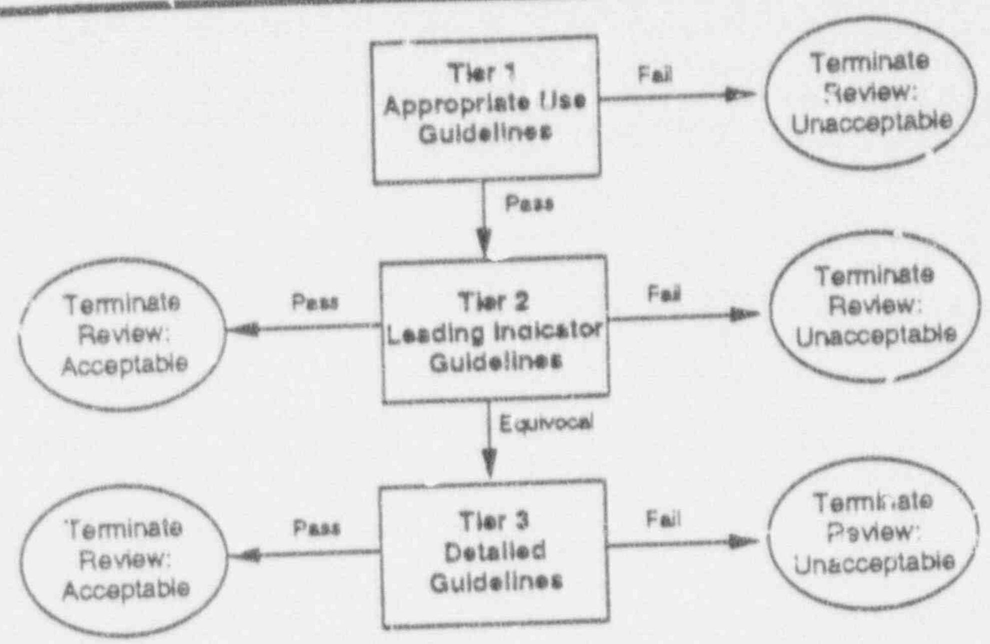

Figure 3.2 Proposed Review Strategy Using Guideline Tiers

As indicated above, the tiering of guidelines is considered experimental at this time pending further evaluation.

3.5 Individual Guideline Formulation

The individual guidelines from the primary source documents were sorted into the Guideline's organizational structure. This process was not straightforward since the documents were all organized differently, used dissimilar terminology to address the same topics, were syntactically different, and were developed to provide design guidance and not review guidance.

There was considerable overlap in the guidelines recommended across the primary source documents. Thus, the guidelines were edited to combine similar guidelines into a single guideline. Where compound guidelines were encountered (several guidelines combined into a single statement), an effort was made to break the compound guideline into several logical units and represent the units as separate guidelines. The goal was to make each individual guideline a clear and distinct thought, and thus easier for a reviewer to use. Information as to the primary source document from which each guideline was derived was recorded. Occasionally primary source documents differed as to the guidance recommended. Conflict resolution was handled case-by-case. Typically, the document prioritization system was used to resolve any conflicts which existed between guidelines. In those instances where conflicts existed between guidelines of the same priority, then the more conservative guideline was used.

The guidelines were developed into a standardized format (see Table 3.4) containing: number, tier, title, guideline, additional information, assessment method, and source. A unique identification number was assigned to each guideline. The number reflects the position of the guideline in the hierarchical structure of the overall document. The tier indicates which of three tiers the guideline belongs to. Each guideline carries a brief title that indicates the subject of the guidance. The guideline itself states the criteria in narrative form. Many of the guidelines have additional information which may contain clarifications, examples, exceptions, details regarding measurement, etc. One or more assessment methods have been tentatively designated for each guideline. The specification of assessment method allows the reviewer to anticipate the information sources that will be needed to perform a given evaluation. The source of each guideline is indicated, i.e.,the primary source documents from which the guideline was adapted.

As discussed in Section 2, there is great diversity in the available HSI designs and dialogue modes in advanced systems. There is also diversity in the types of tasks operators may be called upon to perform and in the ways those tasks can be performed in advanced reactor designs. Thus, it was deemed premature at this time to screen out guidelines as inappropriate based upon a top-down assessment of operator tasks in advanced plants. The present version of the Guideline contains a broader diversity of HCI guidelines than might be expected in a NPP review guideline. For example, it contains guidelines for text processing, although it may seem unlikely that text processing tasks would be a significant operator activity in ACRs. However, these guidelines were kept in the Guideline to provide a basis for review of a particular application utilizing this type of operator activity. One of the values of an interactive document is that guidelines which are inappropriate to a particular design review need not be displayed to the reviewer. Thus, the guidelines are available when needed but need not get in the way when not needed.

At present, there are approximately 1,700 individual guidelines included in the seven sections defined above.

4. INTERACTIVE COMPUTER-BASED GUIDELINE DEVELOPMENT

The purpose of this section is to provide a description of the interactive, computer-based version of the Guideline. The following sections describe the rationale (Section 4.1), requirements analysis (Section 4.2), selection of hardware and software for prototyping (Section 4.3), development of the guidelines databases (Section 4.4), description of functions and utilities (Section 4.5), and description of user interfaces (Section 4.6).

4.1 Rationale

In addition to a hard copy of the Guideline, the guidelines have been developed in an electronic format. Several issues led to the decision to provide the guidelines in an interactive format. One of the issues that reviewers face in the evaluation of HSI incorporating advanced technology is the tremendous diversity in the technology that needs to be reviewed. This situation gives rise to a corresponding increase in the number of guidelines that must be available to the reviewer, even though only a small number may apply to a specific review. An interactive, computer-based document can provide improved access to the guidelines and can provide user aids for the compilation of guidelines needed for a specific review. Another issue is updating the guidelines to keep them current as the knowledge-base improves and technology changes. There is a need to enable frequent modifications and timely updates to the Guideline. A computer-based document can facilitate this task. For these reasons there is a trend in the human factors community to make HFE guidelines available in computer-based form. The U.S. Military's primary human factors guideline (MIL-STD-1472D) and Smith and Mosier's human-software interface guidelines (1986), for example, are available in hypertext-type databases and NASA's Man-System Integration Standard (NASA-STD-3000) is available in a relational database. The USAF has a program (CASHE) to provide the human engineering compendium and HSI guidelines in computer-based form. The computerization of the guidelines provides the flexibility required to review advanced HSIs and to update and improve the document.

An interactive version of the Guideline was developed to facilitate the following activities:

- guideline access and review,
- compilation/reorganization of individual guidelines to identify a subset of guidelines for a specific review,
- guideline editing,
- the incorporation of new guidelines as they become available, and
- to serve as a report preparation and review audit trail aid to a reviewer conducting human factors audits of advanced CR technology.

4.2 Requirements Analysis

An analysis of the inspection task and the variety of ways the document would be used was performed to identify initial interactive document requirements. They were organized into four categories: review and inspection task requirements, general usability requirements, electronic document functionality requirements, and general hardware requirements to support prototype development of the system. Each is summarized below. It should be noted that not all of these requirements are not met in current version of the Guideline. The requirements are being evaluated and modified as a result of the test and evaluation program described in the next section.

4.2.1 Review and Inspection Task Requirements

Based upon an analysis of an NRC reviewer's activities, the following requirements were identified.

- *Support All Review Elements* - as identified in Section 2.

- *Support All Inspection Phases* - document should support all phases of the inspection including:

  - Preparation (such as, review general details of the plant; obtain and review specific information on the human-system interfaces, procedures etc.; record of earlier evaluations; activity preparation; customize guidelines so that reviewers can prepare a customized subset of guidelines in advance of an audit which is tailored to the specific inspection to be performed).

  - On-Site Inspection (such as, interview support; review of plant documentation; equipment inventory; comparison of interfaces with guidelines; issue identification, etc.).

  - Report Writing and Issuance (such as, documentation of all areas reviewed, persons contacted, specific findings,etc.; organization of information into canned formats).

- *Support several "Document Utilization Modes"* - such as:

  - Emulate Guideline Document - The capability to provide a high fidelity emulation of the hardcopy document, including navigation aids (i.e., table of contents and index), glossary, and standard page layout (user sees "raw document" which is essentially the same as the hard copy version - to facilitate user familiarity with the document's content).

  - Perform Review - User sees only those aspects of the document needed for the various phases of review, but can easily access others; the ability to proceed through guidelines without secondary data such as Comment, Source, and Classification fields. These should be accessible through "push buttons" or menu options.

  - Edit Guidelines - For document updating, possibly not available to all users so that the document's content can be controlled.

- *"Organization-by-system" support* - A reviewer can enter a menu that provides a listing by NPP system such as SPDS. Selection of a system option automatically compiles all appropriate guidelines. This capability may require an additional feature which would present a list of questions to better define the appropriate guidelines once a system is selected.

4.2.2 Usability Requirements

Several high-level usability requirements have been identified for the interactive document which were essentially derived from the types of high-level guidance discussed in Section 3, i.e., the design should be representative of the guidelines contained in the database. The interface must satisfy several requirements:

- *Fast Learning* - The design of the interface must minimize the time it takes the evaluators to learn to use it.

- *Efficient performance* - The interface must maximize the efficiency with which different evaluators with a wide range of computer experience will be able to use the document.

- *Minimize user errors* - The interface must be designed to minimize the number of possible errors the evaluators might make.

- *Easy learning and retention* - Since the document will be used on an intermittent basis, its design must be conducive to remembering how to interact with it over time.

- *Minimal memory load* - The electronic version of the Guideline should be designed to minimize requirements for the user to memorize commands, modes, key sequences or other actions not inherent in the inspection process.

- *Minimal User Input* - In order to reduce the opportunity for operator error, the electronic version of the Guideline should permit the user to access the guidelines with a minimum of user input, such as typing. This can be accomplished with pull down menus of keywords, "point and click" access to table of contents and glossary, and "point and click" search term entry.

- *On-line help* - The document should have an on-line help system to provide guidance to users on how to use the system. The on-line help should be accessible from anywhere within the document and should have some measure of context sensitivity.

- *Meaningful error feedback* - The electronic version of the Guideline should provide meaningful feedback to the user in the event of a user error. This feedback should include a description of the error and the user action required to correct the error.

- *High user satisfaction* - Finally, the design should be one which maximizes the user's subjective evaluation of the interface.

4.2.3 Electronic Document Functional Requirements

The following functions were deemed highly desirable based upon a consideration of the ways in which the document will be used:

- *Graphics support* - The capability to display graphic images (e.g., figures, illustrations).

- *Automatic "goto"* - For cross-referenced, indexed, and table of contents materials activated upon user request.

- *Rapid search initiation* - The ability to "point and click" at a word in the document to designate it as the current search term, and initiate a search for the first instance of that term in the document. This minimizes the amount of typing the user will have to do in order to access the guidelines.

- *Restricted field search* - Enables the user to search for words that are restricted to a single field. For example, the user request that the system search for the term "vision" only in the "Sub-area" field.

- *Exact and approximate word search* - The capability to select whether the system will search for a sequence of words that must be an exact or approximate match. For example, in an exact match, if the user entered "display" as the search term, "displays," "displayed," and "displaying" would not be returned. These terms, however, would all be considered "hits" for an approximate match.

- *Keyword list* - A given keyword list with the capability for the user to develop, access and modify an individualized keyword list for his/her own use for frequently used terms and phrases.

- *Browse* - A mechanism to allow the user to "page through" the document by sequentially accessing other related guidelines based on user-specified terms and phrases.

- *Location landmarks* - Running heads on each "page" to identify guideline content areas, i.e., Section: Information Display, Sub-section: Information Format, Area: Graphics, and Sub-area: Flowcharts.

- *Placemarker* - A "book mark" type feature to allow the user to "mark" one or more guidelines for future access.

- *Evaluation function* - On screen recording of whether the item under evaluation passes, fails or is not applicable (N/A) to the current guideline.

- *Note taking* - The capability for the user to append his/her own comments to individual guidelines.

4.2.4 Hardware Requirements

One of the most important characteristics of the electronic version of the Guideline is that it be portable. This feature is necessary to support on-site use of the guidelines by NRC personnel. The principal attributes of the machine which contribute to its portability are capacity requirements, weight, size, design and battery life (i.e., operating time between recharges). In addition, the human factors characteristics of screen design and input devices were considered.

- *Capacity* - The total estimated baseline storage requirement for the electronic version of the Guideline is approximately eight megabytes: the guidelines will require approximately 4000 kilobytes (k) of storage, files developed in course of an on-site inspection will require approximately 200k of storage; users will require access to other basic productivity packages, such as word processing, spell checking and graphics. These packages will require an additional 2000k of storage space; the operating system, and its resources will require a minimum of 500k of storage; users will require an additional 1000k of storage for miscellaneous files (e.g., copies of previous inspection reports, project-related memos, inspection plans, etc.).

- *Weight* - In terms of weight, there is an inherent tradeoff between functionality and absolute weight. For the electronic version of the Guideline, it was assumed that the minimum configuration acceptable would include a hard disk. The assumption is based on the expectations concerning storage capacity which cannot be reasonably handled using standard floppy disks. In addition to storage requirements, a hard disk is required to facilitate frequent, formalized backing up of project files. Pending further testing, it was determined that any computers in the portable and lap-top categories would have acceptable weight.

- *Size* - The primary consideration for size is the area required to place and operate the system. In addition to the machine's footprint (i.e., the number of square inches of work surface required by the machine's case), the size of any additional input devices (e.g., mouse, track ball) must be considered. Pending further evaluation, it was determined that any computers in the portable and lap-top categories would have acceptable size.

- *Design* - Portability requires design characteristics which allow the computer to be easily transported and used. These factors include consideration of the presence, location, and design of handles and grab points; ease of set up/take down; hard disk stability (e.g., autoparking heads); case design for durability; and screen adjustability for different viewing angles. All must be acceptable for the interactive document.

- *Battery life* - Since the electronic version of the Guideline may be used throughout the plant, it cannot rely on alternating current (AC). In some cases, AC power will not be available. Under other circumstances, laying a power cord across a work area would create unacceptable personnel trip hazards. The primary concern for battery life is the number of operating hours between recharges. It is estimated that the computer must be capable of battery powered operation for half a work day before re-charging.

- *Display Screen* - The reviewer will be using the device considerably while performing the inspection and the system must be capable of displaying at least the types of graphics included in the document and must be capable of viewing in non-optimal lighting conditions.

- *Input Devices* - A keyboard and some type of direct manipulation device (e.g., mouse, trackball, etc.) will be required. The design of the input devices must support prolonged user input and meet the human factors guidelines for the selected input device design.

4.3 Hardware and Software Selection for Prototyping

The initial requirements analysis provided a basis for selection of hardware and software for guideline document prototyping. However, before a final decision on hardware and software is made, the document will be further developed and tested to better define the basic requirements.

For the near-term purposes of mocking-up and evaluating a prototype of the interactive document Apple MacIntosh™ computer has been selected and the guidelines database implemented in HyperCard™ software.

HyperCard satisfies the functional requirements of the Guideline very well. It has the capability to display text in multiple, scrolling fields which can be simultaneously displayed on the screen. This provides users with a high degree of control over the access to, manipulation of, and display of information. HyperCard also has the facility to implement such features as, "bookmarks" and an embedded notebook. It supports note links, whereby the user can access notes pertaining to a specific topic or field. Graphics support is included whereby nontextual, bit-mapped images can be displayed in association with the text. In addition, HyperCard offers a powerful help facility, allowing users to seek context sensitive help such as clarification on a document navigation problem, or more detailed information pertaining to a specific area or field of the Guideline.

Among the program's most positive features are adaptability and extendibility. HyperCard contains its own object-oriented programming language, "HyperTalk," which permits the developer to have essentially total control over the "look and feel" of the user interface and the ability to rapidly prototype user interfaces. This capability allows developers to design and demonstrate user interface concepts, present the concepts to potential users and then incorporate user comments into the final design. This will permit developers to work with users during the development of the document to ensure that the final design is acceptable.

4.4 Guideline Database Description

The guidelines are stored in a HyperCard (Version 2.1) database file (called a "stack"). Each guideline is represented as a single record (called a "card") and includes 13 fields (called "containers").

1. *Section Field* - The Section Field (e.g., Section 1. Information Display) contains the numeric sequence number and title for the Guideline Section of the current Guideline.

2. *Sub-Section Field* - The Sub-Section Field (e.g., 1.1 Screen Organization and Layout) contains the numeric sequence number and title for the Guideline Sub-Section of the current Guideline.

3. *"Area" Field* - The Area Field (e.g., 1.1.4 Windows) contains the numeric sequence number and title for the Guideline Area of the current Guideline.

4. *"Sub-Area" Field* - The Sub-Area Field (e.g., 1.1.4.2 Display of Windows) contains the numeric sequence number and title for the Guideline Sub-Area of the current Guideline. Not all Guidelines contain a Sub-Area.

5. *"Guideline Name" Field* - The Guideline Name Field contains the numeric sequence number and title of the current Guideline (e.g., 1.1.1-3 Reserved Screen Areas).

6. *"Guideline" Field* - The Guideline Field contains the text of the current Guideline.

7. *"Additional Information" Field* - The Comments Field contains additional information needed to interpret or apply the current Guideline. Not all Guidelines contain information in the Comments field.

8. *"Method" Field* - The Method Field contains a code for the tentatively recommended method(s) for assessing the current guideline: Observation, Interview, Measurement, Documentation Review, Procedure/Operational Review.

9. *"Guideline Tier" Field* - The Guideline Tier Field indicates whether the current Guideline represents a tier 1, 2, or 3 guideline.

10. *"Source" Field* - The Source Field contains the primary source document from which the guideline was developed.

11. *"Comment" Field* - The Comment Field is initially blank and provides a place for the reviewer to enter information related to their evaluation of the current guideline.

12. *"Meta Guideline Classification" Field* - The Meta Guideline Classification indicates which meta-guideline category the guideline belongs to, if any.

13. *"Search Term" Field* - The Search Term Field stores terms to be searched for. New terms can be identified and stored in this field. The functioning of the search feature is described in Section 4.4.

Each field is limited to 30,000 characters. Thus, for the Guideline application, there is no practical limitation on the amount of information that can be stored or the amount of review-specific user notes (remarks) that can be included.

4.5 Functions and User Interfaces

4.5.1 General

This section provides a description of how the interactive document's databases are presented to the user reviewer and the functions that are available. The present state of the interface can be characterized as a mixture of shells (capabilities or functions which are displayed on the screen but are not yet implemented) which anticipate future revisions and active functioning elements. The description provided below will clarify the differences.

Upon startup of the Guideline, an initialization screen is displayed and user identification (password) is requested before further access is granted (see Figure 4.1). (Since this section references many figures, the figures have been located at the end of the section.) The password feature is not enabled at the present time. (In order to proceed, the user clicks on "Enter Password" to open a dialogue box and click "OK.") Once access to the Guideline is obtained, the next screen provides the "launch points" for document utilization (see Figure 4.2). The screen displays seven buttons: **Tutorial, Help, Administration, Program Planning, Studies and Analyses, HFE Review,** and **Performance Evaluation**. The first three buttons will provide reviewer assistance but not currently implemented. The four remaining buttons provide access to the guidelines contained in the four review modules (of which **HFE Review** is the only fully operational button).

When a mouse button is depressed, menus appear for selection of the guideline module, e.g., "studies and analyses." If "Human Factors Engineering (HFE)" Review guidelines are desired, the cursor is positioned on that title and the mouse button is activated, bringing the reviewer to the Guidelines review screen.

Figure 4.1. Initialization Guideline Screen

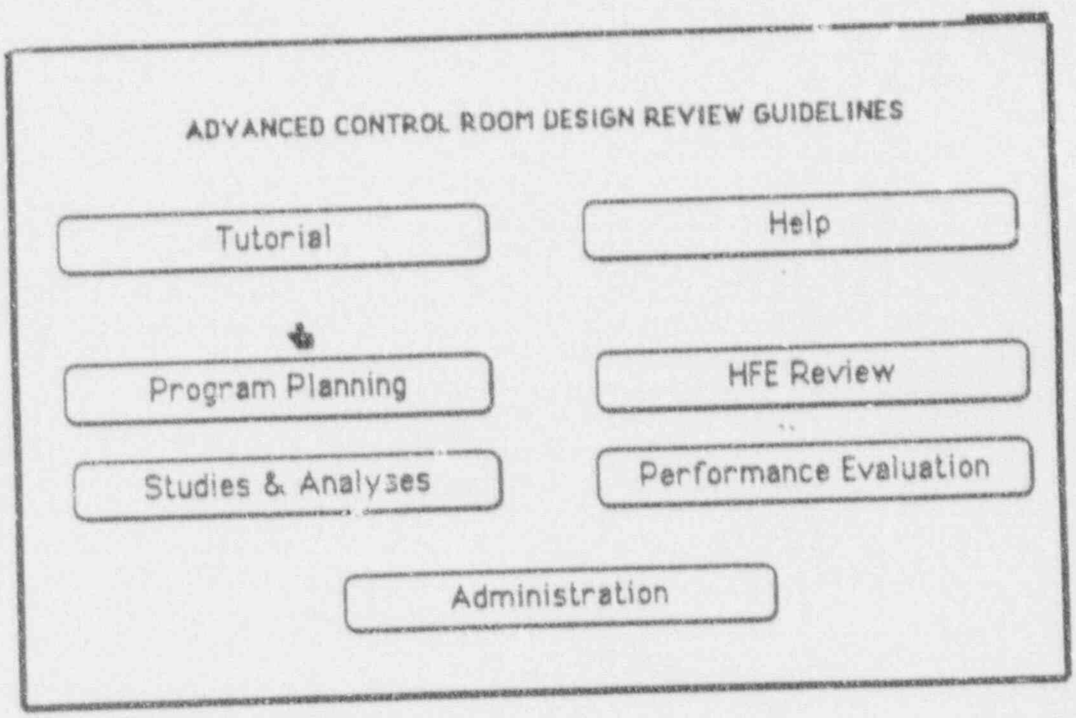

Figure 4.2. Function Selection Screen

The general design of the guideline review screen is shown in Figure 4.3. The screen is divided into two sections: the upper section displays the guidelines and related information, and the lower section provides reviewer support functions. The upper section contains two areas. The guidelines area (at the left of the screen) displays the hierarchical context of the guideline, the guideline title, and the text of the guideline. The additional information area (at the right of the screen) contains a window which provides further information, clarification, or examples related to the guideline. Below this window are three buttons. The **Source** and **Method** buttons, when activated, cause the display of the name of the source document for the guideline and the preferred method of evaluation, respectively. The **Show Figure** button will display the figure, table, or graphic, if any, associated with the guideline. (Currently, only tables are referred to by the guidelines).

The reviewer support section (the lower part of the screen) is divided into three zones: guideline evaluation, navigation, and document support. The guideline evaluation zone contains the evaluation buttons and the reviewer's comments window. The navigation zone contains buttons for moving around in the Guideline document. The document support zone (located across the bottom of the screen) contains buttons that invoke functions frequently used during a review **Table of Contents**, **Glossary**, and **Index**. The **Toggle Functions** button causes the document support zone functions to alternate between those functions just mentioned (the default) and other, less frequently used functions - **Clear All Evaluations**, **Search**, and **Report** (see Figure 4.4). The use of the reviewer support functions is described below.

At the lower right corner of the screen are the **Help** and **Quit** buttons. When the **Help** button is selected, the user can point to any field and click, and the permissible operations from the field are displayed. Pressing the **Quit** button exits the guidelines.

4.5.2 Navigation Functions.

The **Next GL** (or **Prev GL**) buttons cause the next guideline (or previous guideline) in the current section to be displayed. If the **Next GL** button is activated while the last guideline in the section is being displayed, a beep will sound to alert the user and the first guideline in the next section of the document will be displayed. If the **Prev GL** button is activated while the first guideline in the section is being displayed, and a beep will sound.

The **Top of Section** button causes the first guideline of the current section to be displayed. The **Next Section** button causes the first guideline of the section following the current section to be displayed. The **Backup** button retraces the reviewer's path through the guidelines. Note that this is different from **Prev GL**, which backs through the guidelines in the order in which they appear in the document (e.g., from 5 to 4 to 3 to 2, etc.).

Navigation functions can also be executed from the keyboard. Keyboard input options have been implemented for navigation functions. Commands can be made whether the keyboard has function keys or not. Table 4.1 provides a summary of keyboard navigation options.

4.5.3 Evaluation Functions

The evaluation buttons allow reviewers to record their assessments of whether the system being reviewed conforms to the intent of the guideline (**Pass**) or not (**Fail**), or whether the guidance is not applicable (N/A) to the system. The **Return** button allow reviewers to record that a guideline was applicable but that insufficient information was available at the time to make an evaluation.

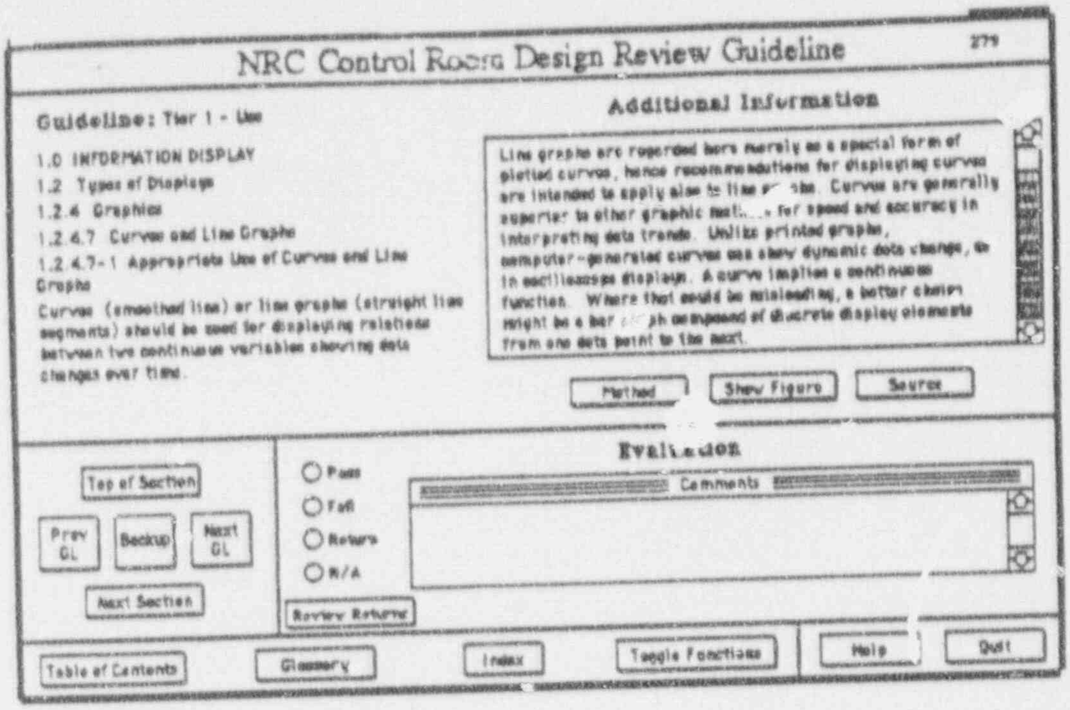

Figure 4.3 General Guideline Presentation and Review Screen

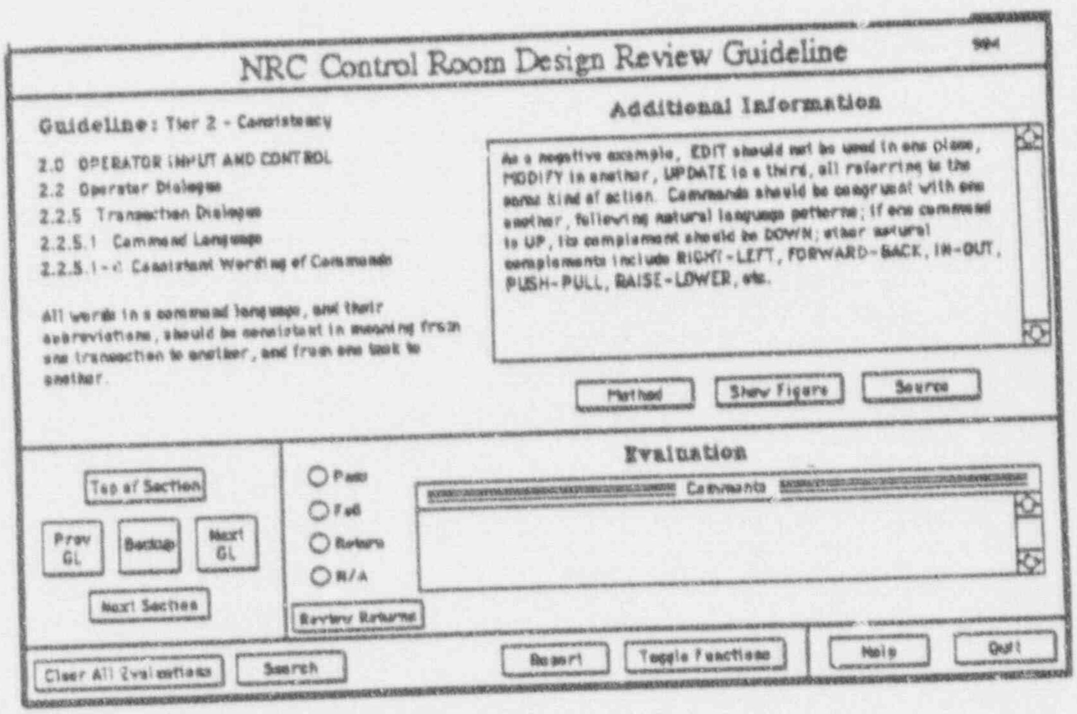

Figure 4.4. General Guideline Presentation and Review Screen with Alternate Functions Displayed

Table 4.1. Keyboard Options for Selected Navigation and Evaluation Functions

FUNCTION	Function Keys	No Function Keys
	TYPE OF KEYBOARD	
Pass	F1	Option-1
Fail	F2	Option-2
Return	F3	Option-3
N/A	F4	Option-4
Next GL	F5	Option-5 or Right Arrow
Prev GL	F6	Option-6 or Left Arrow
Top of Section	F7	Option-7 or Up Arrow
Next Section	F8	Option-8 or Down Arrow

When the **Return** button is selected, a window appears that allows the reviewer to indicate the reason for returning to the guideline by choosing from a pre-defined list (see Figure 4.5). Guidelines recorded as "Return" can be reviewed by using the **Review Returns** button. The reviewer selects the category of "return" items to be reviewed; the **Next** button is used to move through the selected items. The Next button appears on the screen (next to the **Review Returns** button) only when returns are being reviewed.

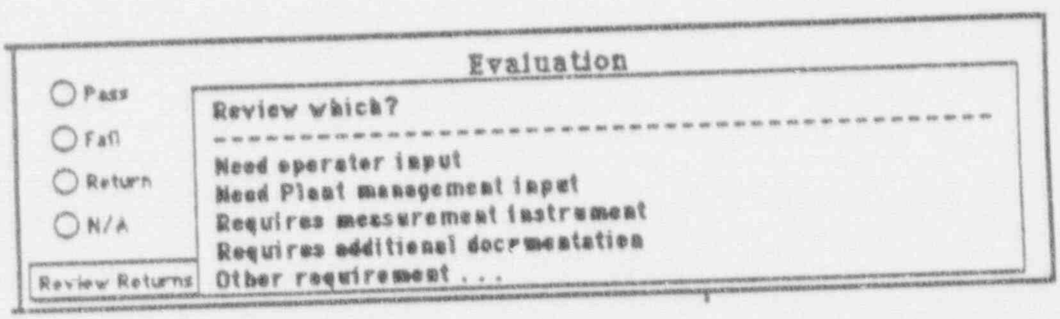

Figure 4.5. Review Return Evaluation Options

As with navigation functions, evaluation functions can also be executed from the keyboard. The keyboard evaluations can be made whether the keyboard has function keys or not. Table 4.1 provides a summary of keyboard evaluation options.

An individual evaluation can be changed by selecting another evaluation option of by selecting the same option again. Selection an option over and over toggles it on and off. A reviewer's comments can be edited by placing the cursor in the Comments Window and using standard Macintosh text editing commands.

4.5.4 Document Support Functions

Primary Document Support Functions. When the **Table of Contents** button is pressed, pop-up scrollable windows open on the screen (see Figure 4.6a). Selection of a section, subsection, area, or subarea brings the reviewer to the first guideline in the selected topic. Pressing the **Index** button causes the Context Index screen to be displayed. When a word in the index is selected, all occurrences of that word in guideline titles or text are displayed in a scrollable window. The index is essentially a "Key Word in Context" (KWIC) display. Each line in the window displays the selected word in the center and the surrounding text (before and after the selected word) as it appears in the displayed section of the guidelines (see Figure 4.6b). Clicking on the desired text transfers the reviewer directly to the guideline form which the selected text came.

A generic HFE glossary is accessible by pushing the **Glossary** button. The glossary appears in a scrollable window in alphabetical order (see Figure 4.7). If a word is typed in the Glossary's "find" function, its definitions are displayed. If a letter is typed, the display moves to the first instance of words beginning with that letter. If the desired word is displayed in the window, double clicking on it with the mouse displays the definition. The glossary is not yet specifically tailored to the Guideline. Definitions can be saved by pushing the **Add to Holder** button, and then the **Save** button. The definition can also be printed by pushing the button labeled **Print**.

Secondary Document Support Functions. Searching the guidelines for a given term may be accomplished in three ways. Pressing the **Search** button causes a dialogue box to be displayed that allows the reviewer to enter the search term. Upon pressing the **OK** button, a field-independent search for the term is initiated (see Figure 4.8). Clicking on the current search term (shown to the right of the Search button) also initiates a field-independent search. Clicking in a specific field while holding down the Shift key limits the search to the selected field. All searches proceed from the current guideline forward through the document. The search will continue forward past the last guideline in the document and continue through the beginning (like searching through a circular card file).

The **Clear All Evaluations** button causes all reviewer's evaluations and comments to be removed. The reviewer is asked three times if they are sure they want to clear all evaluation.

When **Report** is selected, the report specification screen is presented (see Figure 4.9). The screen displays the number of guidelines passed, failed, designated not applicable, or marked for later review. The reviewer may chose to include any or all of these evaluation categories in the summary. Pressing the **Build Summary** button causes the specified summary to be generated and the summary report screen to be displayed (see Figure 4.10). The report can include all or as few as one guideline. The guidelines included in the summary appear in a window. The content of the summary can be viewed by using the navigation buttons (**Page Up, Page Down, Top, Bottom**) at the lower right of the screen. From this screen it is also possible to print the summary to a text file (by pressing **Export Summary**), send the summary to a printer (**Print Summary**), or return to the **Report Specification** screen.

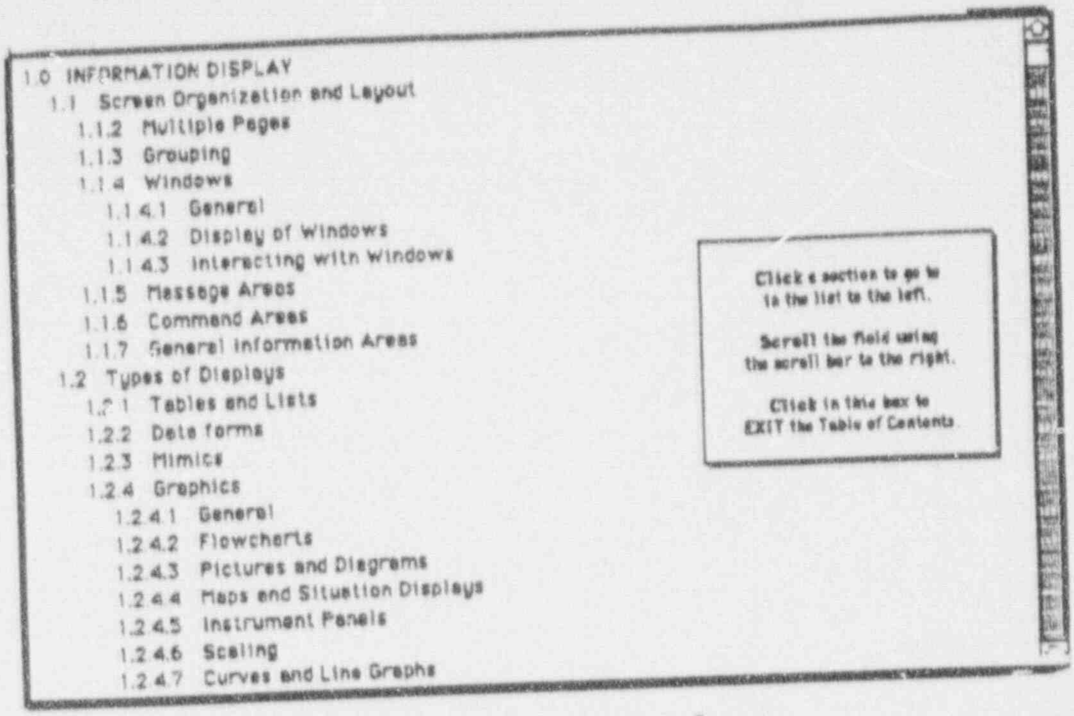

Figure 4.6a. Table of Contents Screen

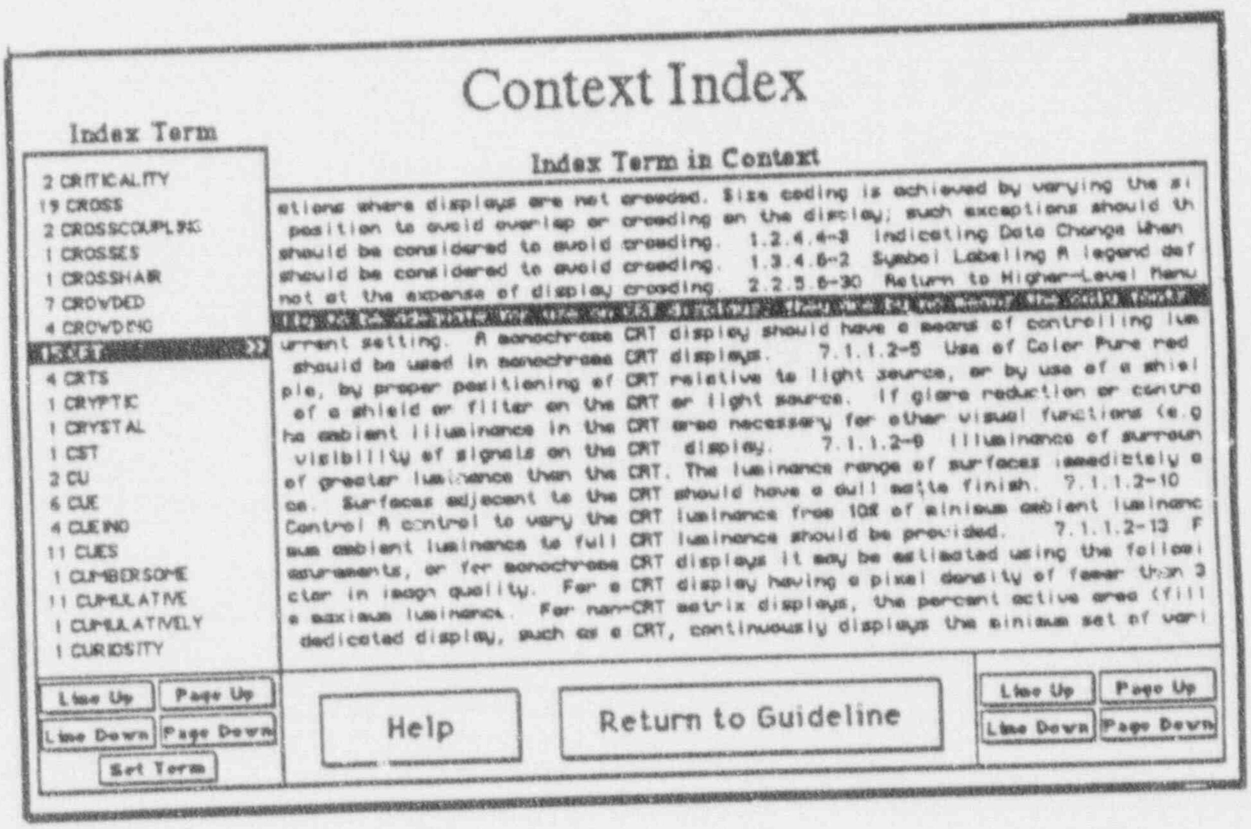

Figure 4.6b. Context Index Screen

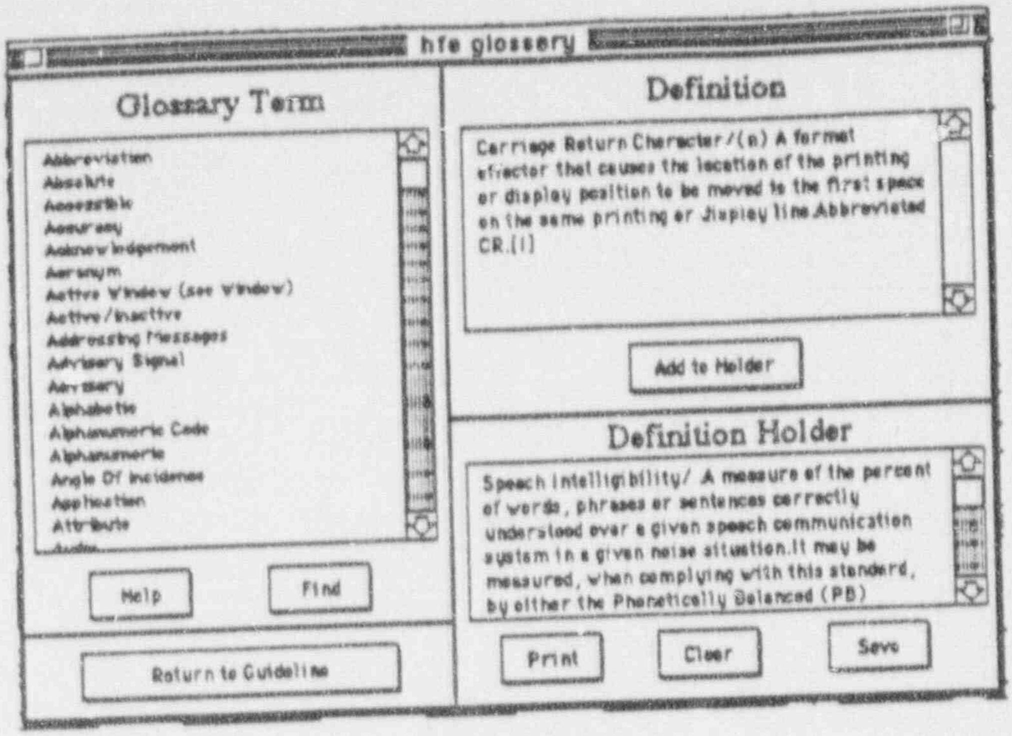

Figure 4.7. Glossary Screen

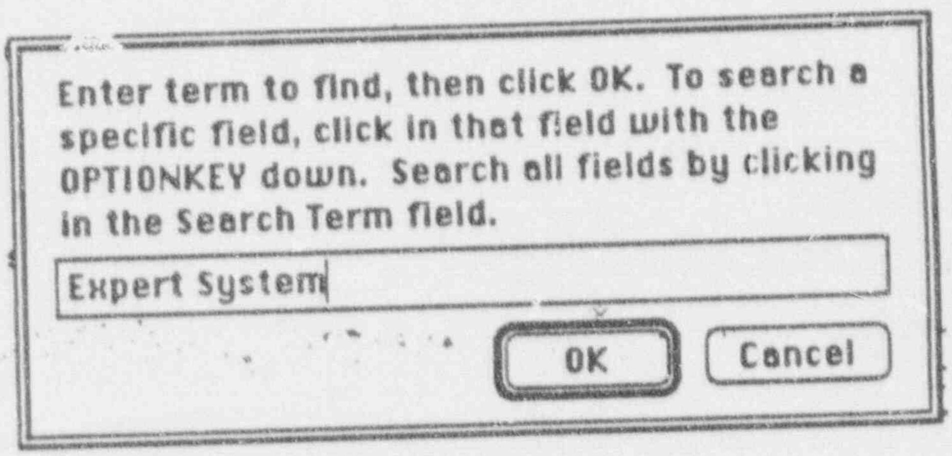

Figure 4.8. Search Function Dialog Box

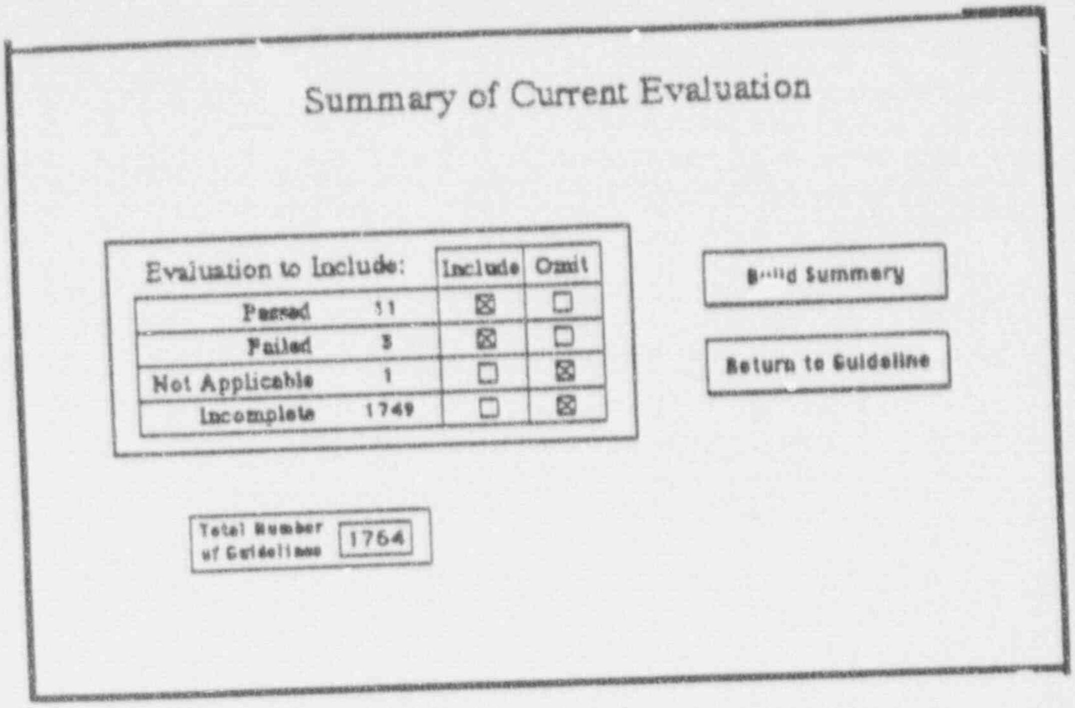

Figure 4.9. Report Function Screen Display

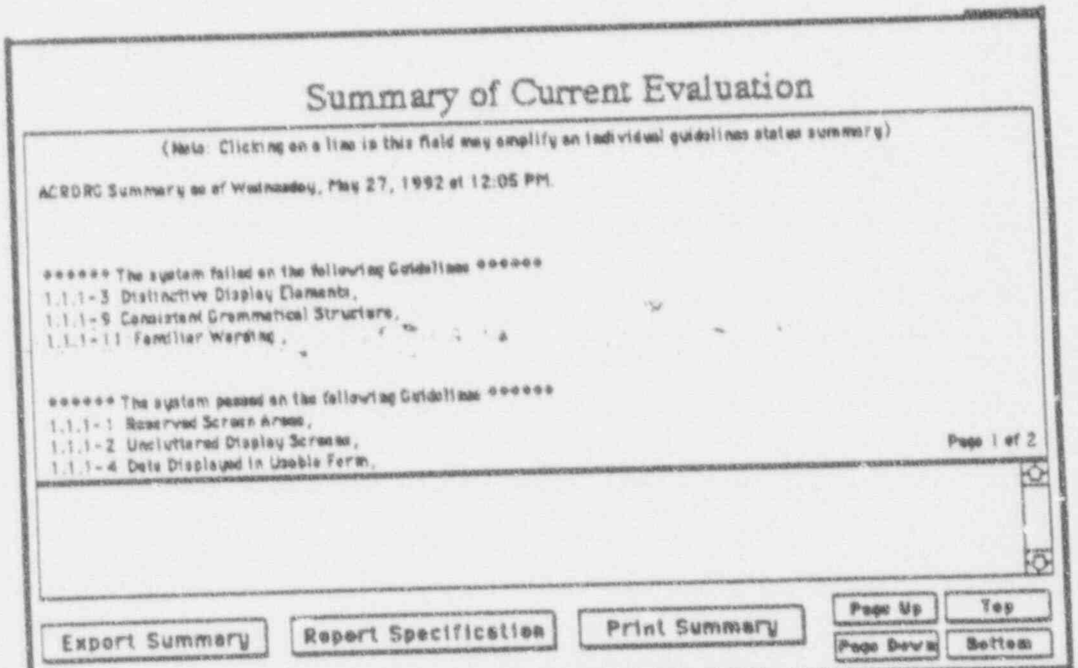

Figure 4.10. Report Summary Screen Display

4.5.5 System Help

On-line help is available from the main screen through the **Help** button. When depressed, the help window is displayed and the user is provided instructions on how to utilize the help function (see Figure 4.11). While in help the reviewer can point to anything on the screen and the help window describes the section of the screen and indicated how the selected function operates. Help is also available for the glossary and index functions.

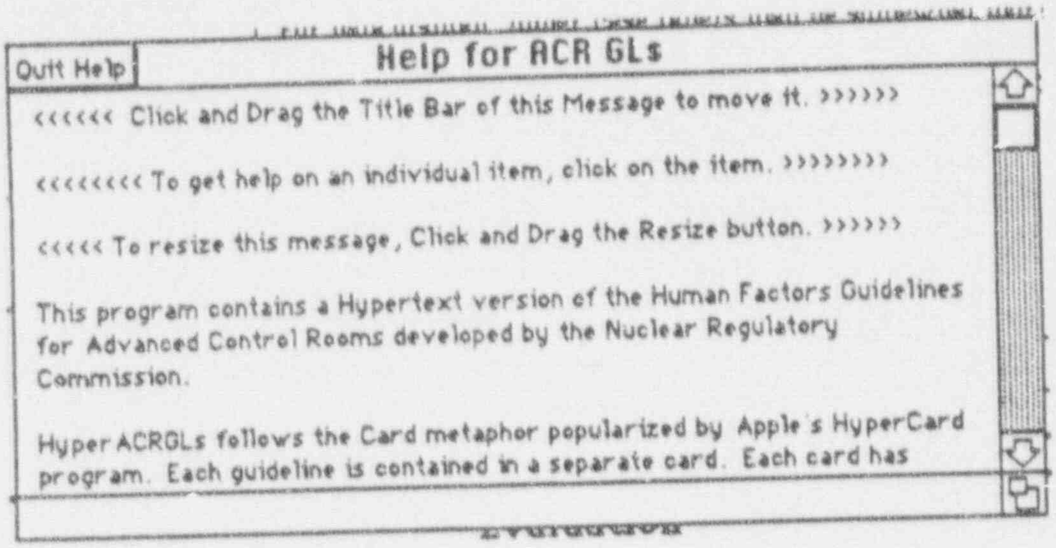

Figure 4.11. Help Screen Display

4.5.6 Guidelines Editing Functions

Simple text editing capabilities are available in HyperCard, such as block definition, text deletion and text insertion. At this time, major editing is accomplished by exporting the guidelines to a word processing program. When editing is completed the guidelines are read back into HyperCard.

5. GUIDELINE TESTS, EVALUATIONS, AND MODIFICATIONS

This section will describe the test and evaluation (T&E) program which is currently underway. Section 5.1 will describe the general objectives and approaches planned. At present, only the development test is completed. A summary of this evaluation is presented in Section 5.2.

5.1 General Test Program

5.1.1 Objectives

The primary purpose of the T&E program is to assess the Guideline in terms of its *technical merit* for achieving the NRC goal of developing a tool for the human factors review of advar   d control room technology. A secondary purpose is to evaluate the *general usability* of the docun nt as an aid to reviewers for meeting the primary objective. Thus the overall objectives of the program can be conceptualized as being divided into two categories: technical content and ease of Guideline implementation as a review aid. The specific objectives in each category are elaborated below.

5.1.1.1 Technical Content Objectives

- **Guideline Technical Basis Validity**
  - To determine if the technical basis of the guideline is valid, i.e., based upon empirical research and/or consistent with current human engineering practice.

- **Guideline Scope**
  - To determine if the guideline covers all aspects of advanced controls and displays required for the evaluation of advanced control rooms and/or advanced technology retrofits in existing plants (note that the scope of the Guideline was limited to compute based HSI, thus it does not presently contain guidance for traditional control room technologies such as those found in NUREG-0700).
  - To determine if the review areas for   available guidance is deficient or missing have been identified.

- **Guideline Content**
  - To determine if the topical organization is appropriate for conducting a review.
  - To determine if the guidelines presented in each section are adequate for the evaluation of HSIs in the areas covered.
  - To determine if the information available for each guideline is sufficient to provide a basis for evaluation.
  - To determine whether the information is presented at an appropriate level of resolution (e.g., enough detail but not overly prescriptive).

- To determine if there are any internal conflicts of contradictions in the Guideline.

5.1.1.2 Guideline Implementation Objectives

- **Requirements Analysis** (The intent of this set of objectives is to determine whether the requirements (for inspection, document functionality, hardware design, and general usability) as set forth in the Guideline development process (see the Task 4 report) were appropriate and properly implemented).
  - To determine if the Guideline achieves the requirements as identified in the requirements analysis (described most completely in the Task 4 report).
  - To determine if the requirements are appropriate (are any of the specified requirements unnecessary or do any require modification).
  - To determine if the requirements are sufficient or whether additional requirements should be specified.
  - Where appropriate, to determine if the requirements are adequately implemented.

- **General User Interface Design**
  - To determine if the interactive document conforms to human factors engineering (HFE) guidelines for human-system interface (HSI) design.

- **Interactive Document Functionality**
  - To determine if the HSI supports the primary task-related functions of evaluation and guideline editing.
  - To determine if the built-in document functions (such as table of contents, glossary, index) are necessary and sufficient.
  - To determine if the built in location landmark features (such as Section headers, etc.) and navigation functions (such as the Hypercard browsing functions and launching features of the table of contents and index) are necessary and sufficient.
  - To determine if the search functions are necessary and sufficient.
  - To determine if the evaluation, note taking, and reporting functions are necessary and sufficient.

- **Interactive Document Usability**
  - To determine if the document is easy to use (i.e., is its usage easy to learn, intuitive, and unobtrusive to the primary task of conducting an evaluation).

- To evaluate the benefits and limitations to conducting evaluations with an interactive, computer-based document when compared with a hard-copy document.

5.1.2 Test and Evaluation Approaches

Not all these T&E objectives can be accomplished in one test. They will be accomplished across three project tasks, each using a different methodology:

- Development Test
- User Test
- Peer-Review Workshop

A brief description of each T&E task will be provided along with the general objectives to be assessed in each.

Development Test

The Development Test provided a preliminary evaluation of the untested prototype Guideline and provided an opportunity to correct major problems prior to subsequent testing. The Guideline was evaluated by the project staff using a variety of review methodologies in order to assess the Guideline Implementation objectives, especially the requirements analysis and general user interface design objectives. The Development Test included a limited field evaluation, also conducted by the project staff. The field test was the first time the Guideline was used to assess a NPP interface. The purpose of the field test was to: (1) provide the project staff with experience in the document's utilization for its intended purpose, (2) to provide a preliminary and partial assessment of the Guideline Technical Content objective, and (3) to provide a pilot test of the procedures and evaluation methods to be used in the User Test. The results of the Development Test were used to modify the Guideline, as well as the testing protocol, in preparation of the more extensive User Test. (The Development Test is described in more detail in Section 5.2.)

User Test

The User Test will be a field test of the Guideline in an environment of greater fidelity to an advanced control room and encompassing a greater diversity of advanced control room technologies than the Development test. The user test will also utilize independent reviewers to conduct the evaluation rather than the project staff. Therefore, the User Test is a simulation of the actual Guideline utilization. Both Technical Content and Guideline Implementation objectives will be assessed. With respect to Technical Content, the objectives of Guideline Scope and Guideline Content will be evaluated. Since the test participants are novice with respect to use of the interactive document, the User Test is well suited for evaluation of the Guideline Implementation objectives. Specifically, the objectives of requirements analysis evaluation, electronic document functionality, and usability as an inspection aid will be evaluated. The results of the User Test will be used to develop recommendations for Guideline modification.

Peer-Review Workshop

The third T&E task is the Peer-Review Workshop. At present, the workshop is expected to last 2-3 days and will involve approximately 10-15 participants. The individuals will be selected based upon their expertise in at least one of the following: (1) human factors evaluations for advanced systems, (2) inspections of NPP CRs, (3) NRC regulatory reviews and issues, and (4) advanced nuclear power plant control room technology. Thus the Guideline will be evaluated by independent experts. The workshop will provide a different type of evaluation than the two testing tasks and can address the broader aspects of the Guideline, such as the general approach to advanced control room review and the Guideline's value in meeting the NRC's need to evaluate advanced HSI. The workshop will assess objectives which cannot be adequately addressed in the other T&E tasks, i.e., the validity and technical basis for the Guideline. The workshop will also provide a good method to evaluate other Technical Content objectives (which are also addressed in the testing tasks): Guideline Scope and Guideline Content. However, given the workshop participants' more limited exposure to the Guideline in its electronic form, the workshop is not as strong a method of evaluating the Guideline Implementation objectives in comparison to the Development and User Tests; although selected aspects of the Requirements Analysis Evaluation will be addressed in the workshop.

Results from the User Test and Workshop will be used to modify the Guideline (as Revision 3). With Revision 3, the first complete draft of the Guideline will be completed.

5.2 Development Test

The Development Test results are reported in BNL Technical Report No. L-1317-4-11/91 and the modifications made to the Guideline based upon these results are presented in BNL Technical Report No. L-1317-5-12/91.

5.2.1 Test Objectives and Overview

The Development Test provided a preliminary evaluation of the untested prototype Guideline and an opportunity to correct interface problems prior to subsequent testing. The Guideline was evaluated by the project staff using a variety of review methodologies in order to assess the Guideline Implementation objectives, especially the requirements analysis and general user interface design objectives. The Development Test included a limited field evaluation, also conducted by the project staff. The field test was the first time the Guideline was used to assess a NPP human-system interface. The purpose of the field test was to (1) provide the project staff with experience in the document's utilization for its intended purpose, (2) to provide a preliminary and partial assessment of the Guideline Technical Content objective, and (3) to provide a pilot test of the procedures and evaluation methods to be used in the User Test. The results of the Development Test will be used to modify the Guideline, as well as the testing protocol, in preparation for the more extensive User Test.

The Project-related objectives for the Development Test are as follows:

- Limited Guideline Content Assessment
- Requirements Analysis Evaluation
- General User Interface Design Evaluation
- Document Functionality Evaluation
- Usability as a Review Aid Evaluation

Two additional Development Test objectives were to:

- develop recommendations for modifications to the Guideline to improve its use as a evaluation tool for the User Test, and
- provide a pilot test of the test methodology and measures so they could be improved for the User Test.

5.2.2 General Methodology and Results

The Development Test consisted of three types of evaluations: a function implementation evaluation, a human factors engineering (HFE) review, and a limited field test. The Function Implementation Evaluation was designed to test the ease with which novice users understand the interface and can use the document's many functions. For the HFE review, the project staff evaluated the user interface design of the electronic document using the guidelines contained in the Guideline itself. The Field Test was designed so that the Project team could evaluate the Guideline's technical content and interface for conducting an evaluation in a control room environment. A variety of data were collected during and following the evaluations, including rating scales, questionnaires, and both user and test conductor comments. The major findings are discussed below. It should be noted that the Development Test was not a formal experiment and that the results are based on a relatively small number of participants who were mainly project personnel (although not involved in the interactive document development). All results should be considered with this limitation in mind.

General Guideline usability was found to be quite good for an untested prototype. Most interface characteristics thought to be indicative of usability (such as visual clarity, consistency, explicitness, ease of use, ease of learning and remembering, response time, etc.) were rated highly. Some difficulties were encountered mainly in the areas of input devices, reporting and help functions. Thus, good progress has been made toward the design objective of developing a straightforward and intuitive interface for reviewers who are not already familiar the host computer system.

While users indicated that improvements in screen design and organization can be achieved, the Guideline was judged to be easy to use and readable. Some inconsistencies in appearance and functioning across different display screens were noted. Most of the functions and controls were evaluated as highly useful and easy to use. The exception to the highly useful category was the glossary function. Since the glossary was not tailored to the Guideline, many terms for which definitions were needed were not in the glossary. In addition, several controls/functions were evaluated as not being easy to use. This included the evaluation function, information input functions, and the reporting function. The evaluation function was hindered by the lack of adequate guideline selection support. In addition, users indicated a need for a method of identifying applicable guidelines for which they were unable to make an immediate pass/fail determination, i.e., it was considered important to be able to distinguish "pending" evaluations from guidelines that were judged "not applicable" or those that the reviewer had not yet accessed. The exclusive reliance on using the mouse/trackball for evaluation and navigation functions was considered time consuming and tedious. Most users indicated a desire for using command (keyboard) inputs for these functions. Finally, the reporting function did not always work properly and was very time consuming.

The technical content of many guidelines was sufficiently abstract as to create difficulty when used for evaluation purposes. This problem reflects a generally recognized limitation of guidelines in the area of advanced technology human-system interface and of human-computer interface guidelines in particular.

The reasons for this problem are many and include limitations in the technical basis for guidance development due to deficiencies in both scientific knowledge and industry experience with advanced technology. Inconsistent wording also contributed to the users' difficulty with some guidelines. In addition, the guidelines were judged to be too detailed in some areas and to contain redundancy. While an effort to correct these problems had been made prior to the Development test, there were over 1900 guidelines and the complete elimination of all redundancy and clarification of all terminology had not successfully been accomplished.

Based upon these results, modifications to the Guideline were recommended, including redesign of the inspection/review screen (as now represented in Revision 2), improvements to existing functions where problems were noted, and the addition of several new functions. The Guideline was also reviewed technically in order to:

- Improve Content - The guidelines were reviewed to eliminate redundancy, review and revise technical terminology to ensure better consistency throughout the document, and to ensure better consistency between the titles and contents of each section.

- Improve User Access to Guidelines - The tiered approach to guideline access was developed (as described in Section 3) to enable reviewers to begin at a higher level of review without requiring them to access all individual guidelines unless/until necessary.

These modifications resulted the present version of the Guideline (Revision 2) and the elimination of several hundred guidelines.

6. IDENTIFICATION OF HFE-HSI AREAS LACKING ADEQUATE GUIDELINES

New guidelines are indicated where gaps exist between the identification of areas for which guidance is needed and the guidance available in the primary source documents. This comparison resulted in a preliminary list topic areas requiring further guidance development. (A more comprehensive list will be developed following testing of the Guideline document through actual application.)

Integration of Advanced Technology into Conventional Control Rooms

As plants age and equipment is replaced, the opportunity to replace systems with digital technology increases. As a result, the control room becomes an increasing mix of conventional and advanced technology. The introduction of digital technology into a conventional CR can pose safety issues since the operator's tasks and methods of interacting with the system can change. Guidelines for the review this integration are needed.

Alarm Systems

The human factors issues of NPP alarm systems have been persistent. Recent efforts to improve these systems have incorporated alarm filtering and prioritization techniques, and more sophisticated method of alarm display (see O'Hara, 1991 for a review of human factors issues associated with advanced alarm systems). Review guidance on these characteristics are needed (and the NRC currently has a project underway to develop this guidance).

Computer-Based Procedures

Procedures (especially emergency operating procedures) play an important role in NPP safety. In several ACR designs, procedures are presented in computerized form. In some cases the computerization is simple and merely represents a VDU version of paper procedures. In other cases the procedures are fully integrated with the plant DMS. Guidance for the review of the computerization of procedures and for the integration of procedures with plant data are needed.

Automation Methodologies

Advanced reactor designs will likely involve more sophisticated interactions between operators and automated systems than currently exists (see IAEA, 1991). This will include task sharing, task trading, and sequence automation, e.g., at certain way points the automated process stops until the operator authorizes the system to proceed. Thus, the operator plays a more active "monitoring" role than is traditionally the case with automated processes. Guidelines for these types of human-system interaction are not available and need to be developed.

Intelligent Operator Aids

Operators in future CRs will be provided with many different types of intelligent aids. Despite the emergence many books on the subject, the availability of "validated" human factors guidelines for these systems is limited as is industry experience with their use in actual systems (as opposed to laboratory studies).

Interface Management and Navigational Strategies

As discussed in Section 2, managing the interface of a computer-based workstation and successful navigation through the data available can impose significant workload on the operator which is not related to his primary task of monitoring and supervising the process control system. This "secondary" task will compete for cognitive resources which would be better allocated to the primary task. Further research is needed on the balance between workstation flexibility and the imposition of interface management workload on operators.

Graphical Presentation of Data

There exist a vast number of graphic display techniques for representing numerical data (e.g., pattern charts, simulated meters, surface charts, segmented column histograms) that are precently found on VDTs. In order to make the most effective use of these screen design techniques, more research is needed on understanding the effects of various graphic data display techniques have on operator perception and assimilation of information. Specific areas where more research is needed include the use of highlighting, spatial relationships, and animation (see Tullis, 1988, for a detailed discussion of these areas). In addition, additional guidance on the appropriate application of different graphic display techniques is needed.

Stereoscopic and Virtual Image Displays

Three-dimensional (stereoscopic) and virtual image display technology has been the subject of a great deal of research in recent years. The technology for these display techniques has noticeably increased and shows considerable promise for commercial applications. However, the psychophysical concepts, measurement techniques, and subjective evaluation data for virtual image three-dimensional displays are nonexistent, and are in need of human factors research.

Visual Display Hardware Characteristics

Human factors guidelines were found to be lacking for many of the variables which impact the readability and legibility of visual display terminals (see Snyder and Bogle, 1989, for a detailed discussion of these areas). Specific areas where additional guidelines are needed include:

- The measurement of raster modulation for color displays,
- Determination of appropriate maximum character and background contrast ratio,
- Determination of polarity recommendations,
- The measurement of display resolution for color CRT and flat panel screens,
- A requirement for luminance uniformity (acceptable variation in luminance),
- Selection and specification of suitable color coding metrics and color spaces,
- Character, line, and word spacing for emissive displays, and
- Flicker sensitivity.

Flat Panel Displays

Flat panel displays have been identified as a potential display technology for use in advanced NPP CRs of the future. Among these flat panel displays are light emitting diodes (LEDs), plasma displays, thin film electroluminescence (TFEL), electrochromics, electrophoretics, and liquid crystals (LC). According to manufacturer specifications, flat panel technology appears to be quite compatible with requirements of the human visual system (e.g., in terms of contrast and viewing angles). However, little human factors guidance exists on these technologies, at least within the primary documents surveyed.

New Input Devices

While many guidelines exist for the more traditional methods for interacting with VDTs (i.e., displacement keyboards), guidance for some of the more recently developed input mediums is sparse. For example, very little human factors guidance was found for membrane keyboards, head movement controllers, glove controllers, and multi degree-of-freedom (>3) handcontrollers. While more guidance was found for other devices (e.g., mice, light pens, touch input devices), the guidance available is not as complete as that which exists for displacement keyboards. Since keyboards have been the primary input devices for computers, this is not surprising. However, with the recent advances made in display technology, graphic displays are becoming more accessible. With the benefits associated with graphic (direct manipulation) user interfaces, new methods for interacting with these displays are being explored and human factors guidelines for these "new" input devices are needed.

Advanced Control Room Design Review Guideline

- ACRDRG Revision 2 -

Volume II

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May 1992

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May 1992

PREFACE TO VOLUME II

Volume II contains a listing of the guidelines for human factors engineering review of advanced human/system interface technology. Following the Table of Contents, the guidelines are presented by section in a hierarchical organization. The section number and title are found at the bottom of each page; pages are numbered consecutively within each section. The place of each subsection in the organization is indicated above the first guideline in that subsection.

The following information is contained in the listing:

- the guideline number and title (boldface)
- the guideline narrative
- additional information (if applicable, shown as a COMMENT in smaller type)
- the source document code (a capital letter in parenthesis following the COMMENT)

The source documents referenced in the listing are:

A	DoD HDBK 761A, 1987
B	Gilmore, Gertman and Blackman, 1989
C	MIL-STD-1472D, 19[illegible]
D	NASA USE-1999, 1988
E	Smith and Mosier, ~~1986~~
F	ANSA/HFS 1000, 1988
G	NUREG-0800

TABLE OF CONTENTS

1.0 INFORMATION DISPLAY

1.1 Screen Organization and Layout

1.1.1 General

1.1.1-1 Reserved Screen Areas (Tier 2 - Screen Organization)
Specific areas of the screen should be reserved for information such as commands, status messages, and input fields; those areas should be consistent on all screens.
COMMENT: (B)

1.1.1-2 Uncluttered Display Screens (Tier 2 - Screen Organization)
Display screens should be perceived as uncluttered.
COMMENT: Distribute the unused area to separate logical groups, rather than having all unused area on one side. (B)

1.1.1-3 Distinctive Display Elements (Tier 2 - Screen Organization)
The different elements of a display format should be distinctive from one another.
COMMENT: Different display areas can be separated by spacing (where space permits). Outlining can also be used are distinct from each other. (E)
to separate different areas, so that displayed data, control options, instructions, etc.,

1.1.1-4 Data Displayed in Usable Form (Tier 2 - Screen Organization)
Data should be displayed to users in directly usable form; users should not have to convert displayed data.
COMMENT: A user should not have to transpose, compute, interpolate, or translate displayed data into other units, or refer to documentation to determine the meaning of displayed data. (A,C,D,E)

1.1.1-5 Data Display Consistent with User Conventions (Tier 2 - Consistency)
Data should be displayed consistently with standards and conventions familiar to users.
COMMENT: (C,E)

1.1.1-6 Establishing Display Standards (Tier 2 - Consistency)
When no specific user conventions have been established, some consistent interface design standards for data display should be adopted.
COMMENT: Both the items on display and the displays themselves should be standardized. Two kinds of standardization are important: standardization of items on a display and standardization of displays. Although standardization is desirable, it should not take precedence over the grouping principles of frequency, sequence, locations, and importance. (B,E)

1.1.1-7 Display Consistent with Entry Requirements (Tier 2 - Consistency)
Data display should be consistent in word choice, format, and basic style with requirements for data and control entry.
COMMENT: When composing data and control entries, users will tend to mimic the vocabulary, formats, and word order used in computer displays, including displayed data, labels, error messages, and other forms of user guidance. When entry formats are consistent with display formats, users are more likely to compose an acceptable entry on their first try. (C,D,E)

1.1.1-8 Consistent Wording (Tier 2 - Consistency)
For displayed data and labels, words should be chosen carefully and used consistently.
COMMENT: Consistent word usage is particularly important for technical terms. Standard terminology should be defined and documented in a glossary for reference by interface designers as well as by users. (A,E)

1.1.1-9 Consistent Grammatical Structure (Tier 2 - Consistency)
Consistent grammatical structure for data and labels should be used within and across displays.
COMMENT: Even minor inconsistencies can distract a user and delay comprehension as the user wonders momentarily whether some apparent difference represents a real difference. (A,E)

1.1.1-10 Consistent Format Organization (Tier 2 - Consistency)
A consistent organization should be adopted for the location of various display features from one display to another.
COMMENT: For example, one location might be used consistently for a display title, another area might be reserved for data output by the computer, and other areas dedicated to display of control options, instructions, error messages, and user command entry. As an exception, it might be desirable to change display formats in some distinctive way to help a user distinguish one task or activity from another, but the displays of any particular type should still be formatted consistently among themselves. The objective is to develop display formats that are consistent with accepted usage and existing user habits. Consistent display formats will help establish and preserve user orientation. There is no fixed display format that is optimum for all data handling applications, since applications will vary in their requirements. However, once a suitable format has been devised, it should be maintained as a pattern to ensure consistent design of other displays. (E)

1.1.1-11 Familiar Wording (Tier 2 - Meaningfulness)
The wording of displayed data and labels should incorporate familiar terms and the task-oriented jargon of the users, and avoid the unfamiliar jargon of designers and programmers.
COMMENT: (A,E)

1.1.1-12 Necessary Data Displayed (Tier 2 - Task Compatibility)
All data required for any transaction should be available for display.
COMMENT: Displayed data should be tailored to user needs, providing only necessary and immediately usable data for any transaction; displays should not be overloaded with extraneous data. (E)

1.1.1-13 Consolidation of Information (Tier 2 - Task Compatibility)
All data related to one task should be simultaneously displayed.
COMMENT: A user should not have to remember data from one screen to the next. (B)

1.1.1-14 User Control of Data Display (Tier 2 - Task Compatibility)
Users should be able to control the amount, format, and complexity of displayed data as necessary to meet task requirements.
COMMENT: (A,E)

1.1.1-15 Date/Time Annotation (Tier 2 - Task Compatibility)
When task performance requires or implies the need to assess currency of information, displays should be annotated with date-time information.
COMMENT: (A)

1.1.1-16 Context for Displayed Data (Tier 2 - Memory Load)
Each data display should provide needed context, recapitulating prior data as necessary so that a user does not have to rely on memory to interpret new data.
COMMENT: (C,E)

1.1.1-17 Invariant Display Fields (Tier 2 - General)
An invariant field, including the page title, an alphanumeric designator, the time, and the date, should be placed at the top of each display page.
COMMENT: The page title should indicate the purpose of the display, is in a consistent location on each page, and is separated by at least one blank line from other information. The alphanumeric designator provides a convenient means for accessing display pages, identifying them, referring to display pages in discussions, and reporting problems in page formats. The designator should be meaningful enough to be easily learned and remembered, as well as be compatible with the designation scheme applied to hardwired instruments on panels. (B)

1.1.1-18 Frame Identification (Tier 2 - General)
Every display frame should have a unique identification to provide a reference for use in requesting the display of that frame.
COMMENT: The frame identification should be an alphanumeric code or an abbreviation which is prominently displayed in a consistent location. It should be short enough (3-7 characters) and/or meaningful enough to be learned

and remembered easily. (C)

1.1.1-19 Display of Information (Tier 2 - General)
Whenever possible, users should be able to see the whole page on which they are working.
COMMENT: (A)

1.1.1-20 Information Density (Tier 2 - General)
Information density should be minimized in displays used for critical task sequences.
COMMENT: For critical information, a minimum of one character space should be left blank vertically above and below critical information, with a minimum of two character spaces left blank horizontally before and after. (A,C,D)

1.1.1-21 Display Background (Tier 2 - General)
Because the background color on a display does not present any information, it should not distract the user from the data.
COMMENT: (A)

1.1.1-22 Frame Identifier Demarcation (Tier 3 - Design Details)
At least one blank line between the title and the body of the display should be provided.
COMMENT: (A,E)

1.1.1-23 Hierarchy of Titles (Tier 3 - Design Details)
Where displays have several levels of titles (and/or labels), the system should provide visual cues to aid users in distinguishing among the levels in the hierarchy.
COMMENT: Character size variation and indentation are two common methods of expressing a hierarchy. Bolding, underlining and letter case are also frequently used, but the method for their implementation has not been well established. (D)

1.1.1-24 Variant Display Fields (Tier 3 - Design Details)
The last four lines (at least) of each display page should be reserved for variant fields.
COMMENT: Variant information might include alarm messages, data source identification, the page number for consecutive pages, system messages (e.g., standby subsystems), error messages, response entry prompts, and program messages. (B)

1.1.1-25 Screen Packing Density (Tier 3 - Design Details)
Screen packing density should not exceed 50% and preferably should be less than 25%.
COMMENT: (B)

1.1.1-26 Display Background Color (Tier 3 - Design Details)
Only one background color should be used on a display.
COMMENT: Background color can influence the way a user interprets a color symbol (e.g., shape, lines). When a color symbol or figure is surrounded by another color, the surrounding color can change the appearance of the enclosed color. For example, green on a yellow background will appear more blue than the same shade of green on a blue background. (A)

1.1.1-27 Display Background Contrast (Tier 3 - Design Details)
The background color should be of an appropriate hue/contrast to allow the data (foreground) to be easily visible.
COMMENT: (A)

1.1.1-28 Hardcopy Request (Tier 3 - Design Details)
Users should be able to obtain a paper copy of the exact contents of the alphanumeric or digital graphic displays
COMMENT: (A)

1.1.1-29 Flexible Design for Data Display (Tier 3 - Design Details)

When data display requirements may change, means for users (or a system administrator) to make necessary changes to display functions should be provided.
COMMENT: (E)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.2 Multiple Pages

1.1.2-1 Data Partitioning on Crowded Displays (Tier 1 - Use)
When a display contains too much data for presentation in a single frame, the data should be partitioned into separately displayable pages.
COMMENT: (A,C,E)

1.1.2-2 Important Information Displayed First (Tier 2 - Task Compatibility)
Required or frequently used data elements should be included on the earliest screens in the application transaction.
COMMENT: (B)

1.1.2-3 Position Within Functional Hierarchy (Tier 2 - Task Compatibility)
Information about a user's position in a functional hierarchy of tasks or task steps and their related displays should be provided.
COMMENT: For example, by graphical representations. (D)

1.1.2-4 Navigation Through Functional Hierarchy (Tier 2 - Task Compatibility)
Users should be able to move to any other display in the display sequence.
COMMENT: For example, by selecting a graphical representation of the display for a given task step. (D)

1.1.2-5 Sequential Steps on Multipage Displays (Tier 2 - Task Compatibility)
When actions on one display in a sequence require completion of actions on a previous display, the user should be able to move to a display only when all of the conditions have been met.
COMMENT: Or when an intentional override procedure has been completed. (D)

1.1.2-6 Position Reference for Sequential Displays (Tier 2 - Task Compatibility)
User's working with a designed sequence of displays performing well-defined sequence of task steps should be provided with a position location reference within the display sequence.
COMMENT: (D)

1.1.2-7 Multitasking Independent Tasks (Tier 2 - Task Compatibility)
During multitasking where tasks do not require integration, they should be designed to present information to different sensory modalities.
COMMENT: For example, a visual tracking task and search for a particular icon (independent tasks) should not be concurrent because both are spatial in nature. In contrast, verbal communication with another part of the plant and search for a particular icon could be performed simultaneously, if necessary. (D)

1.1.2-8 Multitasking Dependent Tasks (Tier 2 - Task Compatibility)
Whenever multitasking involves tasks that are not independent (i.e., require integration), the tasks should be designed to access the same pools of processing resources (i.e., verbal, spatial, auditory, visual, etc.).
COMMENT: For example, if two values must be compared (integration), both values should be displayed visually, rather than one displayed visually and the other in the auditory dimension. Time-sharing is less efficient if the two tasks require resources from the same pool. When the tasks require integration of information, performance is benefitted if the same pool of resources is accessed. (D)

1.1.2-9 Minimize Memory Load (Tier 2 - Memory Load)
Page design and content planning should minimize requirements for operator memory.
COMMENT: (B)

1.1.2-10 On-Screen Help for Continuing (Tier 2 - Feedback)
Displays should indicate how to continue.
COMMENT: The user response that is necessary to continue the interaction sequence should be indicated on each

screen. (B)

1.1.2-11 Navigation Messages (Tier 2 - Feedback)
A message should be available that provides explicit information to the user on how to move from one frame to another or how to select a different display.
COMMENT: (B)

1.1.2-12 Numbering Display Pages (Tier 2 - General)
When display output is more than one page, each page should be annotated to indicate display continuation.
COMMENT: If a large display output is viewed by continuous panning/scrolling rather than by discrete paging, then some other means must be used to label that portion of the display which is currently visible. Typically, the phrase "page x of y" is commonly used for this purpose. A recommended format is to identify pages by a note immediately to the right of the display title. Leading zeros should not be used in the display of page numbers. (C,E)

1.1.2-13 Related Data on Same Page (Tier 2 - General)
When partitioning displays into multiple pages, functionally related data items should be displayed together on one page.
COMMENT: Relations among data sets should appear in an integrated display rather than partitioned into separate windows. (A,C,E)

1.1.2-14 Labels for Multipage Tables (Tier 2 - General)
For a large table that exceeds the capacity of one display frame, users should see column headings and row labels in all displayed sections of the table.
COMMENT: (E)

1.1.2-15 Continuous Numbering in Multipage Lists (Tier 3 - Design Details)
When a list of numbered items exceeds one display page, the items should be numbered continuously in relation to the first item on the first page.
COMMENT: For example, items continued on the next page should be numbered relative to the last item on the previous page (C,E)

1.1.2-16 Annotating Display of Continued Data (Tier 3 - Design Details)
When lists or tables are of variable length, and may extend beyond the limits of one display frame, a user should be informed when data are continued on another page and when data are concluded on the present page.
COMMENT: For example, incomplete lists might be marked "continued on next page," "continued," or "more." Concluding lists might display a note such as "end of list" or "end." As an exception, short lists whose conclusion is evident from the display format need not be annotated in this way. (E)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.3 Grouping

1.1.3-1 Data Grouped by Sequence of Use (Tier 2 - Sequencing and Grouping)
Where displayed data are used in some spatial or temporal order, those data should be grouped by sequence of use to preserve that order.
COMMENT: For example, data in an electronic display should match the order of items in an associated paper data form. (C,E)

1.1.3-2 Data Grouped by Function (Tier 2 - Sequencing and Grouping)
Where sets of data are associated with particular questions or related to particular functions, each set should be grouped together to help illustrate those functional relationships.
COMMENT: (C,E)

1.1.3-3 Data Grouped by Importance (Tier 2 - Sequencing and Grouping)
Displayed data items which are particularly important should be grouped at the top of the display.
COMMENT: (C,E)

1.1.3-4 Data Grouped by Frequency (Tier 2 - Sequencing and Grouping)
Where some data items are used more frequently than others, those items should be grouped at the top of the display.
COMMENT: (C,E)

1.1.3-5 Data Grouped Alphabetically or Chronologically (Tier 2 - Sequencing and Grouping)
When there is no appropriate logic for grouping data by sequence, function, frequency or importance, some other principle should be adopted such as alphabetical or chronological grouping.
COMMENT: (E)

1.1.3-6 Within Group Arrangement (Tier 2 - Sequencing and Grouping)
Similar information should be displayed in groups according to the left-to-right or top-to-bottom rules.
COMMENT: (B)

1.1.3-7 Group Size (Tier 2 - Sequencing and Grouping)
Related data should be displayed in groups which subtend five degrees of visual angle or less. Groups should be visually distinct from one another
COMMENT: For example, by separation from other groups with blank spaces. (D)

1.1.3-8 Grouping for Data Comparison (Tier 2 - Meaningfulness)
If users must analyze sets of data to discern similarities, differences, trends, and relationships, the display format should be structured so that the data are consistently grouped.
COMMENT: Displays should provide cohesive groupings of display elements so that users perceive large screens as consisting of smaller identifiable pieces or chunks. Grouping techniques (e.g., grouping by color, shape, spatial distance, orientation, type of character, etc.) should be used to group functionally similar information and to indicate membership in a common group. (D,E)

1.1.3-9 Group Data to Support Task Completion (Tier 2 - Task Compatibility)
All displayed data necessary to support an operator activity or sequence of activities should be grouped together.
COMMENT: Grouping similar items together in a display format improves their readability and can highlight relationships between different groups of data. Grouping can be used to provide structure in the display and aid in the recognition and identification of specific items of information. (B)

1.1.3-10 Demarcation of Groups (Tier 2 - General)
Groups of information should be separated by blanks, lines, color coding, or other means.
COMMENT: (A,C,E)

1.1.3-11 Grouping Within High Density Displays (Tier 3 - Design Details)
Displays with high information density should have an intermediate number of groups (i.e., 19 to 40 groups). If inherent functional groups of data exist, then they should be preserved.
COMMENT: A display with a low number of groups lacks clear organization and is difficult to work with. A display with too many groups yields performance equally bad because the grouping information is dispersed. An intermediate number of groups yields the best performance. (D)

1.1.3-12 Spacing as a Redundant Demarcation Technique (Tier 3 - Design Details)
Spatial distance should be used for redundant coding when possible.
COMMENT: Although data grouping techniques have been found to be task dependent, grouping based on location has been generally successful across a variety of tasks. Limitations are physical screen size and amount of information to be displayed. (D)

1.1.3-13 Combining Dissimilar Data Groups (Tier 3 - Design Details)
Display items possessing two attributes should not be displayed between two groups of items which share one attribute each with the double-attribute item.
COMMENT: For example, do not display a group of activated Boron Recovery System elements between a group of activated Electrical Power System elements and a group of inactive Boron Recovery System elements. Conjunctive stimuli which are displayed between two groups of elements sharing one dimension each with the conjunctive stimulus are very difficult to detect. (D)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.4 Windows
1.1.4.1 General

1.1.4.1-1 Temporal Proximity of Data (Tier 1 - Use)
A sequence of displays with which the user will have to interact in close temporal proximity should be contained in separate windows which can be displayed simultaneously or nearly simultaneously.
CO. MENT: (D)

1.1.4.1-2 Appropriate Use of Window (Tier 1 - Use)
... n the need to jointly view different data cannot be determined in advance, user's should be abl to define and select separate data windows that will share a single display frame.
COMMENT: Depending upon user needs (and system capability), data windows might appear simultaneously as segments of a joint display (i.e., tiled), might be overlaid in varying degrees so as to obscure one another (i.e, layered), or might be displayed sequentially at the user's option. In the latter condition, multiple display windows will differ little from multiple display pages, except perhaps in speed of sequential access. (A,E)

1.1.4.1-3 Consistent Window Control (Tier 2 - Consistency)
User control of windows should operate consistently from one display to another for each type of window.
COMMENT: Control of predefined windows may simply involve "opening" and "closing" them, by selection of displayed option labels or function keys. Control of user-defined windows may require user specification of window contents, window size and positioning on the display. Such window control must be learned by a user, and consistent design of control logic aids that learning. (A,E)

1.1.4.1-4 Selection of Window Functions (Tier 2 - Task Compatibility)
The capabilities present in a window should be a function of how the user will interact with the window.
COMMENT: For example, a window that simply presents a one-line status message from the system that the user will only read and not respond to might need to only have the ability to be closed. It might not need to be resizeble, movable, etc. (A)

1.1.4.1-5 Window Functions (Tier 3 - Design Details)
As appropriate to the user task, windows should be capable of the following operations: scrolling/panning, resizing, moving, hiding, activating, deactivating, copying to/from, zooming in/out, tabbing, and undo-last,
COMMENT: (A)

1.1.4.1-6 Keeping Track of Open Windows (Tier 3 - Design Details)
Within a session, the system should keep track of the windows that are open (but not necessarily active or displayed), and display them as a menu.
COMMENT: (A)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.4 Windows
1.1.4.2 Display of Windows

1.1.4.2-1 Window Demarcation (Tier 2 - Screen Organization)
Windows should be visually separated from each other and from their background, preferably by borders or similar demarcation.
COMMENT: (A)

1.1.4.2-2 Tiled vs. Layered Windows (Tier 2 - Flexibility of Use)
Users should have the capability to select between "tiling" and "overlapping" window environments.
COMMENT: (D)

1.1.4.2-3 Distinction Between Window Types (Tier 2 - General)
Window types should be perceptually distinct.
COMMENT: For example, interactive windows in both the tiled and layered window environments should be perceptually distinct from noninteractive windows; and active windows in both the tiled and layered window environments should be perceptually distinct from a other window types. (D)

1.1.4.2-4 Prioritization of Caution and Warning Windows (Tier 2 - General)
Caution and warning windows should have display priority under emergency conditions.
COMMENT: (D)

1.1.4.2-5 Prioritization of Active Win During Multitasking (Tier 2 - General)
Active windows should have display priority over all but the interactive window.
COMMENT: (D)

1.1.4.2-6 Nondestructive Overlay (Tier 2 - General)
When a window temporarily obscures other displayed data, the obscured data should not be permanently erased but will reappear if the overlay is later removed.
COMMENT: (A,E)

1.1.4.2-7 Window Design (Tier 3 - Design Details)
Windows should have a rectangular shape. The window should be framed by a border of a single line. The frame should expand and contract with the window.
COMMENT: (D)

1.1.4.2-8 Default Window Size Consistent with Content (Tier 3 - Design Details)
The size and shape of the initial presentation of a window should be consistent with its contents (amount of information, number of menus, data fields, etc.)
COMMENT: (A)

1.1.4.2-9 Default Window Size for Scanning Data (Tier 3 - Design Details)
The default size for text windows and windows used for scanning data should be at least four lines of information.
COMMENT: Window sizes of four lines provide better performance than those with fewer than four lines. Windows with twenty lines show little advantage over windows with four lines. Other research has shown that search time is slower in a 1-line window than in the next largest size (7 lines), but did not vary appreciably among 7, 13, and 19 line windows. (A,D,E)

1.1.4.2-10 Window Default Width (Tier 3 - Design Details)

The default width for a generic text window should cover from 67% to 100% of the full screen..
COMMENT: When users read continuously scrolling text (at a rate set by the user), line lengths of 52 to 78 characters provide the fastest performance. (D)

1.1.4.2-11 Tile Default for Multiple Windows (Tier 3 - Design Details)

When multiple windows are open simultaneously, the default condition should be a tiled window environment, provided that the size for each window is sufficient to hold usable, readable information.
COMMENT: A suggested maximum number of tiled windows is four. The size of the tiled windows might be approximately 1/n of the available display, where n is the number of windows. (D)

1.1.4.2-12 Layered Windows as Default (Tier 3 - Design Details)

When a tiled window environment results in windows of a size that would reduce the user's ability to use the information in the window, a layered window environment should be employed.
COMMENT: The layered windows can overlap and should be the default window size until resized by the user. (D)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.4 Windows
1.1.4.3 Interacting with Windows

1.1.4.3-1 Consistent Control Within Windows (Tier 2 - Consistency)
When control actions such as command entry may be taken by a user working within a window, those control actions should be consistent from one window to another.
COMMENT: For example, cursor positioning controls should operate consistently within all windows. If controls in one window operate differently than in another, user confusion will be unavoidable. (E)

1.1.4.3-2 Closing Windows (Tier 2 - Minimizing User Actions)
Users should be able to close a window with a single action.
COMMENT: (D,E)

1.1.4.3-3 Easy Shifting Among Windows (Tier 2 - Minimizing User Actions)
If several windows are displayed at once, some easy means should be provided for a user to shift among them.
COMMENT: The most direct method might be to allow a user to select a window by pointing anywhere within its displayed borders, but that action might be confused with the selection of a particular item within the window. (A,E)

1.1.4.3-4 Activation of Window Cursor (Tier 2 - Minimizing User Actions)
The action that puts a window into the interactive state should automatically place the placeholding cursor in that window so that the user can provide inputs through that window.
COMMENT: (D)

1.1.4.3-5 Window Opening Methods (Tier 2 - Minimizing User Actions)
The user should be able to open a window by performing any of a set of simple actions.
COMMENT: For example, windows may be opened by issuing a command to open a specific window; selecting a window title from a list on a menu; or selecting an icon for the window. (D)

1.1.4.3-6 Activating a Previously Opened Window (Tier 2 - Flexibility of Use)
The user should be able to put a window in the interactive state by performing any of a set of simple actions in that window or related to that window.
COMMENT: For example, by moving the pointing cursor to the window and performing any action, including pressing a key or a button on a cursor control device; a command to open a specific window; selecting a window title from a list on a menu; or selecting an icon for the window. (D)

1.1.4.3-7 Multiple Methods for Switching Between Windows (Tier 2 - Flexibility of Use)
The system should provide the user several options for moving between active windows.
COMMENT: For example, clicking a mouse button, tab, cursor keys, or function key. (A)

1.1.4.3-8 Multi-Modal Window Designation (Tier 2 - Feedback)
If windows are capable of different modes, the system should provide immediate and unambiguous feedback concerning which mode is active.
COMMENT: (A)

1.1.4.3-9 Interacting with Closed Windows (Tier 2 - Feedback)
When the user is communicating with a closed window, the system should provide feedback that clearly designates the window(s) involved.
COMMENT: Communicating with a closed window entails sending or receiving information between windows, one of which may not be visible. (A)

1.1.4.3-10 Movable Windows (Tier 2 - General)
Window movement capability should be provided such that the user can move windows to different areas of the display.
COMMENT: (D)

1.1.4.3-11 Organizing Layered Windows (Tier 2 - General)
Users should have the capability of moving a window to the front of or behind any or all other windows.
COMMENT: (D)

1.1.4.3-12 Overlapping Tiled Windows (Tier 2 - General)
Users should have the ability to move tiled windows so that they overlap.
COMMENT: (D)

1.1.4.3-13 Smooth Window Movement (Tier 2 - General)
Movement of a window should appear to be smooth and continuous to the user.
COMMENT: (D)

1.1.4.3-14 Moving Windows off Display (Tier 2 - General)
Users should not be allowed to move windows entirely off the display.
COMMENT: (D)

1.1.4.3-15 Critical Function Area Obscurement (Tier 2 - General)
Windows should not be movable to obscure menu bars, access to the command area, or caution and warning messages.
COMMENT: (D)

1.1.4.3-16 Indicate Active Window (Tier 2 - General)
If several windows are displayed at once, indication should be provided to the user of which window (if any) an action can currently be taken.
COMMENT: Adding windows to a display can increase the conceptual complexity of control actions as well as the difficulty of data assimilation. A prominent cursor might be displayed in the currently active window, or perhaps the displayed border of an active window to indicate to a user which window is currently "active." (A,E)

1.1.4.3-17 Hidden Windows (Tier 2 - General)
A window that is not displayed should be capable of sending and receiving information.
COMMENT: (A)

1.1.4.3-18 Alerting User to Information Availability (Tier 2 - General)
The system should be capable of alerting the user to critical information that becomes available in an inactive or non-displayed window.
COMMENT: (A)

1.1.4.3-19 User Alert to Prevent Loss of Information (Tier 2 - General)
If a user-requested action would result in lost or damaged data, the user should be alerted and alternative actions recommended.
COMMENT: For example, "Save file before closing?" (A)

1.1.4.3-20 Keyboard Entry Within Active Window (Tier 2 - General)
Keyboard input should affect only the active window designated by the user.
COMMENT: (A)

1.1.4.3-21 Retrieval of Window Information (Tier 3 - Design Details)
Users should have the capability to obtain information about any and all open windows.
COMMENT: At a minimum, this information should include window name, type, and any process initiated through and displayed in that window. (D)

1.1.4.3-22 Window Activates Upon Opening (Tier 3 - Design Details)
The action that opens a window should automatically make that window active.
COMMENT: (D)

1.1.4.3-23 User Control Over Window Resizing Options (Tier 3 - Design Details)
Users should be able to select between two resizing conditions: (1) Resizing which does not change the size of the window contents, and (2) Resizing in which the size of the window contents increase or decrease with the changes in the size of the window.
COMMENT: The default condition should be resizing which does not change the size of the contents.Many uses for resizing involve sizing the window to fit the graphical or textual contents of the window (e.g., when trying to fit a complex graphical object into a large enough window to permit good resolution of elaborate details). In such cases, the user would want the object to remain the same size while the window changed. In contrast, a user might want to tile a window (e.g., by decreasing its size and moving it to a corner of the screen), but still be able to see the contents of the window. In such a case, the user would want the window contents to change in size with the window. (D)

1.1.4.3-24 Independent Control Along Horizontal/Vertical Axis (Tier 3 - Design Details)
Users should be able to change the horizontal and vertical dimensions of a window independently and with minimal effort.
COMMENT: (D)

1.1.4.3-25 Largest Allowable Window Size (Tier 3 - Design Details)
The upper limit for resizing a window should be the size of the computer screen.
COMMENT: (D)

1.1.4.3-26 Smallest Allowable Window Size (Tier 3 - Design Details)
The lower limit for resizing a window should be the size of the window title.
COMMENT: Users should be able to identify a window of any size. (D)

1.1.4.3-27 Accessibility to Partially Removed Windows (Tier 3 - Design Details)
Windows partially moved off the display should be made readily accessible with a single action.
COMMENT: (D)

1.1.4.3-28 Scrollable Windows (Tier 3 - Design Details)
The user should have the ability to scroll through the contents of a window both horizontally and vertically, if scrolling is required at any point in an application.
COMMENT: (D)

1.1.4.3-29 Command Entry, Prompts and Message Location (Tier 3 - Design Details)
When separate command sets are associated with different display windows they should be shown at the bottom of each window.
COMMENT: For example options for display control such as size of the window, positioning, etc. (A,T)

1.1.4.3-30 User Control of Automatic Updatable Windows (Tier 3 - Design Details)
Automatically updated windows should have display freeze capability.
COMMENT: When a window displays automatically updated information, the user should have control over the rate at which automatically updated screens are scrolled. (A)

1.1.4.3-31 Management of Multiple Windows During Multitasking (Tier 3 - Design Details)

To help the user to manage active windows, the system should provide user aids when multiple windows are active.

COMMENT: An example user aid might be a list of active windows, including the name (title) of the window, the ongoing activity, the time elapsed since the beginning of the activity, the screen location of each window, the relation between activities in the various windows (e.g., if they are hierarchically related as part of the sam[illegible]k), and a menu that would allow users to view the contents of a selected window in the layered environment. (D)

1.0 INFORMATION DISPLAY

1.1 Screen Organization and Layout

1.1.5 Message Areas

1.1.5-1 Location of Message Areas (Tier 1 - Use)
Message areas should be displayed in a window. The windows used for messages from the system and messages from other users should be located at unique, consistent locations.
COMMENT: Once the window appears on the display, it should be under the user's control. The user should be able to remove the message area from the screen, revive it, move the window within the screen, and change the window's size. Each of these actions should require only a single action by the user. (D)

1.1.5-2 System vs. User Message Areas (Tier 2 - General)
Visibly and spatially distinct areas should display messages from the system and messages from other users.
COMMENT: (D)

1.1.5-3 Notification of New Messages (Tier 2 - General)
Notification of messages received should be provided automatically at log on and while the user is logged on.
COMMENT: (D)

1.1.5-4 Nondisruptive Message Notification (Tier 2 - General)
Notification of incoming messages while the user is logged on should be nondisruptive.
COMMENT: Notification of incoming messages should not interrupt the user's current task and should not automatically overwrite the screen areas where the user is working. For example, the system might indicate message arrival to the user by an advisory notice in a portion of the display reserved for that purpose. (D)

1.1.5-5 Notification of Incomplete Message (Tier 2 - General)
The user should be informed when a message extends beyond the area that the window is able to display.
COMMENT: (D)

1.1.5-6 Message Area Dimensions (Tier 3 - Design Details)
By default, the width of message areas should extend across the entire display width and the default height should be three lines.
COMMENT: (D)

1.1.5-7 Time-Stamp Messages (Tier 3 - Design Details)
For real-time operations, messages should be time-stamped.
COMMENT: (D)

1.1.5-8 Message Storage and Retrieval (Tier 3 - Design Details)
Messages should be stored in a message queue that is available to the user.
COMMENT: For example, the user might be able to scroll through a log file containing the message and the time, date, and origin of the message. (D)

1.1.5-9 Rearrangement of Message Order (Tier 3 - Design Details)
The user should be able to rearrange messages such that they can be reviewed regardless of the order in which they are queued.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.6 Command Areas

1.1.6-1 Command Area Located in Window (Tier 1 - Use)
The command area should be contained in a window that the user can open, close, or resize.
COMMENT: A user can only provide input into one command area at a time, even if the system in which the user is working permits multitasking. The presence of multiple command areas would increase the user's workload without a commensurate increase in functionality. (D)

1.1.6-2 Consistent Command Area Location (Tier 2 - Consistency)
A single command area should be in a consistent location on the screen.
COMMENT: (D)

1.1.6-3 Cursor Location Within Command Area (Tier 2 - Minimizing User Actions)
When a command area window is first opened, the placeholder cursor should be in the leftmost position on the first line.
COMMENT: At other times, the user should have the ability to place the placeholder cursor at any location in the command area. (D)

1.1.6-4 Accessibility to Command Area (Tier 2 - General)
The user should always have ready access to the command area.
COMMENT: For example, the command area might be in a window that: (a) could not be covered by other windows, or (b) could easily be "popped" to the front of all other windows by selecting a software-based button. (D)

1.1.6-5 Distinctive Command Area (Tier 2 - General)
The command area should be visibly distinct from all other screen structures.
COMMENT: (D)

1.1.6-6 Command Area Buffer (Tier 2 - General)
When the command area is opened, the user should immediately be able to (1) enter a new command for execution, (2) access previously entered commands and execute them as they appear, or (3) modify previously entered commands and execute them.
COMMENT: The user should be able to edit, cut, paste, and re-execute these commands by the same methods as are used in text input and editing. Making previous commands available will provide continuity between command input episodes and may reduce time in repetitive tasks. (D)

1.1.6-7 Command Area Obscurement (Tier 3 - Design Details)
In general, opening the command area window should not interfere with the user's ability to view other display structures.
COMMENT: However, when the command window is revived and contains commands, the command area should be the same in size, content, and cursor placement as when it was removed. (D)

1.0 INFORMATION DISPLAY
1.1 Screen Organization and Layout
1.1.7 General Information Areas

1.1.7-1 Consistent Location (Tier 2 - Consistency)
Date and Time information should be shown in a consistent location.
COMMENT: (D)

1.1.7-2 Time Display (Tier 3 - Design Details)
The information area should display appropriately formatted time information necessary for a user's task and location.
COMMENT: (D)

1.1.7-3 Access to Software Version Number (Tier 3 - Design Details)
Users should have the capability to access and permanently display the version number of the current application.
COMMENT: (D)

1.1.7-4 Removal of General Interest Information (Tier 3 - Design Details)
Users should be able to remove any general information on the display.
COMMENT: Either for a single session (e.g., by removing the window in which the information is contained) or for all sessions (e.g., by a change in their user profile) (D)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.1 Tables and Lists

1.2.1-1 Appropriate Use of Tables (Tier 1 - Use)
When information handling requires detailed comparison of ordered sets of data, a tabular format for data display should be provided.
COMMENT: (C,E)

1.2.1-2 Lists for Related Items (Tier 1 - Use)
A series of related items (words, phrases, instructions, etc.)should be displayed in a list rather than as continuous text.
COMMENT: A list format will facilitate rapid, accurate scanning. (E)

1.2.1-3 Logical Table Organization (Tier 2 - Sequencing and Grouping)
Tabular data should be organized in some recognizable order to facilitate scanning and assimilation.
COMMENT: If the data in the rows has order, the order should be increasing from left to right. If the data in the columns has order, the order should be increasing from top to bottom of the display. (A,C,E)

1.2.1-4 Logical List Ordering (Tier 2 - Sequencing and Grouping)
Lists should be ordered according to some logical principle.
COMMENT: For example, items in lists shall be arranged in a recognizable order, such as chronological, alphabetical, sequential, functional, or importance. Where no other principle applies, lists should be ordered alphabetically. It is the user's logic which should prevail rather than the designer's logic, where those are different. (C,E)

1.2.1-5 Consistent Spacing Within Tables (Tier 2 - Consistency)
Consistent column spacing should be maintained within a table, and from one table to another. Similarly, spacing between rows should be consistent within a table and between related tables.
COMMENT: As an exception, when columns are grouped under superheadings, extra space between superheadings may help, in order to emphasize that the columns under any single superheading are related. (A,C,D,E)

1.2.1-6 Character Size (Tier 2 - Consistency)
The sizes of alphanumeric characters should be consistent within a table and between related tables.
COMMENT: (D)

1.2.1-7 Character Font and Aspect Ratio (Tier 2 - Consistency)
The fonts and widths of alphanumeric characters should be consistent within a table, except when a word or set of characters is highlighted by varying the typeface.
COMMENT: For example, through the use of italics or a "bold" function. (D)

1.2.1-8 Maintaining Significant Zeros (Tier 2 - General)
Zeros should not be arbitrarily removed after a decimal point if they affect the meaning of the number in terms of significant digits.
COMMENT: For example, when an operator may want to distinguish between 19. 003 and 19.000. (A,E)

1.2.1-9 Leading Zeros (Tier 2 - General)
Leading zeros in numeric entries for whole numbers should be suppressed.
COMMENT: For example, 28 should be displayed rather than 0028. A leading zero should be provided if the number is only a decimal, with no preceding integer (i.e., 0.43 rather than .43) (C,D)

1.2.1-10 Tables Referenced by First Column (Tier 2 - General)
When tables are used for reference, the reference item should be displayed in the left column, and the material most relevant for user response should be dislayed in the next adjacent column.
COMMENT: Associated but less significant material should be displayed in columns further to the right. (A,E)

1.2.1-11 Table Access by Row and Column (Tier 2 - General)
A table should be constructed so that row and column labels represent the information a user has prior to consulting the table.
COMMENT: For example, the information that can be used to access table entries for a particular task. The left-most column should contain the labels for the row variables (that is, the information by which the user will access other row items). The top row should contain the labels for the column variables (that is, the information by which the user will access other columnar items). (C,D,E)

1.2.1-12 Column Scanning Cues (Tier 3 - Design Details)
The columns in a table should be separated by enough blank spaces, dots, or by some other distinctive feature, to ensure separation of entries within a row.
COMMENT: The spacing between columns should be greater than any internal spaces that might be displayed within a tabulated data item. (A,C,D,E)

1.2.1-13 Justification of Numeric Data (Tier 3 - Design Details)
Columns of numeric data should be justified with respect to a fixed decimal point; if there is no decimal point, then numbers should be right-justified.
COMMENT: (A,D,E)

1.2.1-14 Numbered Items Start with "1" (Tier 2 - General)
Item numbers should begin with one rather than zero.
COMMENT: (A,E)

1.2.1-15 Repeated Elements in Hierarchic Numbering (Tier 2 - General)
For hierarchic lists with compound numbers, the complete numbers should be displayed; repeated elements should not be omitted.
COMMENT: Implicit numbering may be acceptable for tasks involving perception of list structure. Complete numbering is better, however, for tasks requiring search and identification of individual items in the list. (A,E)

1.2.1-16 Single-Column List Format (Tier 2 - General)
Lists should be formatted so that each item starts on a new line.
COMMENT: A list should be displayed as a single column. As an exception, listing in multiple columns may be considered where shortage of display space dictates a compact format. (A,C,E)

1.2.1-17 Marking Multiline Items in a List (Tier 2 - General)
When a single item in a list continues for more than one line, items should be marked in some way so that the continuation of an item is obvious.
COMMENT: For example, so that a continued portion does not appear to be a separate item. Items might be separated by a blank space, or continuing lines within an item might be indented, or each item might be numbered or marked by a special symbol such as an arrow or bullet. Some demarcation is particularly needed when a list is comprised (A,C,E)

1.2.1-18 Hierarchic Structure for Long Lists (Tier 3 - Design Details)
For a long list, extending more than one displayed page, a hierarchic structure should be used to permit its logical partitioning into related shorter lists.
COMMENT: (C,E)

1.2.1-19 Justification of Alphabetic Data (Tier 3 - Design Details)
Columns of alphabetic data should be displayed with left justification to permit rapid scanning.
COMMENT: As an exception, indentation can be used to indicate subordinate elements in hierarchic lists. Also, a short list (of just four or five items) could be displayed horizontally on a single line, in the interests of compact display format, if that is done consistently. (A,D,E)

1.2.1-20 Justification of Numeric Entry (Tier 3 - Design Details)
Users should be allowed to make numeric entries in tables without concern for justification; the

computer should right-justify integers, or else justify with respect to a decimal point if present.
COMMENT: (A,D,E)

1.2.1-21 Row Scanning Cues (Tier 3 - Design Details)
In dense tables with many rows, a blank line, dots, or some other distinctive feature (to aid horizontal scanning) should be inserted after a group of rows at regular intervals.
COMMENT: For many applications it will suffice to insert a blank line after every five rows. (A,C,D,E)

1.2.1-22 Density of Tables (Tier 3 - Design Details)
For improved readability, overall screen density for tables should be no greater than 30%.
COMMENT: (D)

1.2.1-23 Arabic Numerals for Numbered List Items (Tier 3 - Design Details)
When listed items are numbered, Arabic rather than Roman numerals should be used.
COMMENT: Arabic numbers are more familiar to most users, and therefore require less interpretation than Roman numerals do. The advantage of Arabic numbers becomes greater when large numbers are used. (A,C,E)

1.2.1-24 Vertical Ordering in Multiple Columns (Tier 3 - Design Details)
If a list is displayed in multiple columns, the items should be ordered vertically within each column.
COMMENT: (A,C,E)

1.2.1-25 Vertical List Extension (Tier 3 - Design Details)
Where lists extend over more than one display page, the last line of one page should be the first line on the succeeding page.
COMMENT: (C)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.2 Data forms

1.2.2-1 Appropriate Use of Forms (Tier 1 - Use)
Forms should be used to display related sets of data items in separately labeled fields.
COMMENT: Forms can aid review of related data items by displaying explanatory labels to caption each data field. (A,D,E)

1.2.2-2 Comparing Data Fields (Tier 2 - Screen Organization)
Data fields to be compared on a character by character basis should be positioned one above the other.
COMMENT: (A)

1.2.2-3 Consistent Format Across Displays (Tier 2 - Consistency)
The ordering and layout of corresponding data fields should be consistent from one display to another.
COMMENT: (A,E)

1.2.2-4 Consistent Format Within Data Fields (Tier 2 - Consistency)
The internal format of frequently used data fields should be consistent from one display to another.
COMMENT: For example, time records might be consistently punctuated with colons, as HH:MM:SS or HH:MM, whatever is appropriate. The convention chosen should be familiar to the prospective users. (A,E)

1.2.2-5 Data Form Placeholder Cursor Location (Tier 2 - Minimizing User Actions)
When the data form is first opened, the placeholder cursor should be in the left-most position of the first available data field.
COMMENT: (D)

1.2.2-6 Data Entry Error Acknowledgement (Tier 2 - Error Handling)
Users should receive an error message only if they continue to make the same error. The error message should describe the proper manner for entering data.
COMMENT: (D)

1.2.2-7 Visually Distinctive Data Fields (Tier 2 - General)
Clear visual definition of data fields should be provided so that the data are distinct from labels and other display features.
COMMENT: (A,E)

1.2.2-8 Field Definition/Delimiters (Tier 2 - General)
Special characters (such as underlining, data field "boxing") should be used to delineate data fields and data field lengths.
COMMENT: (A)

1.2.2-9 Highlight Active Data Entry Field (Tier 2 - General)
The current field to be entered should be highlighted.
COMMENT: Irrelevant objects slow perceptual processing by competing for resources. Use of highlighting makes the current data field discriminable from irrelevant data. (D)

1.2.2-10 Form Compatible for Data Entry and Display (Tier 2 - General)
When forms are used for data entry as well as for data display, the format for data display should be compatible with whatever format is used for data entry.
COMMENT: Use the same item labels and ordering for both. (A,C,E)

1.2.2-11 Identification of Entry Field Length (Tier 3 - Design Details)
Cues should be provided to indicate the maximum length of a data entry field.
COMMENT: For example, a broken underscore could be used to indicate the number of characters available for an entry. (D)

1.2.2-12 Data Entry Cues (Tier 3 - Design Details)
If appropriate, labels should be used to help cue the user as to the expected data entry.
COMMENT: For example, "DATE (MM/DD/YY): _/_/_." (D)

1.2.2-13 Data Form Entry Error (Tier 3 - Design Details)
Data entered that does not match the predefined format of the data form should highlighted and signaled the user.
COMMENT: For example, with a beep. (D)

1.2.2-14 Distinguishing Blanks from Nulls (Tier 3 - Design Details)
Blanks (keyed spaces) should be distinguished from nulls (no entry at all) in the display of data forms, where that can aid task performance.
COMMENT: Some special symbol might be adopted to denote null entry. If field delimiters are displayed to guide data entry, then it will often be sufficient simply to leave those delimiters unchanged when no entry has been made. (A,E)

1.2.2-15 Similar Formats for Data Form and Hardcopy (Tier 3 - Design Details)
When users are highly familiar with a hardcopy version of the data form, the data form should be formatted to be similar to hardcopy source documents.
COMMENT: Users should be able to transfer their previous training and experience with the hardcopy format to the computer display. (D)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.3 Mimics

1.2.3-1 Consistent Use of Symbols (Tier 2 - Consistency)
Mimic symbols should be used consistently.
COMMENT: (B)

1.2.3-2 Mimic Detail (Tier 2 - General)
A mimic should contain just the minimum amount of detail required to yield a meaningful pictorial representation.
COMMENT: (B)

1.2.3-3 Points of Origin (Tier 2 - General)
All mimic origin points should be labeled or begin at labeled components.
COMMENT: (B)

1.2.3-4 Mimic Termination Points (Tier 2 - General)
All mimic destination or terminal points should be labeled or end at labeled components.
COMMENT: (B)

1.2.3-5 Directional Arrowheads (Tier 2 - General)
Flow directions should be clearly indicated by distinctive arrowheads.
COMMENT: (B)

1.2.3-6 Use of Abstract Symbology (Tier 3 - Design Details)
Abstract symbols should conform to common electrical and mechanical symbol conventions whenever possible.
COMMENT: (B)

1.2.3-7 Mimic Line Width (Tier 3 - Design Details)
Differential line widths should be used to code flow paths.
COMMENT: For example, significance, volume, level (B)

1.2.3-8 Overlapping Lines (Tier 3 - Design Details)
Mimic lines should not overlap.
COMMENT: (B)

1.2.3-9 Symbolic Component Identifiers (Tier 3 - Design Details)
Component representations on mimic lines should be identified.
COMMENT: (B)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.1 General

1.2.4.1-1 Graphic Displays: Trends (Tier 1 - Use)
For display of data showing relations in space or time a graphic format should be used.
COMMENT: Relations in space or time are data such as, trend information, spatially structured data, time critical information or relatively imprecise information. People cannot readily assimilate detailed textual or tabular data, although sometimes such data are necessary. Therefore, a graphic display might be used where graphic elements showing trends and differences are combined with text annotation and tabular presentation of detailed data. In some applications, it might prove helpful to supplement a primary graphic display with alternative displays of detailed data available as a user-selected option. (A,C,D,E)

1.2.4.1-2 Graphic Displays: Data Comparison (Tier 1 - Use)
When users must quickly scan and compare related sets of data, the data should be displayed in graphic format
COMMENT: Graphic display might help users discern errors in a data base, since deviant "outliers" will appear visually distinct from the body of correct data. (A,D,E)

1.2.4.1-3 Graphic Displays: Monitoring Data Change (Tier 1 - Use)
A graphic format should be used when users must monitor changing data.
COMMENT: Whenever possible, the computer should handle data monitoring and should call abnormalities to the user's attention. When that is not possible and a user must monitor data changes, graphic display will make it easier for the user to detect critical changes and/or values outside the normal range. (A,D,E)

1.2.4.1-4 Animation for Dynamic Display (Tier 1 - Use)
Movement of data elements under computer control can be used for displaying a temporal sequence of changing events, or for the pictorial display of complex objects.
COMMENT: Animation can be used to enhance a variety of graphic displays, including scatterplots, curves, bar graphs, flow charts, etc. (E)

1.2.4.1-5 Highlighting by Animation (Tier 1 - Use)
When sequential relations or other connectivity between display elements requires highlighting, animation may be used for that purpose.
COMMENT: For example, connectivity might be emphasized by an arrow moving repeatedly between two displayed elements. (E)

1.2.4.1-6 Simplicity (Tier 2 - Screen Organization)
Graphical displays should maintain the visually simplest display consistent with their function. In general, the fewest lines or objects in a graphical display should be used.
COMMENT: (D)

1.2.4.1-7 Consistency (Tier 2 - Consistency)
Consistent logic should be used in the design of graphic displays, and a standard format and labeling practices should be maintained for each method of graphic presentation.
COMMENT: Consistency in graphic design will allow users to focus on changes in displayed data without being distracted by changes in display format. The standardization advocated here has to do with the logic of user interface design, not with internal processing by graphics software. (A,E)

1.2.4.1-8 Consistent Annotation Format (Tier 2 - Consistency)
Any displayed annotation should be formatted consistently in relation to the graphic elements.
COMMENT: For example, labels might always be placed over the displayed points with which they are associated. Sometimes, however, it might be necessary to displace a label from its "standard" position to avoid overlap or crowding on the display; such exceptions should themselves be handled consistently. (A,E)

1.2.4.1-9 Emphasis (Tier 2 - Meaningfulness)
Graphical displays should be designed so that a user notices the most important things first.
COMMENT: (D)

1.2.4.1-10 Only Necessary Information Displayed (Tier 2 - Task Compatibility)
Graphic displays should be tailored to user needs and provide only those data necessary for user tasks.
COMMENT: (A,D,E)

1.2.4.1-11 Zooming for Display Expansion (Tier 2 - General)
When needed to perceive graphic relations accurately, or to view flow diagrams in greater detail, a zooming capability should be provided that allows expanion of the display of any selected area.
COMMENT: Zooming can increase the degree of detail (i.e., can add data to a display). When used this way, a zooming capability implies that graphic data be "layered" hierarchically at different levels of aggregation, which may require complex data files and data management techniques. Zooming might be implemented as a continuous function, by which a display can be expanded to any degree, analogous to a continuous panning capability. Or zooming might be implemented in discrete increments, as in increasing the magnification of an optical instrument to x2, x4, etc. Incremental zooming, with abrupt changes in display scale, may tend to disorient a user, but might prove acceptable in some applications. Zooming can increase display spacing among crowded data items so that they can be perceived better. Thus a control room operator might expand a portion of a Piping and Instrumentation Diagram to see more clearly the type of valves used within a particular line-up. (A,D,E)

1.2.4.1-12 Reference Index or Baseline (Tier 2 - General)
When a user must compare graphic data to some significant level or critical value, a reference index or baseline should be included in the display.
COMMENT: (C,E)

1.2.4.1-13 Highlighting Critical or Abnormal Data (Tier 2 - General)
When a user's attention must be directed to a portion of a graphic display showing critical or off-nominal data, some distinctive means of data coding should be used.
COMMENT: (C,E)

1.2.4.1-14 Data Annotation (Tier 2 - General)
When precise reading of a graphic display is required, the display should be annotated with actual data values to supplement their graphic representation.
COMMENT: For example, adjacent numeric annotation might be added to the ends of displayed bars on a bar graph; numeric data might be displayed to mark the points of a plotted curve. (C,E)

1.2.4.1-15 Text Annotation (Tier 2 - General)
When a graph contains some outstanding or discrepant feature that merits attention by a user, supplementary text should be displayed to emphasize that feature.
COMMENT: For example, a flow diagram for process control might include a current advisory message, POSSIBLE PRESSURE VALVE FAILURE, as well as appropriate graphic indications of the problem. (E)

1.2.4.1-16 Changing Scale (Tier 3 - Design Details)
When a graphic display has been expanded from its normal coverage, some scale indicator of the expansion factor should be provided.
COMMENT: For example, a linear indicator of current map scale might be shown in the margin, or perhaps simply a numeric indication of the display expansion factor (e.g., x4). In many applications it may be helpful to show the scale even for a display with normal, unexpanded coverage. (A,E)

1.2.4.1-17 Overview Position of Visible Section (Tier 3 - Design Details)
Some graphic indicator of the position in the overall display of the visible section should be provided when a display has been expanded from its normal coverage.
COMMENT: A graphic indication of the current coverage of an expanded display will provide some visual context

to help a user maintain a conceptual orientation between the visible part and the whole display from which that part has been expanded. For example, in a corner of any frame of an expanded display, the computer might show a rectangle representing the overall display, in which a smaller rectangle is placed to indicate the position and extent of the currently visible portion of that display. (A,E)

1.2.4.1-18 Printing Graphic Displays (Tier 3 - Design Details)
When on-line graphic displays must be printed, users should be allowed to display the material exactly as it will appear in the printed output.
COMMENT: On-line displays can offer some advantages over printed graphics, in terms of animation and highlighting. When a user is preparing a display for printed output, however, it is important that limitations of the print medium can be taken realistically into account. If the printed version does not appear satisfactory, it may be necessary to reformat the display in some way. (A,E)

1.2.4.1-19 Use of Data Display Codes (Tier 3 - Design Details)
Data display codes should be used only if two or more conditions need to be represented in a display that consists of a graph, diagram or map.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.2 Flowcharts

1.2.4.2-1 Appropriate Use of Flowcharts (Tier 1 - Use)
Flowcharts should be used for schematic representation of sequence information.
COMMENT: Flowcharts should be used for schematic representation of sequence information to display data that are logically related in terms of sequential processes. (A,E)

1.2.4.2-2 Flowcharts to Aid Problem Solving (Tier 1 - Use)
A flowchart should be provided to aid problem solving when a solution can be reached by answering a series of questions, and when no tradeoffs will be required.
COMMENT: A flowchart can add structure to complex problem solving by illustrating a set of discrete decision points. With such a flowchart, a user is given specific steps to follow in solving a problem, helping to ensure that all relevant factors are considered. For simple problems, however, a tabular or text format may be read more quickly than af flowchart. Flowcharts are not useful when a user must make tradeoffs. For example, if a user must evaluate alternative outcomes,then using a flowchart would be cumbersome and time consuming. When a user must evaluate alternatives, a tabular format may be more efficient. For example, n process control, a flowchart might aid problem diagnosis when a user must determine the cause of abnormal conditions and take appropriate action. (E)

1.2.4.2-3 Consistent Wording (Tier 2 - Consistency)
The options displayed at the decision points in a flowchart should be worded in a consistent format.
COMMENT: Sometimes it may not be possible to use a consistent format for displaying options. However, the more consistent a flowchart can be made in format and wording, the easier. (E)

1.2.4.2-4 Necessary Information (Tier 2 - Task Compatibility)
To the greatest extent possible, flowcharts should display only the data required by the user. The user should be able to request more detailed data with a single action.
COMMENT: (D)

1.2.4.2-5 Conventional Path Orientation (Tier 2 - General)
Flowcharts should be designed so that the path of the logical sequence is consistent with familiar orientation conventions.
COMMENT: For example, from left to right and from top to bottom, or clockwise. (A,D,E)

1.2.4.2-6 Ordering to Minimize Path Length (Tier 2 - General)
When there is no inherently logical order to the steps in a flowchart, steps should be ordered to minimize flowchart size
COMMENT: In other words, to minimize average path length. (A,E)

1.2.4.2-7 Highlighting (Tier 2 - General)
If one element in a flowchart represents data of particular significance, implying a special need for user attention, then that element should be highlighted.
COMMENT: For example, line coding by color or bolding might be used to highlight displayed paths, and/or the boxes or other graphic elements representing displayed states. (Color coding may be particularly appropriate in flowcharts, because of the effective primacy of color for guiding the visual scanning required to trace paths.) As a cautionary example, the flowchart instructions for a critical safety function status tree might highlight a box which says "ensure Reactor Coolant System pressure less than x before opening valve y". (D,E)

1.2.4.2-8 Consistent Ordering of Options (Tier 2 - General)
When a flowchart is designed so that a user must make decisions at various steps, the available options should be displayed in some consistent order from step to step.
COMMENT: For example, "yes" might always be on the left and "no" on the right. The point here is that for

options which have no inherently logical order, some order should be consistently imposed. Consistent ordering will permit a user to review a flowchart more quickly. (A,E)

1.2.4.2-9 Single Decision at Each Step (Tier 3 - Design Details)
When a flowchart is designed so that a user must make decisions at various steps, only a single decision should be required at each step; decisions should not be combined to reduce flowchart size.
COMMENT: (A,E)

1.2.4.2-10 Logical Ordering of Options (Tier 3 - Design Details)
When a flowchart is designed so that a user must make decisions at various steps, the available options should be displayed in some logical order.
COMMENT: For example, if options represent stages of a process, those stages should be listed in the order in which they would actually occur. The ordering of options should not be determined merely by the amount of space that is conveniently available to display them. (A,E)

1.2.4.2-11 Flowchart Symbol Set (Tier 3 - Design Details)
There should be a standard set of flowchart symbols. To the greatest extent possible, the symbols should be based on the standards for the task content.
COMMENT: (D)

1.2.4.2-12 Conventional Use of Arrows (Tier 3 - Design Details)
In flow charts and other graphics displays, arrowheads should be used in a conventional fashion to indicate directional relations in the sequential links between various elements.
COMMENT: (D,E)

1.2.4.2-13 Dynamic Flowchart Sizing (Tier 3 - Design Details)
The user should be able to enlarge or reduce the size of a flowchart. The line scale should reflect the change in overall scale.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.3 Pictures and Diagrams

1.2.4.3-1 Appropriate Use of Pictures (Tier 1 - Use)
Pictorial displays should be used in applications where it is necessary to show accurately detailed representations of real or imaginary objects or processes.
COMMENT: Pictorial displays aid in the analysis of objects and events, as in the case of photo interpretation. Pictorial displays also support a variety of computer-aided design applications. For some information handling tasks the display of detailed images (photographs) will help users. In other instances, simplified line drawings may be more readily comprehended. (A,E)

1.2.4.3-2 Appropriate Use of Diagrams (Tier 1 - Use)
Diagrams should be used to show spatial relations, with selective focus on the data specifically required by a user's task, in applications where a full pictorial rendering might be unnecessarily complicated.
COMMENT: Diagrams are used to support many applications, ranging from mechanical assembly/maintenance instruction to the representation of electronic circuitry and process control paths. Diagrams are considered a special form of picture. Diagrams should be kept as simple as possible, omitting unnecessary data. (A,E)

1.2.4.3-3 Display Only Necessary Information (Tier 2 - Meaningfulness)
Diagrams should display only the data required by the user. The user should be able to request more detailed data with a single action.
COMMENT: (D)

1.2.4.3-4 Highlighting (Tier 2 - General)
If a picture or diagram contains data of particular significance, implying a special need for user attention, those data should be highlighted.
COMMENT: For example, selected portions of pictures might be highlighted by adding a box outline to the display, or perhaps a blinking arrow. Diagram elements might be highlighted by bolding or video reversal, or perhaps by color coding. As another example, highlighting might be used to indicate an assessment of damage when monitoring a system that has been degraded in some way. (A,E)

1.2.4.3-5 Dynamic Diagram Sizing (Tier 2 - General)
The user should be able to enlarge or reduce the size of a diagram.
COMMENT: (D)

1.2.4.3-6 Rotation (Tier 3 - Design Details)
In an application where a user must examine a depicted object from different viewpoints, the user should be allowed to rotate its displayed image.
COMMENT: The axis of rotation will generally be the center of the depicted object. Where that is not the case, some indication of the rotation axis should be displayed. In some applications it might also help the user to display some explicit separate indication of the degree of rotation and the current orientation of the depicted object. In applications where a user must make a detailed comparison of two (or more) displayed objects, it may be necessary to allow independent rotation, translation and superposition of their images. (A,E)

1.2.4.3-7 Spatial Relationships (Tier 3 - Design Details)
Diagrams should show relative spatial relations accurately and should include a line scale describing the spatial relations.
COMMENT: (D)

1.2.4.3-8 Aids for Pictorial Analysis (Tier 3 - Design Details)
When users must analyze pictorial images in detail, computer aids should be provided.
COMMENT: For examining the internal structure of a depicted object, it might be helpful to allow a user to request

auxiliary displays of specified cross-sections or transect diagrams. For more detailed structural analysis of depicted objects, it might be necessary to provide computer aids for calculating area, volume, center of gravity, modes of vibration, stresses, heat transfer, etc. (A,E)

1.2.4.3-9 Linking Sectional Diagrams (Tier 3 - Design Details)

When diagrammed data exceed the capacity of a single display frame and must be shown in separate sections, an overview for the diagram should be provided.

COMMENT: A logical linking of its various sections, and an easy means for users to move from one section to another should be provided (e.g., panning). An alternative approach might be to construct a hierarchic diagram with a zooming capability to show greater detail. That capability represents a potential advantage of computer-generated electronic displays over printed diagrams. For example, the sections of a diagram might be assigned letter codes, which could be shown in the overview and at any internal branch points, and which could be entered by a user to request the display of various sections. (A,E)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.4 Maps and Situation Displays

1.2.4.4-1 Appropriate Use of Maps (Tier 1 - Use)
Maps should be provided to display geographic data.
COMMENT: Here the term "map" refers to the display of relatively stable geographic data, or the display of slowly changing data such as weather. When mapped data change more quickly, as in the display of plume tracks, those diagrams are called "situation displays". Design recommendations for maps will generally pertain also to situation displays. (A,E)

1.2.4.4-2 Qualitative Maps (Tier 1 - Use)
Qualitative distributional maps should be used to display relative geographical locations of different kinds of data .
COMMENT: (D)

1.2.4.4-3 Quantitative Maps (Tier 1 - Use)
Quantitative distributional maps should be used to display variations in quantities across different geographical locations.
COMMENT: (D)

1.2.4.4-4 Situation Displays (Tier 1 - Use)
When it is necessary to show the geographic location of changing events, event data should be combined with a map background.
COMMENT: For example, a display for radioactive control might superimpose plume tracks on a background of geographic coordinates, with supplementary annotation and/or coding to indicate track identification, speed, heading, altitude, etc. (A,E)

1.2.4.4-5 Tonal Codes (Tier 1 - Use)
Tonal codes (different shades of one color) rather than spectral codes (different colors) should be used when users must make relative judgments for different colored areas of a display.
COMMENT: People can order categories along a continuous dimension to match tonal variations in one color, whereas people do not have a natural means of ordering different colors. This recommendation represents an exception to other guidelines advocating distinctive code values. Coding by tonal variation should be considered only for applications where perception of relative differences along a single dimension is more important than perception of absolute values. (E)

1.2.4.4-6 Consistent Orientation (Tier 2 - Consistency)
When several different maps will be displayed, a consistent orientation should be used so that the top of each map will always represent the same direction.
COMMENT: In common use, most maps are oriented so that North is upward. (A,D,E)

1.2.4.4-7 Consistent Positioning of Labels (Tier 2 - Consistency)
Labels should be positioned on a map consistently in relation to the displayed features they designate.
COMMENT: As a practical matter, map displays can get very crowded. It may not always prove feasible to maintain a consistent placement for labels, with the result that designers will be tempted to put labels wherever they will fit. In such a crowded display, labels may obscure map features, and vice versa. Locating and reading labels will be slowed, particularly when map features are displayed closely adjacent to the beginning of labels. Under these circumstances, some other approach to map labeling should be considered to avoid crowding. (E)

1.2.4.4-8 Indicating Data Change (Tier 2 - General)
When changes in mapped data are significant for a user's task, auxiliary graphic elements should be included to indicate those changes.

COMMENT: For example, auxiliary coding might be needed to indicate vehicular movement on a map of showing evacuation routes. In dynamic maps (i.e., situation displays), data changes involving movement can be shown directly. On static displays, arrows can be added to indicate the direction of movement of mapped elements. Where movement over an extended area must be represented, directional "pips" can be added to displayed contour lines. (E)

1.2.4.4-9 Area Coding (Tier 2 - General)
Texture patterns, color, or tonal codes should be used when different areas of a map must be defined, or when geographic distribution of a particular variable must be indicated.
COMMENT: In many applications it may be desirable to limit area coding to one variable in order to assure effective information assimilation. Another approach might be to allow a user to specify which variable will be coded on a map and to change that selection at will depending upon current task requirements. In some special applications, however, it may be feasible to superimpose several kinds of area coding to permit multivariate data analysis by skilled users. (E)

1.2.4.4-10 Ordered Coding (Tier 2 - General)
Where different areas of a map are coded by texture patterns or tonal variation, the darkest to lightest shades correspond to the extreme values of the coded variable.
COMMENT: Orderly assignment of code values will help users perceive and remember the categories represented by the code. (E)

1.2.4.4-11 Feature Identification (Tier 2 General)
When it can be done without cluttering, significant features of a map should be labeled directly on the display.
COMMENT: (A,E)

1.2.4.4-12 Highlighting (Tier 2 - General)
If one area in a map represents data of particular significance, implying a special need for user attention, then that area should be highlighted.
COMMENT: (E)

1.2.4.4-13 Aids for Analyzing Maps (Tier 3 - Design Details)
When the use of mapped data may be complex, computer aids should be provided for data analysis.
COMMENT: (A,E)

1.2.4.4-14 Aiding Distance Judgments (Tier 3 - Design Details)
Computer aids should be provided when a user must judge distances accurately on a map or other graphic displayfor that judgment.
COMMENT: For exa.. measurement, it might be better to allow a user to select (point at) any two points and have the computer "read-out" their separation distance directly. The same technique might be used to determine the direction (bearing) between two points. (A,E)

1.2.4.4-15 User Selectable Orientation (Tier 3 - Design Details)
The user should be able to select different orientations and reference points. The system should provide the user with a menu listing the common orientations and reference points.
COMMENT: (D)

1.2.4.4-16 Panning for Flexible Display Framing (Tier 3 - Design Details)
When a map exceeds the capacity of a single display frame users should be provided a capability to pan the display frame over the mapped data in order to examine different areas of current interest.
COMMENT: (A,E)

1.2.4.4-17 Show Overview Position of Visible Section (Tier 3 - Design Details)
Some graphic indicator of the position in the overall display of the visible section should be provided when a user pans over an extended display in order to view different sections.

COMMENT: For example, in a corner of a panned display, the computer might show a rectangle representing the overall display, in which a smaller rectangle is placed to indicate the position and extent of the currently visible portion of that display. While panning across a map, moving from one section to another, a user may lose track of what is being displayed, and be uncertain how to move in order to see some other area of interest. An indicator of current position will help maintain user orientation. (A,E)

1.2.4.4-18 Mapping Non-geographic Data (Tier 3 - Design Details)

In applications where the geographic distribution of nongeographic data must be displayed, other graphic elements should be added to a map for that purpose.

COMMENT: Alphanumeric characters might be added to a map to show data, but those will not aid a direct visual comparison across areas in the same way that graphic symbols can do. Moreover alphanumeric data may be confused with labels and other kinds of annotation. For example, a symbol might be displayed in different sizes to indicate a particular measure in different localities, or small stacked bars might be superimposed on the different areas of a map to indicate the local distribution of some data measure. (E)

1.2.4.4-19 Identification of Map Data (Tier 3 - Design Details)

Where possible, demographic or other data on map displays should be presented graphically rather than by using text descriptions.

COMMENT: (A)

1.2.4.4-20 Stable Reference for Changing Data (Tier 3 - Design Details)

Some stable display elements should be provided when graphic data are changing and displays are automatically updated.

COMMENT: Moving data may overlay and temporarily obscure other display elements, such as fixed background data. When that happens, the display update logic must determine which data categories have priority on the display and which may be obscured by others, and should restore the obscured elements when the overlaid data moves away, and should further ensure that no data are erased from the display in the process of obscuring and restoring data. Stable display elements provide a frame of reference to help users assimilate and interpret data changes. (E)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.5 Instrument Panels

1.2.4.5-1 Software-based Instrument Displays (Tier 1 - Use)
Software-based displays of instruments should be displayable in a function area.
COMMENT: The panel should be contained in a labelled window and should be closely analogous to the hardware panel that is represented. Specific instruments on the panel should be clearly visible and should be labelled appropriately, following standards for hardware panel labels. (D)

1.2.4.5-2 When to Use Binary Displays (Tier 1 - Use)
Binary indicators should only be used for displaying information having two values.
COMMENT: The most common use of binary indicators in a process control environment is for alarm/warning devices. For quantitative measurements, binary indicators should be used only for check-reading purposes. (B)

1.2.4.5-3 Usability of Displayed Values (Tier 2 - Meaningfulness)
Information should be displayed in a directly usable form.
COMMENT: All displays should indicate values in a form immediately usable by the operator without requiring mental conversion. (B)

1.2.4.5-4 Increasing Scales (Tier 3 - Design Details)
Numbers should increase clockwise, left to right, or bottom to top, depending on the display design and orientation.
COMMENT: (B)

1.2.4.5-5 Scale Progression (Tier 3 - Design Details)
Graduation interval values of fixed scales should be 1, 2, 5, or decimal multiples thereof. Numbering by 1, 10, or 100 is recommended for progressions.
COMMENT: (B)

1.2.4.5-6 Scale Intervals (Tier 3 - Design Details)
Nine should be the maximum number of tick marks between numbers.
COMMENT: (B)

1.2.4.5-7 Circular Scales (Tier 3 - Design Details)
For one-revolution, circular scales, zero should be at 7 o'clock and the maximum value should be at 5 o'clock, with a 10-degree break in the arc
COMMENT: (B)

1.2.4.5-8 Location of Scale Values (Tier 3 - Design Details)
Numbers should be outside the graduation (tick) marks unless doing so would constrict the scale.
COMMENT: (B)

1.2.4.5-9 Orientation of Numbers (Tier 3 - Design Details)
All numbers should be oriented upright.
COMMENT: (B)

1.2.4.5-10 Location of Zero (Tier 3 - Design Details)
When check-reading positive and negative values, the zero or null position should be at 12 o'clock or 9 o'clock.
COMMENT: With a matrix of circular displays, deviations from a 9 o'clock null position are easily detected in check reading. Zero is at 12 on multi revolution dials. (B)

1.2.4.5-11 Pointer Orientation (Tier 3 - Design Details)

The pointer on fixed scales should extend from the right of vertical scales and from the bottom of horizontal scales.
COMMENT: (B)

1.2.4.5-12 Pointer Obscurement (Tier 3 - Design Details)
The pointer on fixed scales should extend to but not obscure the shortest graduation marks.
COMMENT: (B)

1.2.4.5-13 Tick Mark Separation (Tier 3 - Design Details)
Tick marks should be separated by at least 0.07 inches for a viewing distance of 28 inches under low illumination (0.03 to 1.0 fL).
COMMENT: (B)

1.2.4.5-14 Number of Tick Marks (Tier 3 - Design Details)
Dials should not be cluttered with more marks than necessary for precision.
COMMENT: (B)

1.2.4.5-15 Display Band Coding (Tier 3 - Design Details)
Zones should be color coded by edge lines or wedges. The colors red, yellow, and green should be used.
COMMENT: Zones can be used to indicate operating ranges, off-normal levels, dangerous levels, etc. (B)

1.2.4.5-16 Digital Displays Level of Accuracy (Tier 3 - Design Details)
Digital displays should include the appropriate number of significant figures for the required level of accuracy.
COMMENT: (B)

1.2.4.5-17 Digital Display Range (Tier 3 - Design Details)
Digital displays should accommodate the full range of the variable.
COMMENT: The full range of the variable means highest and lowest values that are predicted that the variable can obtain, under any conditions (normal operations, emergency operations, etc) for the tasks the display is designed to support. (B)

1.2.4.5-18 Rate of Change (Tier 3 - Design Details)
Digital displays should change slowly enough to be readable.
COMMENT: (B)

1.2.4.5-19 Direction of Change (Tier 3 - Design Details)
Digital displays should be provided with arrows to indicate the direction of change, if that is likely to be needed.
COMMENT: Rapidly changing digital values are difficult to read, and directional indicators will help the operator interpret the direction of trend. (B)

1.2.4.5-20 Binary Display Legends (Tier 3 - Design Details)
Legends should be worded to tell the status indicated by the display.
COMMENT: (B)

1.2.4.5-21 Distinguishability of Binary Controls/Displays (Tier 3 - Design Details)
The legends of illuminated indicators should be readily distinguishable from legend push buttons by form, size, or other factors.
COMMENT: This criterion has special emphasis to touch screen visual display terminals (e.g., CRTs) when touch panels are employed as a control device. (B)

1.2.4.6-1 Scaling Conventions (Tier 2 - Consistency)
Conventional scaling practice should be followed, in which the horizontal X-axis is used to plot time or the postulated cause of an event (the independent variable), and the vertical Y-axis is used to plot a caused effect (the dependent variable).
COMMENT: When the X-axis represents time intervals, the labeled scale points should represent the end of each time interval. This consistent usage will aid interpretation of all data plots, including scatterplots, line graphs, and bar charts. (A,D,E)

1.2.4.6-2 Consistent Scaling (Tier 2 - Consistency)
If users must compare graphic data across a series of charts, the same scale should be used for each chart.
COMMENT: Note that in many applications it may prove more effective to display data for comparison in a single combined chart, rather than requiring users to compare data across a series of charts. Users will find it difficult to compare data sets that are scaled differently. Moreover, users may overlook differences in labeling, and assume that the same scale has been used even when displayed scales are actually different from one another. (A,C,E)

1.2.4.6-3 Scales Consistent with Function (Tier 2 - Task Compatibility)
The scales should be consistent with the intended functional use of the data.
COMMENT: For example, the monitoring of neutron flux at reactor trip must have a variable scale of 0 to 100% of the design value and a time scale resolution of seconds. However, post-trip monitoring may have a variable scale of 0 to 10% with a time scale resolution of minutes. Finally, operational log data of neutron flux may have a time scale resolution of hours. (B)

1.2.4.6-4 Linear Scaling (Tier 2 - General)
A linear scale should be used for displayed data, in preference to logarithmic or other non-linear methods of scaling.
COMMENT: Most users are more familiar with linear scales and will interpret linear scales more accurately than other methods of scaling. However, since logarithmic scales show percentage change rather than arithmetic change, they may be appropriate for some special applications. (A,E)

1.2.4.6-5 Scaling in Standard Intervals (Tier 2 - General)
Scales should have tick marks at a standard interval of 1, 2, 5, or 10 (or their multiples by 10) for labeled divisions; intervening tick marks to aid visual interpolation should be consistent with the labeled scale interval.
COMMENT: Users will find it difficult to interpret scales based on odd intervals, even if computers do not. As a negative example, it is not acceptable to let the computer divide available scale space automatically if that results in a scale labeled in unfamiliar intervals such as 6 or 13. In special instances, the X-axis might be scaled in odd intervals to show customary divisions, such as the 12 months in a year. (A,D,E)

1.2.4.6-6 Numeric Scales Start at Zero (Tier 2 - General)
When users must compare aggregate quantities within a display, or within a series of displays, scaling of numeric data should begin with zero.
COMMENT: Numerical scales generally should have zero at the bottom as the first number on a vertical scale or at the left as the first number on a horizontal scale. The exceptions to this organization would be: a) if the numbers are used for naming categories, b) if zero is not a possible number on the scale, or c) if the scale contains negative numbers. If for any reason the zero point is omitted, the display should include a clear indication of that omission. (A,D,E)

1.2.4.6-7 Positive and Negative Values (Tier 2 - General)
When graphed data represent positive numbers, the graph should be displayed with the origin at the lower left, such that values on an axis increase as they move away from the origin of the graph.

COMMENT: When the data include negative values and the axes must extend in both directions from a zero point, that origin should be displayed in the center of the graph. (A,E)

1.2.4.6-8 Single Scale Only (Tier 2 - General)
Only a single scale should be shown on each axis, rather than including different scales for different curves in the graph.
COMMENT: Single-scale graphs will generally permit more accurate reading than graphs displaying several scales. Many users will be confused by multiple-scale graphs and make errors when interpreting them. Moreover, by changing the relative scale factors of multiple-scale graphs it is possible to change radically their apparent meaning and bias interpretation by users. (A,C,D,E)

1.2.4.6-9 Aids for Scale Interpolation (Tier 2 - General)
If interpolation must be made or where accuracy of reading graphic data is required, computer aids should be provided for exact interpolation.
COMMENT: For example, it might suffice to allow users to request a fine grid as an optional display feature; or it might be better to display vertical and horizontal rules that a user could move to intersect the axes of a chart; or it might prove best simply to let a user point at any data item and have the computer label that item with a readout of its exact value(s). (C,E)

1.2.4.6-10 Unobtrusive Grids (Tier 2 - General)
When grid lines are displayed, they should be unobtrusive and not obscure data elements (e.g., curves, plotted points).
COMMENT: Grid lines should be thinner than data curves, and should be invisible behind depicted objects and areas. Heavy vertical grid lines may conceal the height of plotted peaks. Electronic displays offer more flexibility than printed graphs. Grids can be displayed or suppressed by user selection. For reading the value of a particular data point, perhaps no grid is needed at all. A user might simply ask the computer to display the value of any selected point. (A,C,D,E)

1.2.4.6-11 Direct Display of Differences (Tier 2 - General)
Where users must evaluate the difference between two sets of data, that difference should be plotted directly as a curve in its own right, rather than requiring users to compare visually the curves that represent the original data sets.
COMMENT: (C)

1.2.4.6-12 Indicating Time (Tier 2 - General)
If time is plotted on the X axis, it should increase from left to right. If time is plotted on the Y axis, it should increase from top to bottom.
COMMENT: (B)

1.2.4.6-13 Numbering Grids (Tier 3 - Design Details)
Graphs should be constructed so that numbered grids are bolder than unnumbered grids. If ten-grid intervals are used, the fifth intermediate grid should be less bold than the unnumbered grids.
COMMENT: (B)

1.2.4.6-14 Restricted Use of Broken Axes (Tier 3 - Design Details)
When data comparisons of interest fall within a limited range, the scaled axis should emphasize that range, with a break in the displayed axis to indicate discontinuity with the scale origin.
COMMENT: Note, however, that a broken axis distorts the displayed amount in relation to a base value and so risks confusing users. In effect, a user will expect that a scale marked in regular intervals will continue in a consistent fashion. If an axis must be broken, label that break clearly, perhaps with some indicator that extends across the displayed graph. (A,D,E)

1.2.4.6-15 Duplicate Axes (Tier 3 - Design Details)
When scaled data will contain extreme values, duplicate axes should be displayed, so that the X-axis appears at both the top and bottom, and the Y-axis at both the left and right sides of the graph.
COMMENT: Extreme data values may be located far from conventionally placed axes. When duplicate axes are

displayed at the top and right side, users will find it easier to read the extreme values. (A,D,E)

1.2.4.6-16 Use of Multiple Scales (Tier 3 - Design Details)

At the user's request, the top and bottom x axes may be displayed with different scales.

COMMENT: When different scales are used, the numerical values for the scales should be displayed in different type fonts. (D)

1.2.4.6-17 Multiple Scales (Tier 3 - Design Details)

When two or more dependent variables are displayed in a line graph, the default condition should be that data be shown on separate two dimensional graphs.

COMMENT: The graphs should be in the same display. However, when requested by the user, two independent variables may be displayed on a common graph as follows: the left y- and right y- axes would use different scales, as may the top and bottom x-axes. When different scales are used, the numerical values for the scales should be displayed in different type fonts. (D)

1.2.4.6-18 Scaling Against a Reference Index (Tier 3 - Design Details)

If different variables on a single graph seem to require different scales, they should be scaled against a common baseline index, rather than showing multiple scales.

COMMENT: For example, rather than showing power in megawatts and profits in dollars, both might be graphed in terms of percent change from a baseline period. An indexed chart can permit comparisons among different variables when multiple scales would otherwise be needed. However, care should be taken in selecting an appropriate base period against which to index, in order to ensure that comparisons will not be biased. Index scaling may also be appropriate for showing the effect of a single variable whose units of measurement change in real value with time. (A,E)

1.2.4.6-19 Restricted Use of Three-Dimensional Scaling (Tier 3 - Design Details)

Unless required, use of three-dimensional scales (i.e., where a Z-axis is added to the display) should be avoided.

COMMENT: Showing a Z-axis on a display that is limited to two actual dimensions will confuse many users. If three-dimensional scaling is employed, a consistent method of representation (e.g., isometric or orthographic projection, perspective drawing, or triangular coordinate grid) should be used. It is often possible in graphic display to show a third dimension through use of auxiliary coding (e.g., color or shape coding, or supplementary annotation), which may prove more effective than trying to represent a third spatial dimension pictorially. (A,E)

1.2.4.6-20 Numerical Scale Value Alignment (Tier 3 - Design Details)

Numerical characters that represent a value on a numerical scale should be aligned by their decimal points.

COMMENT: For example, a scale being used to represent a continuous range of numbers rather than a nominal function. When whole numbers are displayed, a decimal point should be assumed. (D)

1.2.4.7-1 Appropriate Use of Curves and Line Graphs (Tier 1 - Use)
Curves (smoothed line) or line graphs (straight line segments) should be used for displaying relations between two continuous variables showing data changes over time.
COMMENT: Line graphs are regarded here merely as a special form of plotted curves, hence recommendations for displaying curves are intended to apply also to line graphs. Curves are generally superior to other graphic methods for speed and accuracy in interpreting data trends. Unlike printed graphs, computer-generated curves can show dynamic data change, as in oscilloscope displays. A curve implies a continuous function. Where that could be misleading, a better choice might be a bar graph composed of discrete display elements from one data point to the next. (A,D,E)

1.2.4.7-2 Preference for Graphs over Tables (Tier 1 - Use)
If the shape of a function is important in making decisions, a graph should be chosen rather than a table or scale.
COMMENT: Further, if data interpolation is necessary, graphs and scales should be used in preference to tables. (B)

1.2.4.7-3 Preference for Graphs over Bar Graphs (Tier 1 - Use)
For tasks requiring both time to estimate trends and accuracy, the line graph should be used rather than horizontal bar or column charts.
COMMENT: (B)

1.2.4.7-4 Surface Charts (Tier 1 - Use)
When curves represent all of the portions of a whole, a surface chart should be used. The areas defined below the curves should be textured or shaded.
COMMENT: Surface charts permit smooth, continuous display of data categories that might be represented in more discrete form by a set of segmented bars. Thus, recommendations for surface charts may be applied also to segmented bar charts. (A,E)

1.2.4.7-5 Consistent Line Codes (Tier 2 - Consistency)
When coding by line type in a series of displayed charts, line codes should be used consistently to represent corresponding data.
COMMENT: (A,E)

1.2.4.7-6 Interpreting Graphs (Tier 2 - Memory Load)
Curve and line graphs should convey enough information to allow the reader to interpret the data without referring to additional sources.
COMMENT: (A)

1.2.4.7-7 Trending Time Intervals (Tier 3 - Design Details)
Trend displays should be capable of showing data collected during time intervals of different lengths.
COMMENT: For example, a short time base of just a few minutes is needed to study fast changing trends, while other trends may not show significant changes for several hours. Although several variable trends may be grouped on the same display, it is very difficult to put an entire process overview in a single trend display. Grouped variables should be related, so the operator can correlate changes in one variable with changes in other key variables. (B)

1.2.4.7-8 Multiple Trend Lines (Tier 3 - Design Details)
Compared curve data should be displayed in one combined graph.
COMMENT: The objective here is an integrated display that will provide a user with all needed information. On the other hand, as more curves are added to a graph the user's task of comparison will become more difficult.

(A,C,D,E)

1.2.4.7-9 Safety Status Trends (Tier 3 - Design Details)
Time history displays of safety status parameters should present the 30-min interval immediately preceding the current real time.
COMMENT: Time history displays of parameters over a recent time interval are a preferred means of displaying trend and rate-of-change data. A time history of each safety status parameter for the thirty minutes immediately preceding current real time is acceptable. Availability of time history data displays on either the primary SPDS display format or on a secondary SPDS display format is acceptable. (B)

1.2.4.7-10 Single Value Line Chart (Tier 3 - Design Details)
On a parameter vs. parameter type chart, where one dimension is plotted against the other on an X-Y axis, the target area should be defined.
COMMENT: The classic display example is the pressure-temperature map, which presents a saturation curve that bisects the subcooled water region and the superheated steam region. This sort of display is best used for detecting deviations from normal if a target area can be defined. By plotting a brief time history, one may be able to predict where the values are headed. Care should be taken to distinguish the current value from past values, especially when the values change slowly. This can be done by placing an X or some other mark at the current value. (B)

1.2.4.7-11 Minimize Clutter on Single-Value Charts (Tier 3 - Design Details)
Old data points should be removed after some fixed period of time.
COMMENT: Ideally, as one new point is plotted the oldest point should be removed, thereby maintaining a constant number of displayed points. (B)

1.2.4.7-12 Line Coding to Distinguish Curves (Tier 3 - Design Details)
When multiple curves are displayed in a single graph then line coding should be provided.
COMMENT: Line coding must be provided particularly if curves approach and/or intersect one another. Line coding is required to distinguish one curve from another. (A,E)

1.2.4.7-13 Highlighting Multiple Curves (Tier 3 - Design Details)
In charts displaying multiple curves, if one curve represents data of particular significance, then that curve should be highlighted .
COMMENT: For example, if one curve represents critical/discrepant data, that curve might be displayed with a noticeably thicker line stroke or in a different color. If line coding is already used to distinguish among multiple curves, then the means of highlighting any particular curve should be selected so that it will not be confused with coding for visual separation. For example, if displayed curves are distinguished by line codes (solid, dashed, dotted, etc.), then one curve might be highlighted by displaying it in a different color. (A,E)

1.2.4.7-14 Multiple Paramcters: Identification (Tier 3 - Design Details)
When more than one parameter is presented in a plot, there should be means of identifying each individual parameter.
COMMENT: (B)

1.2.4.7-15 Multiple Parameters: Grouping (Tier 3 - Design Details)
When more than one parameter is displayed on a plot, the grouping of parameters should enhance the operator's assessment of the safety status of the plant.
COMMENT: (B)

1.2.4.7-16 Linear Profile Chart (Tier 3 - Design Details)
A horizontal line representing normal operating conditions should be superimposed on the display.
COMMENT: (B)

1.2.4.7-17 Linear Profile Pattern Recognition (Tier 3 - Design Details)
The chart should be designed so that it forms recognizable geometric patterns for specific abnormal conditions.
COMMENT: The linear aspect of this display format is confusing and makes pattern recognition marginal, but it is

considered adequate for determining the problem as well as severity. For example, an irregular profile would be indicative of abnormal operating conditions. (B)

1.2.4.7-18 Coding Linear Profile Charts (Tier 3 - Design Details)

The area below the profile line should be shaded to provide a more distinguishable profile.

COMMENT: (B)

1.2.4.7-19 Labeling Linear Profile Charts (Tier 3 - Design Details)

Labels should be provided along the bottom to identify each parameter.

COMMENT: (B)

1.2.4.7-20 Circular Profile Chart (Tier 3 - Design Details)

The circular profile chart should be designed so that it forms a recognizable geometric pattern for specific abnormal conditions.

COMMENT: Under normal operating conditions, the profile should be circular. An irregular profile is indicative of an abnormal operating condition. As the user becomes experienced with the circular profile, the asymmetrical polygons that result from off-normal situations should become more familiar. For example, a steam generator tube rupture may result in an hourglass shape or a loss-of-coolant accident might produce a cloverleaf design. (B)

1.2.4.7-21 Labeling Circular Profile Displays (Tier 3 - Design Details)

Labels should be provided to identify each radial line.

COMMENT: (B)

1.2.4.7-22 Coding Circular Profile Displays (Tier 3 - Design Details)

The area within the profile should be shaded to enhance the operator's perception of plant status.

COMMENT: (B)

1.2.4.7-23 Broken Lines for Projected Curves (Tier 3 - Design Details)

Curves representing planned, projected or extrapolated data (e.g., broken, dashed or dotted lines) should be distinctive from curves representing actual data (e.g., solid curves).

COMMENT: (A,E)

1.2.4.7-24 Cumulative Curves (Tier 3 - Design Details)

Cumulative curves may be used to show the current total at any point. Cumulative curves should not be used to extract quantitative or rate of change data.

COMMENT: Cumulative curves tend to "wash out" local variations in the displayed data. The rate of change in incremental data can be estimated by judging the slope of a cumulative curve at any point, but that is hard to do. (A,E)

1.2.4.7-25 Repeating Display of Cyclic Data (Tier 3 - Design Details)

Where curves represent cyclic data, the graph should be extended to repeat uncompleted portions of the displayed cycle.

COMMENT: The intent here is to allow users to scan any critical portion of the displayed cycle without having to return visually to the beginning of the plot. How much extension is desirable will depend on the particular application. In short, data that are used together should be displayed together. (A,E)

1.2.4.7-26 Ordering Data in Surface Charts (Tier 3 - Design Details)

The data categories in a surface chart should be ordered so that the least variable curves are displayed at the bottom and the most variable at the top.

COMMENT: Sometimes there are independent logical grounds for the ordering of data categories. If a surface chart constructed on a logical basis produces confusing irregularity of curves, then it might be better to display the data in some other graphic format. In a surface chart, any irregularity in the bottom curve will "propagate" throughout the curves above it, which will make it difficult for a user to distinguish whether apparent irregularity in upper curves is real or merely a consequence of this method of presentation. (A,E)

1.2.4.7-27 Labeling Surface Charts (Tier 3 - Design Details)

Where space permits, the different areas of surface charts should be labeled directly within the textured or shaded bands.
COMMENT: (A,E)

1.2.4.7-28 Band Charts (Tier 3 - Design Details)

All items on a band chart should be related to the total.
COMMENT: A band chart contains a series of bands depicting the components of a total series. The values of the bands (or strata) are plotted on an X-Y plot. Each of the bands are added to one another so that the topmost boundary represents the sum of all bands. For example, band charts can be used to show how much each turbine is contributing to total flow. This format is most useful when all elements contribute equally to the total under normal circumstances. Band charts should not be used when changes in the movement of a series are abrupt, or where accurate reading of a component is of paramount importance. (B)

1.2.4.7-29 Reference Index (Tier 3 - Design Details)

When curves must be compared with some critical value, a reference index in the chart to aid that comparison should be included.
COMMENT: In such cases, the index might be displayed as a horizontal or vertical line, or perhaps as a reference curve of some kind. (A,E)

1.2.4.7-30 Compatible Ordering in Legends (Tier 3 - Design Details)

If a legend must be displayed, the codes in the legend should be ordered to match the spatial order of their corresponding curves in the graph itself.
COMMENT: If legends are shown for a series of related graphs, then adopt some logical order consistently for all of those legends. (A,E)

1.2.4.7-31 Screen Area of Coverage (Tier 3 - Design Details)

Graphs should exceed eight degrees of visual angle.
COMMENT: Figures composed of distinct smaller elements are perceived holistically when less than eight degrees of visual angle in size. The perception of the smaller elements predominates when the figure is greater than eight degrees. (D)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.8 Bar/Column Graphs and Histograms

1.2.4.8-1 Appropriate Use of BarGraphs and Histograms (Tier 1 - Use)
Bar graphs should be used when comparing a single measure across a set of several entities, for a variable sampled at discrete intervals, for a variable at different times, or to show apportionment of a total into its component parts.
COMMENT: The value of the bar graph format, as with other graphic displays, is to speed information assimilation by a user. In some applications, however, a us · can scan displays in a leisurely way, as when reviewing printed output. In such cases, the data shown in a bar graph could often be presented more economically (i.e., more compactly) by a textual description or in a small table. (A,C,D,E)

1.2.4.8-2 Histograms (Tier 1 - Use)
Histograms (bar graphs without spaces between the bars) may be used when there are a great many entities or intervals to be plotted.
COMMENT: Histograms are often used to plot frequency data, i.e., the frequency of observations for each of many intervals scaled along the X- axis. For such applications, a histogram will avoid the "picket fence" appearance which might result from spaces between bars. (A,C,E)

1.2.4.8-3 Stroke Type Charts (Tier 1 - Use)
Stroke type charts can be used as alternatives to conventional full bars.
COMMENT: (B)

1.2.4.8-4 Vertical Bar Charts (Tier 1 - Use)
Column charts or vertical bar charts should be used when the direction of change of the measurement is to be emphasized or when time is represented by one of the axes of the chart.
COMMENT: Column charts can be more effective than line graphs in displaying a single set of data which covers a short period of time (e.g., data measure over a period of a week). (B,D)

1.2.4.8-5 Stacked or Segmented Bars (Tier 1 - Use)
Stacked bars, in which differently coded segments are shown cumulatively within a bar, should be used when both the total measures and the portions represented by the segments are of interest.
COMMENT: (A,E)

1.2.4.8-6 Consistent Orientation of Bars (Tier 2 - Consistency)
In a related series of bar graphs, a consistent orientation of the bars (vertical or horizontal) should be adopted.
COMMENT: If bar length is used to represent time duration, then it might be more appropriate to orient the bars horizontally, in accord with the general convention of plotting time on the horizontal axis of a graph. Vertical bars can be used to display frequency counts or a large variety of other measured attributes. (A,E)

1.2.4.8-7 Reference Index for Normal Operations (Tier 2 - General)
Bar charts should contain reference(s) to the normal operating condition(s).
COMMENT: With references showing normal parameter operating values, the operators are more likely to notice deviations from normal conditions. (B)

1.2.4.8-8 Reference Index for Critical Values (Tier 2 - General)
A reference index should be included in the chart when the extent of displayed bars must be compared with some critical value.
COMMENT: Indexing may be complicated in situations where the displayed bars do not represent a common measure. In such a case, it might help to choose (or devise) an index scheme so that bar lengths will fall in the same zone under normal conditions, so that deviations in bar length will be readily noticed by users who must monitor changing data. For example, a horizontal line might be an adequate reference index for a vertical bar graph.

(A,E)

1.2.4.8-9 Bar Spacing (Tier 2 - General)
When data must be compared, bars should be adjacent to one another. Adjacent bars should be spaced such that a direct visual comparison can be made without eye movement.
COMMENT: In this regard, the spacing between bars should be less than the bar width. If there are a great many bars to be displayed, then spacing will produce an alternating pattern of bright and dark bands that could prove visually disturbing. (A,C,E)

1.2.4.8-10 Paired or Overlapped Bars (Tier 2 - General)
When paired measures from two data sets must be compared, each pair should be displayed as contiguous or (partially) overlapped bars.
COMMENT: For example, a common application of paired data is the display of planned versus actual quantities. Paired bars will permit a direct visual comparison by the user. When more than two data sets must be compared, a display of grouped bars will be less effective. As the number of matched items becomes larger, it might be better to display the [illegible] sets in separate bar graphs, or to allow users to select different sets of data for simultaneous display.
(E)

1.2.4.8-[illegible] Highlig[illegible] (Tier 3 - Design Details)
In a simple [illegible] one bar represents data of particular significance, then that bar should be highlighted.
COMMENT: If one [illegible] represents critical/discrepant data, then that bar might be coded differently, for example, using solid black rath[illegible] than cross-hatched highlighting. However, if bar coding is already used for other purposes, such as to distinguish among different sets of grouped bars, then no additional highlighting code should be superimposed on the bars themselves; perhaps some other means of highlighting (e.g., an arrow) might be add[illegible].
(E)

1.2.4.8-12 Ordering Data in Stacked Bars (Tier 3 - Design Details)
In stacked bars, the data categories should be ordered within each bar in the same sequence, with the least variable categories displayed at the bottom and the most variable at the top.
COMMENT: In effect, a series of stacked [illegible] is analogous to the stacked curves of a surface chart. (A,E)

1.2.4.8-13 Restricted Use of Icons (Tier 3 - Design Details)
Iconic symbols of varying size (rather than simple bars) should be used to represent quantitative values in bar graphs only in special cases when unambiguous icons can be provided and when no interpolation will be necessary.
COMMENT: In general, use of icons to represent quantitative information should be avoided. Icons are often ambiguous, and so must be explained somewhere on the display. In addition, users will find it difficult to interpolate using icons. (A,E)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.9 Pie Charts

1.2.4.9-1 Restricted Use of Pie Charts (Tier 1 - Use)
A pie chart should be used only to show the relative distribution of data among categories.
COMMENT: In other words, for displaying data that represent proportional parts of a whole. Pie charts should not be used when the viewer is to extract quantitative information; a bar graph will permit more accurate interpretation for such applications. Multiple pie charts will not permit accurate comparison of different totals, although different-sized pies can be used to indicate gross differences. Stacked bar graphs will prove more effective for this purpose and should be used when it is necessary to show proportions of different totals. (A,E)

1.2.4.9-2 Numeric Labels (Tier 2 - General)
Numbers should be added to pie chart segment labels to indicate the percentage and/or absolute values represented in the display index.
COMMENT: (E)

1.2.4.9-3 Highlighting (Tier 2 - General)
If a particular segment of a pie chart requires emphasis, it should be highlighted by special hatching or shading and/or by "exploding".
COMMENT: "Exploding" means displacing it slightly from the remainder of the pie. (A,E)

1.2.4.9-4 Partitioning the Pie (Tier 3 - Design Details)
Partitioning should be limited to five segments or less.
COMMENT: (A)

1.0 INFORMATION DISPLAY
1.2 Types of Displays
1.2.4 Graphics
1.2.4.10 Scatterplots

1.2.4.10-1 Appropriate Use of Scatterplots (Tier 1 - Use)

Scatterplots can be used to show variable correlations or the distribution of points in space.

COMMENT: Scatterplots, as the name implies, are sometimes used to show a dispersal intended to indicate non-correlation of variables. But scatterplots may not be convincing for that purpose, because users will often perceive or imagine patterns in scattered data points where none actually exist. Note that scatterplots cannot be shown effectively in most forms of three-dimensional spatial representation because of inherent display ambiguities. (Here the triangular grid might be considered an exception.) A third dimension might be represented by coding the symbols used to plot different data categories. If that is done, however, the visual correlation between any two variables in the scatterplot will be obscured. Curves can be superimposed on scatterplots (data plotted as points in a two- dimensional graph) to indicate computed data trends, correlations, or other derived statistical measures, thus combining two types of graphic display. (A,D,E)

1.2.4.10-2 Highlighting (Tier 2 - General)

If some plotted points represent data of particular significance, they should be highlighted to make them visually distinctive from others.

COMMENT: Significant data points might be highlighted by bolding, color, blinking, shape coding, or other means, or might be designated by supplementary display annotation. (A,E)

1.2.4.10-3 Grouping Scatterplots to Show Multiple Relations (Tier 3 - Design Details)

When relations among several variables must be examined, an ordered group (matrix) of scatterplots should be displayed, each showing the relation between just two variables.

COMMENT: The ordering of several scatterplots in a single display might help a user discern relations among interacting variables. (A,E)

1.2.4.10-4 Interactive Analysis of Grouped Scatterplots (Tier 3 - Design Details)

When scatterplots are grouped in a single display to show relations among several variables, an interactive aid should be provided for analysis so that if a user selects a set of data in one plot then the corresponding data points in other plots will be highlighted.

COMMENT: Data selection might be accomplished by "brushing" a scatterplot with a superimposed box of controllable size to define the data set of interest. That technique can exploit the capabilities of interactive graphics to permit a range of data analysis not possible when using printed graphs. (E)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.1 General

1.3.1-1 Display Update Rate (Tier 2 - Task Compatibility)
The rate of update should be controllable by the user and should be determined by the use to be made of the information. The maximum update rate should be determined by the time required for the user to identify and process the changed feature of the display.
COMMENT: The minimum and maximum update rate should be determined by the requirements of the user's informational needs and rate of cognitive processing of the information by the user for each type of task. (C,D)

1.3.1-2 Freeze Feedback (Tier 2 - Feedback)
An appropriate label should be provided to remind the operator when the display is in the freeze mode.
COMMENT: (C)

1.3.1-3 Number System (Tier 2 - General)
When numeric data is displayed or required for control input, such data should be in the decimal, rather than binary, octal, hexadecimal or other number system.
COMMENT: (C)

1.3.1-4 Parameter Validity Check (Tier 2 - General)
The system should support the user in monitoring: critical parameters, parameters that change very rapidly, and parameters that change very slowly. The system should alert the user when values are out of range.
COMMENT: Users may not be able to perceive the values of changed parameters if the update rate is very fast. For slowly changing data, fixation on a display for an extended period of time (1-10 minutes) may result in selective adaptation. This lowers sensitivity to a stimulus similar to the one fixated upon. Long term fixation to an unchanging display may result in delayed reaction time to an updated stimulus which is similar in form. (D)

1.3.1-5 Display Freeze or Snapshot (Tier 2 - General)
A display freeze mode should be provided to allow close scrutiny of any selected frame that is updated or advanced automatically by the system.
COMMENT: For frozen display frames, an option should be provided to allow resumption at the point of stoppage or at the current real-time point. (C,D)

1.3.1-6 Continuous vs. Discrete Data Changes (Tier 3 - Design Details)
Continuous changes should be used to present real-time data or to show trends in recorded data. Discrete changes should occur at the user's request or as some standard increment is reached by real-time data values.
COMMENT: (D)

1.3.1-7 Continuous Viewing Requirement (Tier 3 - Design Details)
When the requirements of an operation-monitoring task dictate that current data changes be continuously viewed, the user should have the option of simultaneously viewing the "snapshot" display and the continuous display.
COMMENT: (D)

1.3.1-8 Changing Values (Tier 3 - Decign Details)
Changing alphanumeric values which the operator must reliably read should not be updated more often than once per second.
COMMENT: Changing values which the viewer uses to identify rate of change or to read gross values should not be updated faster than 5 times per second, nor slower than 2 per second, when the display is to be considered as real-time. (C)

1.3.1-9 Display Motion (Tier 3 - Design Details)
Items on a graphic display should not move faster than 60 degrees per second of visual angle, with 20 degrees per second preferred.
COMMENT: During motion, gross visual attributes and spatial orientation are usually preserved while small details may be lost or processing slowed. Perception of fast moving stimuli may be incomplete. (D)

1.3.2.1-1 Distinctive Cursor (Tier 2 - General)
Cursors should have distinctive visual features (shape, blink, or other means of highlighting).
COMMENT: A cursor is the most immediate and continuously available form of user guidance, since it will generally mark the current focus of user attention. Different cursor formats may denote different operational conditions. If that is done, each of those different cursors should be distinctive from other displayed items, and from each other. An underscore cursor would be difficult to see on a display of underscored text, or on a graphical display containing many other lines. If the cursor is changed to denote different functions (e.g., to signal deletion rather than entry), then each different cursor should be distinguishable from the others. If multiple cursors are used on the same display (e.g., one for alphanumeric entry and one for line drawing), then each cursor should be distinguishable from the others. (D,E)

1.3.2.1-2 Non-Distracting Design (Tier 2 - General)
The cursor should not be so distracting as to impair the searching of the display for information unrelated to the cursor.
COMMENT: (B)

1.3.2.1-3 Stable Cursor (Tier 2 - General)
The displayed cursor should be stable.
COMMENT: I.e., it should remain where it is placed until moved by the user (or by the computer) to another position. The intent of the recommendation here is to avoid unwanted "drift". Some special applications, such as aided tracking, may benefit from computer-controlled cursor movement. (E)

1.3.2.1-4 Consistent Cursor Positioning (Tier 2 - General)
When entering a display, the computer should automatically positions the cursor in a consistent display location.
COMMENT: For example, for data entry displays, the cursor should be placed initially at the first data field. (E)

1.3.2.1-5 Cursor Selection Area (Tier 3 - Design Details)
When cursors are used in selecting display areas, a large area for pointing should be provided, including the area of the displayed text label, plus a half-character distance around the label.
COMMENT: (A)

1.3.2.1-6 Multiple Pointing Cursor Control Devices (Tier 3 - Design Details)
When there are multiple cursor control/pointing devices, a unique pointing cursor shape should be associated with each device.
COMMENT: (D)

1.3.2.1-7 Unique Shapes (Tier 3 - Design Details)
Cursors of different shapes should be used for different purposes.
COMMENT: The shape of a cursor should reflect the state of the system or processing mode. A specific cursor should be uniquely assigned to a specific purpose to provide state or mode information to the user. A straight line cursor might be used as the placeholder cursor to indicate entry position in a word processing task, an arrow might be used as a pointing cursor to indicate screen structures, and an X-shaped pointing cursor might be used when the user cannot interact with the system. Within this general framework, the number of cursor shapes used should be kept to a minimum. (D)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.2 Cursor
1.3.2.2 Pointing Cursors

1.3.2.2-1 Pointing Cursor Visibility (Tier 2 - General)
The pointing cursor should be visible to the user at all times and may obscure characters unless it interferes with performance within an application.
COMMENT: To maintain pointing cursor quality, the cursor should obscure other characters, not vice versa. (D)

1.3.2.2-2 Pointing Cursor Blink (Tier 2 - General)
The pointing cursor should not blink.
COMMENT: (D)

1.3.2.2-3 Pointing Cursor: Image Quality (Tier 3 - Design Details)
Pointing cursors should maintain image quality throughout an entire range of motion within the display. The position of the pointing cursor should be clearly visible during movement from one screen position to another. Flicker should be minimized.
COMMENT: (D)

1.3.2.2-4 Pointing Cursor Shape (Tier 3 - Design Details)
To the greatest degree possible, pointing cursors should be completely graphic and should not contain a label.
COMMENT: However, if a pointi. g cursor includes a label, the text should be large enough to be readable. (D)

1.3.2.2-5 Pointing Cursor: Size Constancy (Tier 3 - Design Details)
The pointing cursor should maintain its size across all screen and display locations.
COMMENT: (D)

1.3.2.2-6 Pointing Cursor: Movement (Tier 3 - Design Details)
The movement of the pointing cursor should appear to the user to be smooth and continuous with smooth and continuous movement of the cursor control device. The pointing cursor should not move in the absence of any input from the user.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.2 Cursor
1.3.2.3 Placeholder Cursors

1.3.2.3-1 Placeholder Cursor Visibility (Tier 2 - General)
The placeholder cursor should only be visible when text entry is possible.
COMMENT: (D)

1.3.2.3-2 Identification of Placeholder Cursor (Tier 2 - General)
At the initiation of a task, an application, or a new display, the user should be able to determine the location of the placeholder cursor without an extensive search. Following the initial placement of the placeholder cursor, the position of the cursor should be under the user's control.
COMMENT: For example, the cursor might be placed initially at the first data field in a data form, at the upper left corner of a blank display in a word processing task, and immediately following the last character of a word processing display containing alphanumeric characters. (D)

1.3.2.3-3 Placeholder Cursor Blink (Tier 2 - General)
If placeholder cursor blinking is to be used to direct the user's attention, the default blink rate should be 3 Hz.
COMMENT: A blinking cursor need not obscure characters -- for example, the blinking cursor may be an underline that does not cover the entire character. (D)

1.3.2.3-4 Nonobscuring Placeholder Cursor (Tier 3 - Design Details)
The placeholding cursor should not obscure any other character displayed in the position designated by the cursor.
COMMENT: As an example, a block cursor might employ brightness inversion ("reverse video"). (A,E)

1.3.2.3-5 Number of Placeholder Cursors (Tier 3 - Design Details)
There should be only one placeholder cursor per window.
COMMENT: (D)

1.3.2.3-6 Placeholder Cursor Size (Tier 3 - Design Details)
The placeholder cursor should assume the height and/or width of the text characters adjacent to it.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.3 Text, Style, Character

1.3.3-1 Consistent Text Format (Tier 2 - Consistency)
A consistent format should be used from one display to another when textual material is formatted, as in structured messages,.
COMMENT: (A,E)

1.3.3-2 Consistent Word Spacing (Tier 2 - Consistency)
Consistent spacing between the words of displayed text should be maintained, with left justification of lines and ragged right margins.
COMMENT: Reading is easier with constant spacing, which outweighs the advantage of an even right margin achieved at the cost of uneven (nonproportional) spacing. Uneven spacing is a greater problem with narrow column formats than with wide columns. Uneven spacing handicaps poor readers more than good readers. Right justification with nonproportional spacing (fill justified) slows reading time. Right justification should only be employed if it can be achieved by variable spacing, maintaining constant proportional differences in spacing between and within words, and consistent spacing between words in a line. (A,D,E)

1.3.3-3 Conventional Text Display (Tier 2 - Meaningfulness)
Computer-generated displays of textual data, messages, or instructions, should generally follow design conventions for printed text.
COMMENT: Adoption of familiar design conventions for text display will permit users to rely on prior reading skills. (A,E)

1.3.3-4 Conventional Punctuation (Tier 2 - General)
Conventional punctuation should be used in textual display; sentences should end with a period or other special punctuation.
COMMENT: (A,E)

1.3.3-5 Clarity of Wording (Tier 2 - General)
Text displays, especially text composed for user guidance, should employ simplicity and clarity of wording.
COMMENT: (A,E)

1.3.3-6 Distinct Wording (Tier 2 - General)
Distinct words rather than contractions or combined forms should be used, especially in phrases involving negation.
COMMENT: For example, "will not" should be used rather than "won't." This practice will help users understand the sense of a message. (A,E)

1.3.3-7 Conventional Use of Mixed Case (Tier 2 - General)
Text should be presented using upper and lower case characters.
COMMENT: Reading text is easier and faster when capitalization is used conventionally to start sentences and to indicate proper nouns and acronyms. There are several exceptions, however. An item intended to attract the user's attention, such as a label or title, might be displayed in upper case. Also, upper case should be used when lower case letters will have decreased legibility, e.g., on a display terminal that cannot show true descenders for lower case letters. (A,D,E)

1.3.3-8 Time-insensitive Character Recognition (Tier 3 - Design Details)
The height of characters for reading tasks in which identification of individual characters is not time-critical should be 10 minutes of arc minimum.
COMMENT: (F)

1.3.3-9 Readability (Tier 3 - Design Details)

The minimum character height should be 16 minutes of arc and the maximum character height should be 24 minutes of arc for tasks in which readability is important.
COMMENT: Character heights of 20 to 22 minutes of arc are preferred for reading tasks. (F)

1.3.3-10 Legibility (Tier 3 - Design Details)
A minimum character height should be 16 minutes of arc for tasks in which legibility is important.
COMMENT: The preferred character height for these tasks is 20 to 22 minutes of arc. Characters should not be larger than 45 minutes of arc when groups of characters are displayed. (F)

1.3.3-11 Character Format/Aspect Ratio (Tier 3 - Design Details)
A 4x5 (width-to-height) character matrix should be the minimum matrix used for superscripts a... for numerators and denominators of fractions that are to be displayed in a single character position.

COMMENT: The 4x5 matrix may be used also for alphanumeric information not related to the user's task, such as copyright identification. A 5x7 (width-to-height) character matrix should be the minimum matrix used for numeric and uppercase-only presentations. The vertical height should be increased upward by two dot positions if diacritical marks are used. A 7x9 (width-to-height) character matrix should be the minimum matrix for tasks that require continuous reading for context, or when individual alphabetic character legibility is important, such as in proofreading. The vertical height should be increased upward by two dot (pixel) positions if diacritical marks are used. If lower case is used, the vertical height should be increased downward by at least one dot (pixel) position, preferably two or more, to accommodate descenders of lower case letters. Stroke width should be greater than 1/12 of the character height. A stroke width may be more than one pixel wide. (F)

1.3.3-12 Character Height-to-Width Ratio (Tier 3 - Design Details)
For fixed (as opposed to proportionally spaced) column presentations, the height-to-width ratio should be between 1:0.7 to 1:0.9. For display formats requiring more than 80 characters on a line, ratios as low as 1:0.5 are permitted
COMMENT: For proportionally spaced presentations, a height-to-width ratio closer to 1:1 should be permitted for some characters, for example, the capital letters M and W. The height-to-width ratio of a given character is the vertical distance between the top and bottom edges, and the left and right edges of a nonaccented capital letter. Some letters, however, are customarily seen as narrower than others. For example, in a given character set the letter I, and sometimes the letter J, appear narrower than M and 2. Lowercase letters may similarly vary in width. Accordingly, the height-to-width ratio of a given character set should be the modal character width - that is, the width that occurs most often - in the set of capital letters. These measurements are to be made at the same luminance level as the resolution measurement. (F)

1.3.3-13 Character Height (Tier 3 - Design Details)
The default value for character height should be 15.0 to 22.0 minutes of arc, with 20.0 minutes of arc preferred.
COMMENT: Minutes of arc can be converted into height in millimeters as follows: Height (in mm) = $2\pi D(MA)/21600$, where MA is minutes of arc, and D is the distance from the user to the screen (in mm). (D)

1.3.3-14 Character Width (Tier 3 - Design Details)
The default value for character width should be 60% to 80% of the upper case character height
COMMENT: (D)

1.3.3-15 Inter-Word Spacing (Tier 3 - Design Details)
A minimum of one character width (capital N for proportional spacing) should be used between words.
COMMENT: (F)

1.3.3-16 Inter-Line Spacing (Tier 3 - Design Details)
A minimum of two stroke widths or 15 percent of character height, whichever is greater, should be used for spacing between lines of text.
COMMENT: The space between lines of text should not be used for uppercase accent marks or for lower case

descenders of characters. (F)

1.3.3-17 Inter-Character Spacing (Tier 3 - Design Details)
Between-character spacing should be a minimum of 10 percent of character height.
COMMENT: (F)

1.3.3-18 Interline Spacing (Tier 3 - Design Details)
Spacing between lines of character groups should be at least one-third to one-half the height of the tallest character.
COMMENT: (D)

1.3.3-19 Interline Serif Spacing (Tier 3 - Design Details)
The space between the tallest character of a lower line should not be less than one stroke width from a character above it that projects below the line.
COMMENT: (D)

1.3.3-20 Separation of Paragraphs (Tier 3 - Design Details)
Displayed paragraphs of text should be separated by at least one blank line.
COMMENT: (A,E)

1.3.3-21 Justification Options (Tier 3 - Design Details)
Right justification and fill-justification options should be available to the user.
COMMENT: (D)

1.3.3-22 Line Length Options (Tier 3 - Design Details)
Users should have the ability to change the line length for an entire text file or for any particular section of a file, down to a specific line.
COMMENT: (D)

1.3.3-23 Default Line Length (Tier 3 - Design Details)
The default condition for line length should be between 52 and 80 characters.
COMMENT: Line lengths of less than 52 characters result in slower reading times, but line lengths from 52 to 78 characters do not produce differences in reading time. However, 80 characters is more standard than 78 characters. (D)

1.3.3-24 Default Margin Settings (Tier 3 - Design Details)
The default values for the margins in a text file should be set to permit viewing of all of the characters in the entire horizontal line.
COMMENT: (D)

1.3.3-25 Setting Tabs (Tier 3 - Design Details)
Users should have the ability to set tabs for any particular section of a text file, including the entire file.
COMMENT: (D)

1.3.3-26 Changing Line Spacing (Tier 3 - Design Details)
Users should have the ability to change the line spacing for an entire text file or for any particular section of a file.
COMMENT: (D)

1.3.3-27 Intercharacter Spacing (Tier 3 - Design Details)
Minimum spacing between successive characters on a line should be one pixel or 20% of character width (whichever is greater).
COMMENT: (D)

1.3.3-28 Sentences Begin with Main Topic (Tier 3 - Design Details)

The main topic of each sentence should be located near the beginning of the sentence.
COMMENT: (E)

1.3.3-29 Concise Wording (Tier 3 - Design Details)
When speed of display output for textual material is slower than the user's normal reading speed, the text should be worded concisely to aid comprehension.
COMMENT: The goal here is to make wording concise but not cryptic. Omitting articles ("the", "a"), prepositions ("of", "by") and relative pronouns ("that", "which", "who") may save some space, but may also reduce understandability. (E)

1.3.3-30 Affirmative Sentences (Tier 3 - Design Details)
Affirmative statements rather than negative statements should be used.
COMMENT: The user should be told what to do rather than what to avoid. For example, " Clear the screen before entering data" is preferred over "Do not enter data before clearing the screen." (A,E)

1.3.3-31 Active Voice (Tier 3 - Design Details)
Sentences should be composed in the active rather than passive voice.
COMMENT: Sentences in the active voice will generally be easier to understand. For example, "Clear the screen by pressing RESET" is preferred over "The screen is cleared by pressing RESET." (A,E)

1.3.3-32 Temporal Sequence (Tier 3 - Design Details)
When a sentence describes a sequence of events, it should be phrased with a corresponding word order.
COMMENT: Temporal order is clearer. Reverse order may confuse a user. For example, "Enter LOGON before running programs" is preferred over "Before running programs enter LOGON (E)

1.3.3-33 Adequate Display Capacity (Tier 3 - Design Details)
When a user must read continuous text on line, at least four lines of text should be displayed at one time.
COMMENT: Four lines of text is the minimum that should be displayed when the reading material is simple in content. If the content is more complex, or if a reader will need to refer frequently to previous material, then more lines of text should be displayed. (A,D,E)

1.3.3-34 Text Displayed in Wide Columns (Tier 3 - Design Details)
Continuous text should be displayed in wide columns, containing at least 50 characters per line.
COMMENT: When space for text display is limited, a few long lines of text rather than many short lines of text should be displayed.Text displayed in wide columns will be read significantly faster than text displayed in narrow columns. (E)

1.3.3-35 Brightness Ratio (Tier 3 - Design Details)
The characters should be at least twice as light (or dark) as the background.
COMMENT: (D)

1.3.3-36 Combining Text with Other Data (Tier 3 - Design Details)
When text is combined with graphics or other data in a single display, thus limiting the space available for text, the text should be formatted in a few wide lines rather than in narrow columns of many short lines.
COMMENT: (E)

1.3.3-37 Placing Figures Near Their Citations (Tier 3 - Design Details)
When tables and/or graphics are combined with text, each figure should be placed near its first citation in the text, preferably in the same display frame.
COMMENT: Readers may not bother to find and look at a figure if it is displayed separately from its citation in the text. As an exception, if a figure is cited at several points in the text, then it might be desirable to allow optional display of the figure at user request, perhaps as a temporary window overlay at each point of citation. Also, if a figure is cited at several points in printed text, and particularly if that text may be accessed at different places by its

readers, then it might be desirable to group figures consistently at a particular location, such as at the end of each section. (A,E)

1.3.3-38 Figure-Ground Contrast (Tier 3 - Design Details)

Under normal illumination (non-dark adapted), dark characters on a light background should be used. In environments requiring dark adaptation, light characters on a dark background should be used.

COMMENT: (D)

1.3.3-39 Font Style (Tier 3 - Design Details)

The following fonts have been specifically recommended for use on CRTs: NAMEL font for the alpha characters, AMEL or AND font for numerals, and Leroy font and Lincoln/MITRE font for alphanumerics.

COMMENT: The basic evaluation criterion for font selection should be legibility and, for most computers, is more influenced by resolution, character size, spacing, and interline spacing than by font styles. Preference should be given to simple styles with straight lines. Script and other highly stylized fonts should be avoided (e.g., shadow, calligraphy). The number of actual fonts available for use on visual display terminals is unlimited. While the above fonts have been demonstrated empirically to be adequate for use on CRT displays, they are by no means the only fonts recommended for use. (B,D)

1.3.3-40 Font Styles to Avoid (Tier 3 - Design Details)

In general, fonts should have true ascenders and descenders, uniform stroke width, and uniform aspect ratio.

COMMENT: Avoid type faces that have extended serifs, internal patterns, or stripes; are italicized, stenciled, shadowed or 3-dimensional; appear like handwritten script or like Old English script; or are distorted to look tall and thin or wide and fat. (D)

1.3.3-41 User Selectable Font Size (Tier 3 - Design Details)

For word processing and graphics applications, character size should be under the user's control through selection of font sizes.

COMMENT: The font size selection would determine the character height and width, spacing between characters, and the row spacing. (D)

1.3.3-42 Distinguishability of Characters (Tier 3 - Design Details)

For a given font, it should be possible to clearly distinguish between the following characters: X and K, T and Y, I and L, I and 1, O and Q, S and 5, and U and V.

COMMENT: (B)

1.3.3-43 Minimal Hyphenation (Tier 3 - Design Details)

In display of textual material, words should be kept intact, with minimal breaking by hyphenation between lines.

COMMENT: Text is more readable if each word is entirely on one line, even if that makes the right margin more ragged. (A,E)

1.3.3-44 Printing Lengthy Text Displays (Tier 3 - Design Details)

When a user must read lengthy textual material, that text should be provided in printed form rather than requiring the user to read it on-line.

COMMENT: The intent of this guideline is not to discourage the on-line display of text when it is needed, but rather to discourage on-line display when the text would be more useful in paper form. For instance, if HELP displays consist merely of screen after screen of text which is not tailored to a user's current task, than that text might be better displayed in a printed users' manual. There are many good reasons for displaying lengthy textual material on line. However, reading lengthy text on an electronic display may be 20-30 percent slower than reading it from a printed copy. Lengthy text may be displayed for editing, mailing, or search tasks. Or a lengthy text might be updated frequently, and so on-line display would be the best way to ensure that all users are reading the most recent version. (A,E)

1.3.4.1-1 Group Labels (Tier 1 - Use)
Each individual data group, field, or message, should contain a distinct, unique, and descriptive label.
COMMENT: (A,C,D,E)

1.3.4.1-2 Display Title (Tier 1 - Use)
Every display should begin with a title or header at the top, describing briefly the contents or purpose of the display. There should be at least one blank line between the title and the body of the display.
COMMENT: (A,C,D,E)

1.3.4.1-3 Label Location (Tier 2 - Consistency)
Label locations and formats should be consistent across and within displays. Data group labels should be located adjacent to the data group or message they describe.
COMMENT: Data group labels should also preferably be above or to the left of the data group or message they describe (A,C,D,E)

1.3.4.1-4 Consistent Wording of Labels (Tier 2 - Consistency)
Labels should be worded consistently, so that the same data item is given the same label if it appears in different displayed forms.
COMMENT: Consistent grammatical format for different labels should also be employed; i.e., single words or phrases for some labels and short sentences for others, or verbs for some and nouns for others should not be used. (E)

1.3.4.1-5 Meaningfulness (Tier 2 - Meaningfulness)
Labels should be meaningful. Labels should be English words or should use the currently accepted technical term.
COMMENT: (D,E)

1.3.4.1-6 Wording of Labels (Tier 2 - General)
Labels should describe the data content of a data group accurately, using the fewest characters possible.
COMMENT: However, labels should consist of the entire word or sequence of words, rather than an abbreviation, whenever space permits. (A,D)

1.3.4.1-7 Label Emphasis (Tier 2 - General)
Labels should be highlighted or otherwise emphasized to differentiate them from other screen structures and data in a unique and consistent manner.
COMMENT: The technique used should be easily distinguished from that used to highlight or code emergency or critical messages, such as by bolding, underlining and use of capitals. (A,C,D,E)

1.3.4.1-8 Labeling User Options (Tier 2 - General)
Data group labels should reflect the question or decision being posed to the user, when presenting a list of user options.
COMMENT: (C)

1.3.4.1-9 Proximity to Data Field (Tier 3 - Design Details)
A label should be separated from its associated data field by at least one standard character space, but should be close enough to the data field to allow the user to associate it with the appropriate data.

COMMENT: (D,E)

1.3.4.1-10 Label Separation (Tier 3 - Design Details)
Labels should be separated from one another by at least two standard character spaces.
COMMENT: (D)

1.3.4.1-11 Label Contractions and Punctuation (Tier 3 - Design Details)
Labels should not include contractions, short forms or punctuation unless absolutely necessary for meaning, to accommodate space limitations, or unless the label is an accepted standard.
COMMENT: (D)

1.3.4.1-12 Frame Labels (Tier 3 - Design Details)
Display frames labels should be an alphanumeric code or an abbreviation which is prominently displayed and is short enough (3-7 characters) or meaningful enough to be learned and remembered easily.
COMMENT: (A)

1.0 INFORMATION DISPLAY
1.2 Display Elements
1.3 Labels
1.3.4.2 Scaling, Graphs, Barcharts and Histograms

1.3.4.2-1 Normal Orientation for Labels (Tier 2 - General)

The annotation of graphic displays, including labels for the axes of graphs, should be displayed in a normal orientation for reading text.

COMMENT: For example, users should be presented with horizontally displayed labels, even for the vertical axis of a graph. A conventional text orientation of labels will permit faster, more accurate reading. With a printed graph, it may be possible to tilt the page to read a disoriented label. With an electronic display, a user usually cannot tilt the display screen but instead must tilt his/her head. (E)

1.3.4.2-2 Axes Labels (Tier 2 - General)

Charts and axes should be clearly labeled, with its description and measurement units, if any.

COMMENT: Labels should be displayed in conventional text orientation on both the X- and Y-axis for ease of reading. (A,E)

1.3.4.2-3 Labeling Curves (Tier 2 - General)

When multiple curves are included in a single graph, each curve should be identified directly by an adjacent label, rather than by a separate legend.

COMMENT: As an exception, where displayed curves are too close for direct labeling, an acceptable alternative might be to distinguish the various curves in some way, perhaps by color coding or line coding, and identify their codes in a separate legend. Direct labeling will permit users to assimilate information more rapidly than displaying a separate legend. (A)

1.3.4.2-4 Graphical Objects (Tier 2 - General)

The label for a specific graphical object (e.g., a data graph, a schematic, or an icon) should be placed in close proximity to the graphical object.

COMMENT: When possible, the label should be on the component if it does not obscure the component. If multiple component parts of the graphical object are close to the label, a line should point from the label to the associated part. The label locations for graphical objects should be consistent across all displays and the labels should not overlap. (D)

1.3.4.2-5 Labeling Single Bars (Tier 2 - General)

Each bar on the display should have a unique identification label.

COMMENT: The label provides a positive identification of the parameter each bar represents. It would not be acceptable for an operator to have to memorize the position of each parameter on the display. (B)

1.3.4.2-6 Labeling Paired Bars (Tier 2 - General)

When bars are displayed in pairs, they should be labeled as a unit, with a legend or individual distinguishing labels for each pair.

COMMENT: Direct labeling of bars will permit efficient information assimilation by a user. If the user has to refer to a separately displayed legend, interpretation of the chart will be slower and more subject to error. (E)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.3 Windows

1.3.4.3-1 Window Identification (Tier 1 - Use)
Windows should be identified by a label consistently located at the top of the window's border.
COMMENT: (A)

1.3.4.3-2 Multiple Window Identification (Tier 2 - General)
Where several windows can be displayed at one time, active windows should be indicated by labeling or other means.
COMMENT: (A)

1.3.4.3-3 Scrollable Windows (Tier 3 - Design Details)
Labels should remain on the screen while the data scrolls underneath them.
COMMENT: (A)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.4 Display Control

1.3.4.4-1 Display Identification (Tier 1 - Use)
When a user can select/manipulate data displays, each display should have an identifying label and other identifying information to support display control and data access.
COMMENT: There should be an identifying label in any separately selected "window" that might be overlaid on another display. An identifying label will help users remember different displays and provide a convenient means for requesting them. Even in systems where users exercise little initiative in data selection, where displays are largely configured in advance by designers, some kind of display identification will help users understand the displayed consequences of sequence control actions. (A,E)

1.3.4.4-2 Consistent Label Location (Tier 2 - Consistency)
Identifying labels should be located in a prominent and consistent location.
COMMENT: As an example, the top left corner of the display might be used for this purpose. (A,E)

1.3.4.4-3 Paging vs. Scrolling Labels (Tier 2 - Consistency)
Paging vs. scrolling labels should be consistently distinct and unambiguous.
COMMENT: For example, UP may be used to scroll up a line within a frame and PREVIOUS to go to a preceding page. (A)

1.3.4.4-4 Labeling Paging Displays (Tier 2 - Task Compatibility)
Labeling used for display paging should be referred to in functional terms.
COMMENT: For example, FORWARD and BACK, or NEXT and PREVIOUS. (A)

1.3.4.4-5 Labeling Display Freeze (Tier 2 - General)
When a display has been frozen, that display should be annotated with some appropriate label to remind users of its frozen status.
COMMENT: (E)

1.3.4.4-6 Labeling Display Suppression (Tier 2 - General)
When data have been suppressed from a display, the display should be annotated with some appropriate label to remind users that data have been suppressed.
COMMENT: (E)

1.3.4.4-7 Labeling Panning Functions (Tier 3 - Design Details)
When a panning orientation is maintained consistently, names for display framing functions should refer to movement of the display frame (or window) and not to movement of the displayed data.
COMMENT: For example, the command "Up 10" should mean that the display frame will move up ten lines, with the effect that ten lines of previous data will appear at the top of the display, and ten lines of subsequent data will disappear at the bottom. (E)

1.3.4.4-8 Labeling Scrolling Functions (Tier 3 - Design Details)
When a scrolling orientation is maintained consistently, names for display framing functions should refer to movement of the data being displayed, and not to movement of the display frame or window.
COMMENT: For example, the command "Up 10" should mean that displayed data will move up ten lines behind the (conceptually fixed) display frame, with the effect that ten lines of previous data will disappear from the top of the display, and ten lines of subsequent data will appear at the bottom. (E)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.5 Functions Keys

1.3.4.5-1 Distinctive Labels (Tier 2 - Meaningfulness)
Function keys should be distinctively and informatively labeled to designate the function it performs.
COMMENT: (A,E)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.6 Pictures, Drawings, Maps, and Situation Displays

1.3.4.6-1 Consistent Positioning of Labels (Tier 2 - Consistency)

Labels on a map should be positioned consistently in relation to the displayed features they designate.

COMMENT: For example, equipment names might always be placed immediately above the corresponding symbols showing their locations. As a practical matter, map displays can get very crowded. It may not always prove feasible to maintain a consistent placement for labels, with the result that designers will be tempted to put labels wherever they will fit. In such a crowded display, labels may obscure map features, and vice versa. Locating and reading labels will be slowed,particularly when map features are displayed closely adjacent to the beginning of label. Under these circumstances, some other approach to map labeling should be considered to avoid crowding. (A,E)

1.3.4.6-2 Symbol Labeling (Tier 2 - Memory Load)

A legend defining symbols should be displayed or available at user option.

COMMENT: (A)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.7 Menus

1.3.4.7-1 Title (Tier 2 - General)
An explanatory title for each menu should be provided.
COMMENT: (A)

1.3.4.7-2 Sub-Group Labels (Tier 2 - General)
Where menu options are grouped in logical subunits, each group should be provided a descriptive label that is distinctive in format from the option labels themselves.
COMMENT: Although this practice might sometimes seem to waste display space, it helps provide user guidance. Moreover, careful use of group labels may serve to reduce the number of words needed for individual option labels. (A,E)

1.0 INFORMA' ON DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.8 Pie Charts

1.3.4.8-1 Labeling Pie Charts (Tier 3 - Design Details)
Pie chart segments should be labeled directly rather than by a separate legend.
COMMENT: The label should be in a normal orientation for reading text. (E)

1.3.4.8-2 Numeric Labels (Tier 3 - Design Details)
Numbers should be added to pie chart segment labels to indicate the percentage and/or absolute values represented in the display index.
COMMENT: (E)

1.3.4.8-3 Segment Labeling (Tier 3 - Design Details)
If a segment is too small to contain the label, the label should be placed outside the segment with a line from it to the segment.
COMMENT: (A,E)

1.3.4.9-1 Row and Column Labels (Tier 1 - Use)
Each row and column should be uniquely and informatively labeled and should be visually distinct from data entries.
COMMENT: (A,D,E)

1.3.4.9-2 Individual Field Labels (Tier 2 - General)
Each individual field should be labeled. The user should not have to rely on contextual clues alone to identify a field.
COMMENT: (A)

1.3.4.9-3 Labeling Units of Measurement (Tier 2 - General)
Labels should include the unit of measure for the data described. Labeling units of measurement should be part of column labels, or placed after the first row or column data entry.
COMMENT: (A,C,D,E)

1.3.4.9-4 Proximity to Rows (Tier 2 - General)
Labels should be centered and in close proximity to rows in a numerical data matrix.
COMMENT: (D)

1.3.4.9-5 Justification (Tier 2 - General)
Labels should be left justified in a tabular array with numerous subheadings or sublabels.
COMMENT: (E)

1.3.4.9-6 Scrollable Table Labeling (Tier 2 - General)
Labels should not scroll off the visible portion of the display.
COMMENT: (A)

1.3.4.9-7 Multipage Table Labeling (Tier 3 - Design Details)
Where more data fields exist than can be displayed on a single display page, row and column labels should remain along the top (or bottom) and left (or right) edges of the display.
COMMENT: (A,E)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.4 Labels
1.3.4.10 Data Fields

1.3.4.10-1 Consistent Formatting (Tier 2 - Consistency)
Label formats should be consistent.
COMMENT: For example, by spacial relation to associated data field, color, fonts, size, and location. (A)

1.3.4.10-2 Data Field Definition (Tier 2 - General)
Data fields should be defined by a label and character entry space.
COMMENT: (D)

1.3.4.10-3 Labeling Units of Measurement (Tier 2 - General)
The units of measurement for displayed data should be included either in the label or as part of each data item.
COMMENT: (A,E)

1.3.4.10-4 Location of Group Labels (Tier 2 - General)
A field group heading should be centered above the labels to which it applies. It should be completely spelled out and related to the labels.
COMMENT: (B)

1.3.4.10-5 Field Labels in Uppercase (Tier 2 - General)
Data field labels should appear in upper case only, while entered text may appear in both upper and lower case.
COMMENT: (A)

1.3.4.10-6 Separation of Character Entry Area and Label (Tier 3 - Design Details)
The label and the character entry area should be separated by at least one character space. At least two character spaces should be maintained horizontally between a character entry area and a succeeding label on the same row.
COMMENT: (B,D)

1.3.4.10-7 Data Field Separation (Tier 3 - Design Details)
At least five spaces should appear between the longest data field in one column and the rightmost label in an adjacent column.
COMMENT: The design goal is visual separation of columns of fields. Note that these separation guidelines are minimums. If wider spacing is feasible, utilize it. For example, WARNING: _ __________ DATE: _____ ___STATUS: __________ TIME: __________ (B)

1.3.4.10-8 Separation of Columns (Tier 3 - Design Details)
Where space constraints exist, vertical lines may be substituted for spaces for separation of columns of fields.
COMMENT: (B)

1.3.4.10-9 Justification of Data Field Labels (Tier 3 - Design Details)
Labels should be left justified and end with a colon.
COMMENT: (B,D)

1.3.4.10-10 Justification: Equal Label Length (Tier 3 - Design Details)
When label sizes are relatively equal, both labels and data fields should be left justified. One space should be left between the longest label and the data field column.
COMMENT: (B)

1.3.4.10-11 Justification: Unequal Label Length (Tier 3 - Design Details)
When label sizes vary greatly, labels should be right justified and the data fields should be left-justified. One space should be left between each label and the data field.
COMMENT: For example,

FEED FLOW.
STEAM GENERATOR PRESSURE: ________

In most instances, however, left-justification of captions and right-justification of data fields will usually yield a more balanced display. (B)

1.3.4.10-12 Section Headings and Label Indentation (Tier 3 - Design Details)
When section headings are located on the line above related screen fields, the labels should be indented a minimum of five spaces from the start of the heading.
COMMENT: Scanning an inquiry screen will be aided if logical groupings of fields are identified by headings. This permits scanning of headings until the correct one is located, at which point the visual search steps down one level to the items within the grouping itself. The above guideline is intended to provide easily scanned headings. For example,

SECONDARY CONTAINMENT
LEVEL: ________
PRESS: ________

(B)

1.3.4.10-13 Section Heading Proximity to Subordinate Labels (Tier 3 - Design Details)
When section headings are placed adjacent to the related fields, they should be located to the left of the topmost row of related fields. The column of labels should be separated from the longest heading by a minimum of three blank spaces.
COMMENT: (B)

1.3.4.10-14 Multiple Fields Without Group Headings (Tier 3 - Design Details)
For multiple-occurrence fields without group headings, at least three spaces should exist between the columns of fields.
COMMENT: (B)

1.3.4.10-15 Multiple Fields With Group Headings (Tier 3 - Design Details)
For multiple-occurrence fields with group headings, at least three spaces should appear between columns of related fields and at least five spaces should appear between groupings.
COMMENT: (B)

1.3.4.11 ~~General~~ Data Entry

1.3.4.11-1 Label Punctuation as Entry Cue (Tier 3 - Design Details)

The label for each entry field should end with a special symbol, signifying that an entry may be made.

COMMENT: Asymbol should be reserved exclusively for prompting user entries, or at least rarely used for any other purpose. (E)

1.3.4.11-2 Data Format Cueing in Labels (Tier 3 - Design Details)

Field labels should include additional cueing of data format when that seems helpful.

COMMENT: For example, DATE (MM/DD/YY): __ __/__ __/__ __. (E)

1.3.4.11-3 Protected Labels (Tier 3 - Design Details)

Field labels should be protected from keyed entry by making the cursor skip over them automatically when a user is spacing or tabbing.

COMMENT: When a user must change a displayed form, including changes to field labels, then that user must be able to override label protection. (E)

1.0 INFORMATION DISPLAY
1.3 Display Elements
1.3.5 Icons

1.3.5-1 Appropriate Use of Icons (Tier 1 - Use)
The primary use of icons in graphic displays should be to represent concrete objects or actions.
COMMENT: Icons may be used to graphically represent operations, processes and data structures, and may be used as means of exercising control (e.g., by selecting an icon and commanding operations) over system functions, components, and data structures. (A,D)

1.3.5-2 Cross-mode Standardization (Tier 2 - Consistency)
Icons should be consistent and predictable across operating modes and across applications.
COMMENT: (A)

1.3.5-3 Icon Control (Tier 2 - Flexibility of Use)
The user should be able to initiate the process related to a selected icon in numerous ways.
COMMENT: For example, the user might open a file by selecting a file icon and entering a command, entering a keystroke command, choosing a menu item, or moving the file icon to an icon that represented the action, to open. (D)

1.3.5-4 Iconic Representation (Tier 2 - General)
Icons should be graphically designed to look like the objects, processes or operations they represent, by use of literal, functional, or operational representations.
COMMENT: Some pictorial symbols have conventional meanings within a user population, which must be followed to ensure their correct interpretation. Examples of representations: Literal, a figure of a thermometer Funcuonal, a figure of a file cabinet Operational, a hand on a switch. (A,C,E)

1.3.5-5 Distinguishability (Tier 2 - General)
Each icon should represent a single object or action, and should be easily discriminable from all other icons and all display structures in use on the same display as that icon.
COMMENT: The distinguishing feature between icons should be the external geometric configuration of the icon. (D)

1.3.5-6 Simple Design (Tier 2 - General)
Icons should be simple closed figures when possible.
COMMENT: When icons are too visually complex, they are not quickly recognized. This eliminates the primary advantage of using icons--quick recognition. Simple, closed figures are processed more efficiently than are open figures. (D)

1.3.5-7 Icon Size (Tier 2 - General)
The size of the icon should be large enough for the user to perceive the representation and discriminate it from other icons.
COMMENT: (D)

1.3.5-8 Nonpictographic Icons (Tier 2 - General)
When pictographic icons are not possible , nonpictographic icons should be used so that functionally similar objects or actions are represented by perceptually similar icons.
COMMENT: Pictographic icons may not be possible when the object does not have a pictographic equivalent. (D)

1.3.5-9 Selecting Icons (Tier 2 - General)
An icon that the user has selected should be highlighted.
COMMENT: (D)

1.3.5-10 Labels for Control Option Icons (Tier 2 - General)

If icons are used to represent control actions in menus, a label should be associated with each icon.
COMMENT: (A,E)

1.3.5-11 Moving Icons (Tier 3 - Design Details)
Users should be able to move to and select icons, as well as move a selected icon, by use of any available cursor control device, including X-Y controllers and arrow keys.
COMMENT: (D)

1.3.5-12 Origination Point (Tier 3 - Design Details)
Icons that are being moved should indicate where the icon originally was.
COMMENT: For example, the solid line icon might remain at the original location while an outline of the icon followed under the cursor until the icon was no longer selected. (D)

1.3.5-13 Labeling Icons (Tier 3 - Design Details)
To the greatest extent possible, icons should be accompanied by a text label, especially when the icons do not closely resemble the symbolized object or action.
COMMENT: To the extent that it does not clutter or cause distortion of the icon, the label should be incorporated into the icon itself. When icons are designed such that the label is inside of the icon, the number of perceptual objects is reduced, resulting in enhanced processing of the label and the icon. (D)

1.3.5-14 Screen Arrangement (Tier 3 - Design Details)
Under default conditions, icons should be grouped spatially together on the display. The user should be able to change the spatial location of an icon.
COMMENT: (D)

1.3.5-15 Glossary (Tier 3 - Design Details)
The user should have access to a glossary that contains a list of the standard icons and their associated objects or actions through the on-line Help system.
COMMENT: (D)

1.0 INFORMATION DISPLAY

1. Coding

1.4.1 General

1.4.1-1 Coding by Highlighting Critical Data (Tier 1 - Use)

Distinctive highlighting should be used to call a user's attention to changes in the state of the system, and to indicate important, hazardous, or critical information which requires user action.

COMMENT: For example, such items might include recently changed data, or discrepant data exceeding acceptable limits, or data failing to meet some other defined criteria. "Highlight" is used here in its general sense, meaning to emphasize or make prominent, and is not restricted to any particular method of display coding such as brightening or inverse video. Highlighting is most effective when used sparingly, adding emphasis to a display which is relatively uniform in appearance except for just a few highlighted items. For some purposes, position coding (i.e., displaying important items consistently in a particular location) might be a sufficient means of highlighting, as when an error message appears in a space otherwise left blank. But auxiliary codes may still be needed to highlight important items, even if they are positioned consistently. (A,C,E)

1.4.1-2 Coding by Data Category (Tier 1 - Use)

Display coding should be provided in applications where a user must distinguish rapidly among different categories of displayed data.

COMMENT: Particularly when those data are distributed in an irregular way on the display. (A,E)

1.4.1-3 Consistent Coding Across Displays (Tier 2 - Consistency)

Consistent meanings should be assigned to symbols and other codes, from one display to another.

COMMENT: When coding is not consistent, the user's task of display interpretation may be made more difficult than if no auxiliary coding were used at all. (A,E)

1.4.1-4 Meaningful Codes (Tier 2 - Meaningfulness)

Meaningful or familiar codes should be used, rather than arbitrary codes.

COMMENT: For example, a three-letter mnemonic code (RHR = Residual Heat Removal) is easier to remember than a three-digit numeric code or a two character arbitrary code (ND = Residual Heat Removal), although an arbitrary code may eventually become familiar through frequent use. (C,E)

1.4.1-5 Familiar Coding Conventions (Tier 2 - Meaningfulness)

Codes for display (and entry) should conform with accepted abbreviations and general user expectations.

COMMENT: For example, use M for "male", F for "female", rather than arbitrary digits 1 and 2. (A,E)

1.4.1-6 Warning Coding (Tier 2 - General)

Conditions requiring special attention should be coded distinctively.

COMMENT: For example, messages might be marked with a blinking symbol and accompanied by an auditory signal. (E)

1.4.1-7 Coding and Legibility (Tier 2 - General)

Coding should neither reduce legibility nor increase transmission time.

COMMENT: (C)

1.4.1-8 Definition of Display Codes (Tier 3 - Design Details)

When codes are assigned special meaning in a display, a definition should be provided at the bottom of the display that replicates the code being defined.

COMMENT: For a color code, each definition should be displayed in its appropriate color (e.g., Red = Open, Green = Close). (D,E)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.2 Text Coding
1.4.2.1 Abbreviations and Acronyms

1.4.2.1-1 Minimal Use of Abbreviation (Tier 1 - Use)
Complete words should be displayed in preference to abbreviations.
COMMENT: Abbreviations may be displayed if they are significantly shorter, save needed space, and will be understood by the prospective users. (A,E)

1.4.2.1-2 Use of Random Characters (Tier 1 - Use)
When grouping alphabetic characters, acronyms or abbreviations should be used in preference to randomly selected characters that have little relevance to the system.
COMMENT: (A)

1.4.2.1-3 When to Abbreviate (Tier 1 - Use)
Abbreviations and acronyms should be used only if a display does not have sufficient space for the unabbreviated word or if the abbreviation or acronym is more frequently used than the full word or phrase.
COMMENT: (D)

1.4.2.1-4 Common Abbreviations (Tier 2 - Meaningfulness)
When abbreviations are used, those abbreviations should be commonly recognized, and abbreviated words should not produce uncommon or ambiguous abbreviations.
COMMENT: For example, CST Pressure Low would be acceptable, but Condensate Storage Tank Prssr Lw is unacceptable. The point here is that when abbreviation is necessary due to space constraints, the words chosen for abbreviation should be those that are commonly known in their abbreviated form, and/or those words whose abbreviations can be unambiguously interpreted. (E)

1.4.2.1-5 Distinctive Abbreviations (Tier 2 - General)
Abbreviations should be distinctive so that abbreviations for different words are distinguishable.
COMMENT: (A,C,E)

1.4.2.1-6 Dictionary of Abbreviations (Tier 2 - General)
If abbreviations are used, a dictionary of abbreviations should be available for on-line user reference.
COMMENT: (A,C,D,E)

1.4.2.1-7 Minimal Punctuation of Abbreviations (Tier 3 - Design Details)
Punctuation of abbreviations and acronyms should be minimized.
COMMENT: For example, SPDS is preferred over S.P.D.S. Punctuation should be retained when needed for clarity, e.g.,"4-in. front dimension" rather than "4 in front dimension". (A,E)

1.4.2.1-8 Abbreviations Should be Understandable and Shorter than the Original Word (Tier 3 - Design Details)
Abbreviations and acronyms should be used only if significantly shorter than the complete word, saves needed space, and can be understood by the user population.
COMMENT: (D)

1.4.2.1-9 Simple Abbreviation Rule (Tier 3 - Design Details)
When defining abbreviations, some simple rule should be used and users should be able to understand that rule.
COMMENT: Abbreviation by truncation is the best method, except when word endings convey important information. When a truncation rule is used, abbreviations are easy to derive and easy for a user to decode. If an abbreviation deviates from the consistent rule, it may be helpful to give it some special mark whenever it is

displayed. (E)

1.4.2.1-10 Abbreviations Defined in Text (Tier 3 - Design Details)

When words in text displays are abbreviated, each abbreviation should be defined in parentheses following its first appearance.

COMMENT: This practice will help only those users who read displayed text from front to back and remember what they have read. For forgetful users, and for users who sample later sections of a multipage text display, abbreviations may still seem undefined. For such users, it might be helpful to have an on-line dictionary of abbreviations for convenient reference. (E)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.2 Text Coding
1.4.2.2 Alphanumerics

1.4.2.2-1 Alphanumeric Coding (Tier 1 - Use)
Alphanumeric characters for auxiliary coding should be used in display applications such as graphics where the basic data presentation is not already alphanumeric.
COMMENT: Alphanumeric codes that are visually distinct for visual displays, and phonetically distinct for auditory displays (or in any application where displayed codes must be spoken) should be used. (A,E)

1.4.2.2-2 Consistent Case in Alphabetic Coding (Tier 2 - Consistency)
For alphabetic codes, all letters should be consistently displayed either in upper case or in lower case.
COMMENT: For data display, upper case labels may be somewhat more legible. For data entry, computer logic should not distinguish between upper and lower case codes, because users find it hard to remember any such distinction. (A,D,E)

1.4.2.2-3 Meaningful Alphanumeric Codes (Tier 2 - Meaningfulness)
Whenever possible, a meaningful alphanumeric code should be used in preference to a nonmeaningful code.
COMMENT: For example, an acronym should be used instead of an arbitrary set of letters and numbers. (D)

1.4.2.2-4 Short Codes (Tier 2 - Memory Load)
When arbitrary codes must be remembered by the user, characters should be grouped in blocks of three to five characters, separated by a minimum of one blank space or other separating character such as a hyphen or slash.
COMMENT: Arbitrary codes are alphanumeric characters without natural organization. When a code is meaningful, such as a mnemonic abbreviation or a word, it can be longer. (A,D,E)

1.4.2.2-5 Avoid O and I (Tier 2 - General)
The use of the letters O and I in an alphanumeric code should be avoided; they are easily confused with the numbers 0 (zero) and 1 (one), respectively.
COMMENT: (D)

1.4.2.2-6 Combining Letters and Numbers (Tier 2 - General)
When codes combine both letters and numbers, letters should be grouped together and numbers grouped together rather than interspersing letters with numbers.
COMMENT: For example, letter-letter-number ("HW5") will be read and remembered somewhat more accurately than letter-number-letter ("H5W"). (A,D,E)

1.4.2.2-7 No Punctuation (Tier 2 - General)
Alphanumeric codes should have no punctuation except for codes which may be confused with words.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.2 Text Coding
1.4.2.3 Font

1.4.2.3-1 Highlighting With Font Style (Tier 1 - Use)
Highlighting of characters within a text file or a table may be accomplished by use of a different style of font or the use of a larger size of font.
COMMENT: Plain text should not be used as a highlighting method. (D)

1.4.2.3-2 Style Before Size When Highlighting (Tier 2 - General)
The use of a different font style should be preferred over the use of a different size for highlighting information.
COMMENT: (D)

1.4.2.3-3 Highlighted Font Should Not Obscure Other Font (Tier 3 - Design Details)
The use of a different style or size of font should not obscure any nonhighlighted characters.
COMMENT: (D)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.2 Text Coding
1.4.2.4 Enhancement/Highlighting

1.4.2.4-1 Highlighting Text (Tier 1 - Use)
When a critical passage merits emphasis to set it apart from other text, that passage should be highlighted by bolding/brightening or color coding or by some auxiliary annotation, rather than by capitalization.
COMMENT: A single word might be capitalized for emphasis, but capitalizing an extended passage will reduce its readability. (E)

1.4.2.4-2 Easily Recognizable Highlighting (Tier 1 - Use)
Highlighting should be easily recognizable and be used to attract the user's attention to active fields, special conditions, or as a means to provide feedback.
COMMENT: (A)

1.4.2.4-3 Minimal Highlighting (Tier 2 - General)
Highlighting of information should be minimized.
COMMENT: A good rule of thumb for displays of nominal conditions is to limit the maximum amount of highlighting to 10% of the display information. If highlighting is to be used to attract the user's attention, the highlighting technique should be distinctive. If a large portion of a display is highlighted, the highlighting will no longer be distinctive. (D)

1.4.2.4-4 Consistency (Tier 2 - General)
A particular highlighting method for related functions should be used consistently.
COMMENT: (D)

1.4.2.4-5 Removing Highlighting (Tier 2 - General)
If highlighting is used to emphasize important display items, such highlighting should be removed when it no longer has meaning.
COMMENT: If highlighting identifies an error, that highlighting should be removed when the error is corrected. (A,E)

1.4.2.4-6 Readability of Displayed Information (Tier 3 - Design Details)
Highlighting should not interfere with the readability of displayed information.
COMMENT: (A)

1.4.2.4-7 Highlighting Printed Output (Tier 3 - Design Details)
A highlighting technique similar to that used on the VDT should be provided for printed output.
COMMENT: (A)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.2 Text Coding
1.4.2.5 Underlining

1.4.2.5-1 Underlining to Indicate Unusual Values, Errors, Changes (Tier 1 - Use)
Underlining may be used to indicate unusual values, errors in entry, and data changes.
COMMENT: (A,C)

1.4.2.5-2 Underlining Should Not Impact Perception of the Display (Tier 1 - Use)
Underlining should not be used when it has an impact on the perception of the display.
COMMENT: For example, there should be space between the character and the underline mark. (D)

1.4.2.5-3 Underlining for Emphasis (Tier 2 - General)
When a line is added simply to mark or emphasize a displayed item, it should be placed under the designated item.
COMMENT: Underlining probably detracts from legibility less than would "overlining". (E)

1.4.3.1 Auditory

1.4.3.1-1 Use of Auditory Coding (Tier 1 - Use)

Auditory displays should be used as a means of supplementing visual display, or as an alternative means of data output in applications where visual displays are not feasible.

COMMENT: Auditory signals may provide feedback for control actuation, data entry, or completion of timing cycles and sequences. For example, auditory signals may be helpful in alerting users to critical changes in a visual display. Auditory output might be used to permit telephone access to computer-stored data. Auditory display may be impractical in situations where high ambient noise prevents accurate listening. As compared with visual displays, an auditory display offers a potential advantage in attracting a user's attention; a user does not have to "listen at" an auditory display in order to hear it. On the other hand, auditory displays suffer from a number of comparative disadvantages. Auditory displays generally do not offer as great a range of coding options. Auditory displays do not permit easy scanning to discern critical data items, or items that may have been missed at first listening. For human listeners with normal vision, auditory displays do not provide a natural representation of spatial relations. (A,E)

1.4.3.1-2 Tonal Signals (Tier 1 - Use)

A tonal signal should be used when: A) Immediate action is required on the part of the listeners. B) a specific point in time is to be indicated, C) a spoken message would be inappropriate. D) the intended listeners are familiar with the tonal signal implication or code.

COMMENT: A tonal signal is preferred over a spoken message when: A) the spoken message would compromise the security of a situation. B) noise conditions are unfavorable for receiving spoken messages. C) speech channels are overloaded. D) a spoken message could annoy listeners for whom it is not intended or when the spoken message could mask other messages. E) it is desired to use the simplest audio signal. (B)

1.4.3.1-3 Necessary Information (Tier 2 - Task Compatibility)

Audio signals should provide only that information which is necessary for the user.

COMMENT: (B)

1.4.3.1-4 Distinctive Auditory Coding (Tier 2 - General)

For auditory displays, distinctive sounds should be used to code items requiring special user attention.

COMMENT: For example, a variety of signals may be available, including sirens, bells, chimes, buzzers, and tones of different frequency. Tones may be presented in sequence to enlarge the signal repertoire. (E)

1.4.3.1-5 Redundancy with Visual Warnings (Tier 2 - General)

Auditory alerts, as well as caution and warning sounds, should be redundant with visual warnings presented by pictures, messages, and blink coding.

COMMENT: (D)

1.4.3.1-6 Non-duplication of Auditory Signals (Tier 2 - General)

Once a particular auditory signal code is established for a given operating situation, the same signal should not be designated for some other display.

COMMENT: (B)

1.4.3.1-7 Association with Certain Activities (Tier 2 - General)

If a signal type is commonly associated with a certain type of activity, it should not be used for other purposes when the situation is such that the more common convention is in use.

COMMENT: (B)

1.4.3.1-8 Signal Compatible with Environment (Tier 2 - General)

The intensity, duration, and source location of the signal should be compatible with the acoustical

environment of the intended receiver as well as with the requirements of other personnel in the signal area.
COMMENT: (A,B)

1.4.3.1-9 Intensity (Tier 2 - General)
Audio signals should not startle listeners, add to overall noise levels, or interfere with local speech activity.
COMMENT: Most auditory signals are too loud and too long. There are three important consequences: -no more than one warning can be heard at any one time -communications are often blocked out in the presence of a continuous signal -when manual override is available, operators often disable warning signals. (B)

1.4.3.1-10 Intensity (Tier 2 - General)
The intensity of audio signals should be at least 60 dB above the absolute threshold.
COMMENT: (B)

1.4.3.1-11 Intermittent Signals (Tier 2 - General)
Signals should be intermittent in nature to allow the user sufficient time to respond.
COMMENT: (A)

1.4.3.1-12 Two-stage Signals (Tier 2 - General)
When complex information is to be presented, two-stage signals should be used.
COMMENT: These stages consist of: -an attention-demanding signal to attract attention and identify a general category of information -a designation signal to follow the attention-demanding signal and designate the precise information within the general class indicated above. (B)

1.4.3.1-13 Listening to More than One Channel (Tier 2 - General)
If a person is to listen concurrently to two or more channels, the frequency of the channels should be different.
COMMENT: (B)

1.4.3.1-14 Turning Off Non-critical Auditory Signals (Tier 2 - General)
Noncritical auditory signals should be capable of being turned off at the discretion of the user. A simple, consistent means of acknowledging and turning off warning signals should be provided.
COMMENT: (A,D)

1.4.3.1-15 Computer-Generated Speech Output (Tier 2 - General)
If computer-generated speech output is used for auditory display, a special alerting signal should distinguish them from routine voice messages.
COMMENT: (A)

1.4.3.1-16 Total Number of Signals (Tier 3 - Design Details)
The number of signals to be identified should not exceed four.
COMMENT: (A)

1.4.3.1-17 Indicating Who is to Respond (Tier 3 - Design Details)
When the signal must indicate which operator (of a group of operators) is to respond, a simple repetition code should be used
COMMENT: (B)

1.4.3.1-18 Voice Output (Tier 3 - Design Details)
For auditory displays with voice output, different voices should be used to distinguish different categories of data.
COMMENT: (A)

1.4.3.1-19 Frequency of Auditory Signals (Tier 3 - Design Details)
The frequency of an audio signal should be within the range of 200 to 5000 Hz, and preferably

between 500 and 3000 Hz.
COMMENT: The signal frequency of auditory displays should be compatible with the midrange of the ear's response curve for both pitch and loudness, i.e., avoid the use of signals at the extreme ends of the sensitivity curves, where response reliability is more easily masked. (B)

1.4.3.1-20 Detecting Small Changes in Intensity (Tier 3 - Design Details)
When small changes in signal intensity must be detected, the signal frequency should be from 1000 to 4000 Hz.
COMMENT: (B)

1.4.3.1-21 Signal Travel Over 1000 ft (Tier 3 - Design Details)
When an audio signal must travel over 1000 ft., its frequency should be less than 1000 Hz.
COMMENT: (B)

1.4.3.1-22 Signal Bending Around Obstacles (Tier 3 - Design Details)
When an audio signal must bend around major obstacles or pass through partitions, its frequency should be less than 500 Hz.
COMMENT: (B)

1.4.3.1-23 Noise Environment Difficult to Penetrate (Tier 3 - Design Details)
When the noise environment is unknown or suspected of being difficult to penetrate, audio signals should have a shifting frequency that passes through the entire noise spectrum and/or be combined with a visual signal.
COMMENT: (B)

1.4.3.1-24 Maintaining Security with Auditory Signaling (Tier 3 - Design Details)
If a signal must occur in an area in which only certain personnel should be privy to its purpose and others are not to be unduly annoyed, a simple bell tone should be used that is recognizable among ambient speech sounds without being loud
COMMENT: (B)

1.4.3.2-1 Limited Use of Brightness Coding (Tier 1 - Use)
Coding by differences in brightness should be used for applications that only require discrimination between two categories of displayed items.
COMMENT: Brightness should be treated as a two-valued code, bright and dim. For example, a data form might display dim labels and bright data items, in order to facilitate data scanning. (E)

1.4.3.2-2 Brightness Inversion (Tier 1 - Use)
Brightness inversion should be used for highlighting critical items that require user attention when brightness inversion is available (reverse video), where dark characters on a bright background can be changed under computer control to bright on dark, or vice versa.
COMMENT: Brightness inversion is obviously limited to use as a two- valued code, i.e., a displayed item is either shown with standard or inverted brightness. If brightness inversion is used for alerting purposes, as recommended here, it should be reserved consistently for thatpurpose, and not be used for general highlighting. (E)

1.4.3.2-3 Brightness Intensity Coding (Tier 1 - Use)
Brightness intensity coding may be used to differentiate between adjacent items of information or to code two to three state conditions (ON-STANDBY-OFF, or RUN-STOP).
COMMENT: Brightness coding should have only one meaning (e.g., ON-OFF or FAST-SLOW, or STANDBY-RUN, but not all three). (A)

1.4.3.2-4 Distinguishing Data Entries (Tier 1 - Use)
Brightness and boldness coding should be used to distinguish data entries in data forms from other display structures.
COMMENT: (D)

1.4.3.2-5 Highlighting in a List (Tier 2 - Feedback)
In a list, the option(s) selected by the user should be highlighted.
COMMENT: (B)

1.4.3.2-6 Primary Information (Tier 2 - General)
High brightness levels should be used to signify information of primary importance, and lower levels should be used to signify information of secondary interest.
COMMENT: (B)

1.4.3.2-7 Absolute intensity coding (Tier 2 - General)
The number of intensity levels should be limited to 2 or 3 when absolute recognition is required.
COMMENT: None of the intensities used must be less than 20 cd/m2. Levels approximating 33 percent and 100 percent of the display luminance should be used with displays having a maximum luminance between 60 and 100 cd/m2. A maximum of three levels, approximating 20, 40, and 100 percent of the display luminance, should be used with displays that have a maximum luminance above 100 cd/m2. Intensity coding, as the only dimension for absolute discrimination, should not be used for displays with a maximum display luminance of less than 60 cd/m2. (F)

1.4.3.2-8 Brightness Inversion (Tier 2 - General)
When used for alerting purposes, brightness inversion should be reserved consistently for that purpose, and not be used for general highlighting.
COMMENT: (D)

1.4.3.2-9 Relative intensity coding (Tier 3 - Design Details)
For relative discrimination, a luminance difference of at least 7 percent between adjacent areas

(e.g., sections of a pie chart), and a luminance difference of at least 20 percent between non-adjacent areas (e.g., highlighted text) should be provided.
COMMENT: (F)

1.4.3.2-10 Separating Levels of Brightness Coding (Tier 3 - Design Details)
Each level of brightness coding should be separated from the next nearest level by a 2:1 ratio.
COMMENT: (A)

1.4.3.2-11 Not with Shape or Size Coding (Tier 3 - Design Details)
Brightness coding should not be used in conjunction with shape or size coding.
COMMENT: (B)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.3 Color

1.4.3.3-1 Color Coding for Data Categories (Tier 1 - Use)
When a user must distinguish rapidly among several discrete categories of data a unique color should be used to display the data in each category.

COMMENT: This should be followed particularly when data items are dispersed on a display. No more than five different colors should be used for category coding. With some display equipment now providing millions of different colors, designers may be tempted to exploit that capability by using many different colors for coding. The capability to display many colors may be useful for depicting complex objects, and for providing tonal codes to show the relative values of a single variable. However, such a capability is not useful for coding discrete categories, except that it may allow a designer to select more carefully the particular colors to be used as codes. (A,E)

1.4.3.3-2 Color in Mimic Designs (Tier 1 - Use)
Color should be used in mimics to differentiate process flow paths.

COMMENT: For example, blue may be used to code water lines; white, steam lines; yellow, oil lines; and so forth. Such color differential is potentially valuable in helping operators to sort out complex interrelationships (B)

1.4.3.3-3 When Not to Use Color Coding (Tier 1 - Use)
Color coding should not be used if the information will be accessed from monochromatic displays or hardcopy printouts, or if users may be deficient in color perception.

COMMENT: (A)

1.4.3.3-4 Color Coding for Relative Values (Tier 1 - Use)
When the relative rather than the absolute values of a variable are important, gradual color changes as a tonal code should be used to show the relative values of a single variable.

COMMENT: For example, in displaying tank depth, a saturated blue might be used to show the deepest point, with gradually desaturated blues to show decreasing depth. (E)

1.4.3.3-5 Conventional Assignment of Color Codes (Tier 2 - Meaningfulness)
Colors for coding should be based on conventional associations with particular colors.

COMMENT: Red is associated with danger in our society, and is an appropriate color for warning conditions. Yellow is associated with caution, and might be used for alerting messages or to denote changed data. Green is associated with normal "go ahead" conditions, and might be used for routine data display. White is a color with neutral association, which might be used for general data display purposes. (A,B,E)

1.4.3.3-6 Conservative Use of Color (Tier 2 - General)
Color coding should be employed conservatively, using relatively few colors and only to designate critical categories of displayed data.

COMMENT: Casual, arbitrary use of colors on every display may cause displays to appear "busy" or cluttered. Casual use of color will also reduce the likelihood that significant color coding on particular displays will be interpreted appropriately and quickly by a user. (A,B,E)

1.4.3.3-7 Redundant Color Coding (Tier 2 - General)
Color coding should be redundant with some other display feature such as symbology.

COMMENT: Displayed data should provide necessary information even when viewed on a monochromatic display terminal or hard-copy printout, or when viewed by a user with defective color vision. (A,B,E)

1.4.3.3-8 Conforming to Already Existing Meanings for a Job (Tier 2 - General)
Color codes should conform to color meanings that already exist in the user's job.

COMMENT: Color meanings will be more easily learned if color codes conform to color meanings that already exist in a person's job. Color codes employing different meanings will be much more difficult to use. (B)

1.4.3.3-9 Easily Discriminable Colors (Tier 2 - General)
When selecting colors for coding discrete categories of data, those colors should be easily discriminable.
COMMENT: For example, on a light background: red, dark yellow, green, blue and black -- on a dark background: desaturated red, green and blue, plus yellow and white. If color coding is applied to symbols that subtend small visual angles, which makes color perception difficult, there will be a special need to limit the number of colors used.
If colors are used for displaying text, care should be taken to ensure that colored letters are legible as well as discriminable. (A,E)

1.4.3.3-10 Unique Assignment of Color Codes (Tier 2 - General)
When color coding is used, each color should represent only one category of displayed data.
COMMENT: Color will prove the dominant coding dimension on a display. If several different categories of data are displayed in red, say, they will have an unwanted visual coherence which may hinder proper assimilation of information by a user. (E)

1.4.3.3-11 Limited Color Coding for Group Membership (Tier 2 - General)
Color coding for group membership should be limited to five or fewer colors.
COMMENT: (D)

1.4.3.3-12 Saturated Blue for Background Color (Tier 3 - Design Details)
Saturated blue should only be used for background features in a display, and not for critical data.
COMMENT: The human eye is not equally sensitive to all colors, nor are its optics color-corrected. Blue symbols appear dimmer than others, and are more difficult to focus. If blue is used for displayed data, it should be a desaturated blue or cyan in order to make the data more legible. (E)

1.4.3.3-13 Brightness and Saturation to Draw Attention (Tier 3 - Design Details)
Brighter and/or more saturated colors should be used when it is necessary to draw a user's attention to critical data.
COMMENT: Both intensity and saturation should be used to draw a user's attention to critical data. Although saturated and/or intense hues are useful for drawing a user's attention, their overuse will result in a display which is garish and difficult to view for long periods. (A,E)

1.4.3.3-14 Color and Quantitative Values (Tier 3 - Design Details)
Differences in color should not be used to represent differences in quantities.
COMMENT: For example, the color should not change from blue to red as volume increases in the Refueling Water Holdup Tank. (D)

1.4.3.3-15 Color Should Not be Distracting (Tier 3 - Design Details)
The use of color should not be distracting to the user
COMMENT: (B)

1.4.3.3-16 Colored Ambient Light and CRTs (Tier 3 - Design Details)
Colored ambient lighting should not be used in conjunction with color-coded CRTs.
COMMENT: (B)

1.4.3.3-17 Unplanned Patterns from Color Coding (Tier 3 - Design Details)
Color coding should not create unplanned or obvious new patterns on the screen.
COMMENT: (B)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.4 Flashing/Blinking

1.4.3.4-1 Blink Coding (Tier 1 - Use)
Blink coding should be used when a displayed item implies an urgent need for user attention.
COMMENT: If used sparingly, blinking symbols are effective in calling a user's attention to displayed items of unusual significance. Blinking characters may have somewhat reduced legibility, and may cause visual fatigue if used too much. (A,D,E,F)

1.4.3.4-2 Flashing (Tier 1 - Use)
Flashing should not be used as a means to highlight routine information. Flashing should only be used as an alerting/warninging code.
COMMENT: (A)

1.4.3.4-3 No Blinking for Attention to Detail or Reading (Tier 1 - Use)
Blink coding should not be used for displays requiring attention to detail or reading of text.
COMMENT: Blink coding generally reduces search times, especially in dense displays. Equal benefit has been found if the entire stimulus is blinked, part of the stimulus is blinked or even if all of the nonstimuli are blinked. Visual search was not degraded, even in the nonstimulus blink condition. (A)

1.4.3.4-4 Off Never Used to Attract Attention (Tier 1 - Use)
An "off" condition should never be used to attract attention to a message.
COMMENT: (B)

1.4.3.4-5 Long-persistence Phosphor Displays (Tier 1 - Use)
Blink coding should not be used with long-persistence phosphor displays.
COMMENT: (B)

1.4.3.4-6 Blinking (Tier 2 - General)
No more than two blink rates should be used to draw attention to critical information.
COMMENT: (F)

1.4.3.4-7 Event Acknowledgement Keys (Tier 2 - General)
Event acknowledgement or flash suppression keys should be provided.
COMMENT: (A)

1.4.3.4-8 Small Area (Tier 2 - General)
Only a small area of the screen should blink at any time.
COMMENT: (A)

1.4.3.4-9 Optimal Blink Rate (Tier 3 - Design Details)
When blink coding is used, a blink rate in the range from 2 to 5 Hz, with a minimum duty cycle (ON interval) of 50 percent should be used.
COMMENT: The differences between the two blink rates should be at least 2 Hz. The slow blink should be not less than 0.8 Hz and the fast blink rate should not be more than 5 Hz. The percentage of time that the image should be "on" should be greater than or equal to the time that it is "off." A 50 percent duty cycle is preferred. (A,D,E,F)

1.4.3.4-10 Blinking Marker Symbols (Tier 3 - Design Details)
When a user must read a displayed item that is blink coded, an extra symbol such as an asterisk to mark the item should be used, and the marker symbol [illegible] blink rather than the item itself.
COMMENT: This practice will draw attention to an item with[illegible]acting from its legibility. (A,D,E)

1.4.3.4-11 Flashing Arrow (Tier 3 - Design Details)

When flashing arrow is used to highlight a specific line of text or value in a table,the spatial relation between the arrow and the item to which the arrow points should be consistent.
COMMENT: The arrow should not obscure any characters. (D)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.5 Image Reversal

1.4.3.5-1 Reverse Video to Indicate Selection (Tier 1 - Use)
Reverse video may be used to indicate selection of a parameter or set of data.
COMMENT: (D)

1.4.3.5-2 Image Reversal (Tier 1 - Use)
Image reversal should be used primarily for highlighting in dense data fields.
COMMENT: (B)

1.4.3.5-3 Coding Annunciator Information (Tier 1 - Use)
Image reversal can be used to code annunciator information that requires immediate response.
COMMENT: (B)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.6 Line

1.4.3.6-1 Coding by Line Length (Tier 1 - Use)
Codes with lines of varying length should be used for applications involving spatial categorization in a single dimension.
COMMENT: For example, the length of a displayed vector might be used to indicate speed. (A,E)

1.4.3.6-2 Coding by Line Direction (Tier 1 - Use)
Codes with lines of varying direction should be used for applications involving spatial categorization in two dimensions.
COMMENT: For example, the angle of a displayed vector might be used to indicate direction, i.e., heading or bearing. (A,E)

1.4.3.6-3 Line Coding (Tier 1 - Use)
For graphic displays, auxiliary methods of line coding should be used, including variation in line type (e.g., solid, dashed, dotted) and line width.
COMMENT: Three or four line types may be readily distinguished, and two or three line widths. (A,E)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.7 Shape and Symbol

1.4.3.7-1 Shape Coding (Tier 1 - Use)
Coding with geometric shapes should be used to help users discriminate different categories of data on graphic displays.
COMMENT: Approximately 15 different shapes can be distinguished readily. (A,B,D,E)

1.4.3.7-2 Symbols to Represent Equipment Data (Tier 1 - Use)
Symbols should be used to represent equipment components and process flow or signal paths, along with numerical or coded data reflecting inputs and outputs associated with equipment.
COMMENT: (B)

1.4.3.7-3 Special Symbols (Tier 1 - Use)
Special symbols, such as asterisks, arrows, etc., should be used to draw attention to selected items in alphanumeric displays.
COMMENT: (A,E)

1.4.3.7-4 Graphical Coding Over Word Messages (Tier 1 - Use)
When rate of comprehension and detection is important, graphical coding should be used rather than word messages.
COMMENT: In general, symbolic/pictographic signs are more quickly detected and comprehended than word messages. (B)

1.4.3.7-5 No Alternating Words and Symbols (Tier 1 - Use)
Words and symbols should not be used alternately.
COMMENT: Alternate use of symbols and words could cause confusion and retard task performance. If a particular situation includes items that cannot be completely pictorialized, i.e., if some items are easy to pictorialize but others are not, it is better to stick to a word labeling system; observers will only be confused if they find some pictorials and some word labels on an operator panel. (B)

1.4.3.7-6 Standard Symbols (Tier 2 - Consistency)
Graphic symbols should have standard meanings and be used consistently within a system and among systems with the same users.
COMMENT: (D,E)

1.4.3.7-7 Consistent Use of Special Symbols (Tier 2 - Consistency)
Special symbols to signal critical conditions should be consistently used only for that purpose.
COMMENT: (A,B,E)

1.4.3.7-8 Establishing Standards for Shape Coding (Tier 2 - Meaningfulness)
When shape coding is used, codes should be based on established standards or conventional meanings.
COMMENT: Although shape codes can often be mnemonic in form, their interpretation will generally rely on learned association as well as immediate perception. Existing user standards must be taken into account. (B,C,D,E)

1.4.3.7-9 Clearly Discriminable Shapes (Tier 2 - General)
Shapes used in coding for data groups should be clearly discriminable.
COMMENT: For example, the elements of one group in a display might be triangles and the elements of a second group might be circles. (D)

1.4.3.7-10 Upright Symbols (Tier 2 - General)

Pictorial symbols should always be oriented "upright."
COMMENT: (B)

1.4.3.7-11 Maximum Viewing Distance/Minimal Ambient Lighting (Tier 2 - General)
The pictorial pattern should be identifiable from the maximum viewing distance and/or under minimal ambient lighting conditions.
COMMENT: Some pictorial patterns may be effective only when the viewing distance and lighting conditions are optimum; be sure that a particular pictorial pattern does not lose its identity when it becomes smaller or more distant and/or when the ambient lighting or atmospheric condition are not good. (B)

1.4.3.7-12 Legends (Tier 2 - General)
Displays should use legend(s) to indicate the meaning of all symbols within the display.
COMMENT: The legend(s) should indicate the meaning of all symbols in a display, both symbols associated with multiple referents and those associated with only a single referent. The legend(s) should be clearly associated with its window and distinguishable from the display information. (D)

1.4.3.7-13 Lowercase Letters for Labels (Tier 3 - Design Details)
When letters are used, perhaps to annotate geometric display symbols, lowercase letters should be used to improve discriminability.
COMMENT: (B)

1.4.3.7-14 More than One Legend (Tier 3 - Design Details)
More than one legend should be provided if a display has many different symbols.
COMMENT: If multiple legends are used on a display, the symbols should be grouped in legends according to perceptual similarity (e.g., a color legend and a shape legend). (D)

1.4.3.7-15 Data Grouping by Shape Coding (Tier 3 - Design Details)
Under most conditions, the preferred technique for data grouping in a graphic display should be shape coding.
COMMENT: Shape coding is achieved by items having the same shape, provided the shapes used are large enough to permit discrimination of different shapes (D)

1.4.3.7-16 Miminum of 20 Min of Arc (Tier 3 - Design Details)
Symbols should subtend a minimum of 20 min. of arc. If the viewing distance is longer than the normal 28 in., it should form a visual angle of about 22 min. of arc.
COMMENT: The size of any symbol can be measure at the surface of the screen, but this does not determine the visibility of the symbol. What is important, is the angle that is subtended by the symbol at the viewer's eye, and this angle depends on symbol height and viewing distance. (B)

1.4.3.7-17 Stroke Width-to-Height Ratio (Tier 3 - Design Details)
The stroke width-to-height ratio should be 1:8 or 1:10 for symbols of 0.4 in. or larger viewed up to a distance of 7 ft.
COMMENT: (B)

1.4.3.7-18 Markers Close to Words Marked (Tier 3 - Design Details)
When a special symbol is used to mark a word, the symbol should be separated from the beginning of the word by a space.
COMMENT: A symbol immediately adjacent to the beginning of a word will impair legibility. (E)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.8 Size

1.4.3.8-1 Limited Use of Size Coding (Tier 1 - Use)
Size coding should be used only for applications where displays are not crowded.
COMMENT: Size coding is achieved by varying the size of displayed alphanumerics, labels, and other symbols. No more that three distinct sizes should be used in size coding. (E)

1.4.3.8-2 Adequate Differences in Size (Tier 3 - Design Details)
For size coding, a larger symbol should be at least 1.5 times the height of the next smaller symbol.
COMMENT: An increase in symbol height must usually be accompanied by a proportional increase in width to preserve a constant aspect ratio and so facilitate symbol recognition. (A,E)

1.4.3.8-3 Symbol and Size (Tier 3 - Design Details)
Where size difference between symbols is employed, the major dimensions of the larger should be at least 150 percent of the major dimension of the smaller with a maximum of three size levels permitted.
COMMENT: (A)

1.4.3.8-4 Symbol Size Proportional to Data Value (Tier 3 - Design Details)
When the symbol size is to be proportional to the data value, the scaled parameter should be the symbol area rather than a linear dimension such as diameter.
COMMENT: (B)

1.4.3.8-5 Area Coding (Tier 3 - Design Details)
For area coding, the maximum number of codesteps should be six, with three recommended.
COMMENT: (B)

1.4.3.8-6 Length Coding (Tier 3 - Design Details)
For length coding, the maximum number of code steps should be six, with three recommended.
COMMENT: (B)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.9 Spatial/Position/Pattern/Location

1.4.3.9-1 Pattern/Location Coding (Tier 1 - Use)
Pattern and location coding may be used to reduce search time by restricting the area to be searched to prescribed segments.
COMMENT: (A,C)

1.4.3.9-2 Grouping Techniques (Tier 1 - Use)
Grouping techniques should be used to group functionally similar information and to indicate membership in a common group.
COMMENT: Grouping techniques include grouping by color, shape, spatial distance, orientation, type of character, etc. (D)

1.4.3.9-3 Spacial Distance for Redundant Coding (Tier 1 - Use)
Spatial distance should be used for redundant coding when possible. Limitations are physical screen size and amount of information to be displayed.
COMMENT: Although data grouping techniques have been found to be task dependent, grouping based on location has been generally successful across a variety of tasks. (D)

1.4.3.9-4 Bordering Single Blocks (Tier 1 - Use)
A border should be used to improve the readability of a single block of numbers or letters.
COMMENT: (B)

1.4.3.9-5 Cohesive Groupings (Tier 2 - Sequencing and Grouping)
Displays should provide cohesive groupings of display elements so that users perceive large screens as consisting of smaller identifiable pieces or chunks.
COMMENT: (D)

1.4.3.9-6 Distinctive Borders Around Critical Information (Tier 2 - General)
If several labels or messages are clustered in the same area, distinctive borders should be placed around the critical ones only.
COMMENT: (B)

1.0 INFORMATION DISPLAY
1.4 Coding
1.4.3 Other Coding
1.4.3.10 Texture

1.4.3.10-1 Darkest/Lightest Correspond to Extreme Values (Tier 3 - Design Details)
Where texture patterns or tonal variation coding is used, values should be selected so that the darkest and lightest shades correspond to the extreme values of the coded variable.
COMMENT: (A)

1.4.3.10-2 Simple Texture Codes (Tier 3 - Design Details)
In selecting textures to code displayed areas, choose simple hatching rather than elaborate patterns.

COMMENT: Compared with manual drafting methods, it is temptingly easy to have a computer generate texture codes of considerable complexity. Texture coding is a technique specifically related to graphics. Other kinds of display coding (e.g., size, shape, brightness, color), can be applied more generally in display design. (E)

1.0 INFORMATION DISPLAY

1.5. Display of Safety Parameters

1.5.1. General

1.5.1-1 Indication of Plant Status (SPDS)
The display does not give false indications of plant status.
COMMENT: (G)

1.5.1-2 Sampling Rate (SPDS)
The sampling rate for each critical plant variable is such that there is no meaningful loss of information in the data presented to the control room operator.
COMMENT: (G)

1.5.1-3 Rapid Recognition of Status (SPDS)
Operator comprehension of a change in the safety status of the plant from the SPDS display could be achieved in a matter of seconds.
COMMENT: (G)

1.5.1-4 Range of Conditions Portrayed (SPDS)
The display system correctly portrays information about the plant's safety status for a wide range of events and includes symptoms of severe accidents.
COMMENT: (G)

1.5.1-5 Trend Indication (SPDS)
The SPDS display has the capability of indicating trends of each SPDS variable.
COMMENT: (G)

1.5.1-6 Display of Derivatives (SPDS)
Display of time derivatives of variables is acceptable only when the derivatives unambiguously reflect the trends is the critical plant variables.
COMMENT: (G)

1.5.1-7 Perceptual Cues (SPDS)
The SPDS, where feasible, includes perceptual cues to alert personnel to the abnormal operating condition.
COMMENT: (G)

1.5.1-8 Distinctive Display (SPDS)
The SPDS is readily distinguished from other displays on the control board.
COMMENT: (G)

1.5.1-9 Display Readability (SPDS)
The display meet the intent of the appropriate display readability guidelines stated in NUREG-0700.
COMMENT: (G)

1.5.1-10 Control of Display Content (SPDS)
The control room operating crew, not personnel outside the control room, control images displayed on the control room SPDS.
COMMENT: (G)

1.5.1-11 Dedicated Display (SPDS)
A dedicated display, such as a CRT, continuously displays the minimum set of variables necessary to assess the safety status of the plant.
COMMENT: (G)

1.5.1-12 Hierarchical Display (SPDS)
A hierarchical display system is used with control room operator-controlled means to access all levels of display formats needed to evaluate the safety status of the plant.
COMMENT: (G)

1.5.1-13 Alert to Primary Display (SPDS)
Perceptual (audible or visual) cues are provided by the system to alert the control room operator to return to the primary display format while viewing secondary information.
COMMENT: (G)

1.5.1-14 Backup Procedures (SPDS)
Operating procedures and training are provided to the control room operating crew that will allow timely and correct safety status assessment when the SPDS is not operating.
COMMENT: (G)

1.5.1-15 Training (SPDS)
The control room operator's training program contains instruction and training in the use of the SPDS in conjunction with operating procedures for normal, abnormal, and emergency operating conditions.
COMMENT: (G)

1.5.1-16 User's Manual (SPDS)
An SPDS user's manual is available for reference in the control room.
COMMENT: (G)

1.5.1-17 Hierarchical Displays (SPDS)
The design provides a primary display supported by a coordinated set of hierarchical subordinate displays for each mode of plant operation.
COMMENT: (G)

1.5.1-18 Use of Graphic Overlays (SPDS)
Graphic overlays should not distract the operator or interfere with the observation of displayed information or interpretation of plant operating conditions.
COMMENT: (G)

1.5.1-19 Choice of Setpoints (SPDS)
Setpoints used to indicate a change in status are chosen specifically for their suitability to perform the desired function.
COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.2. Data Quality

1.5.2-1 Time Delay (SPDS)
The time delay from when the sensor signal is sampled to when it is displayed is consistent with other control room displays and should be responsive to control room operators' needs in performing assigned tasks.
COMMENT: (G)

1.5.2-2 Accuracy (SPDS)
Each critical plant variable is displayed with an accuracy sufficient for the control room operator to discriminate between conditions that impact the plant's safety status and normal operating condition.
COMMENT: (G)

1.5.2-3 Data Verification (SPDS)
Redundant sensor readings are compared before displaying the critical plant variable.
COMMENT:

1.5.2-4 Analytical Redundancy (SPDS)
Analytical redundancy among different critical plant parameters is used and models and equations have been documented and validated.
COMMENT: (G)

1.5.2-5 Identification of Data Quality (SPDS)
Validated data, unvalidated data, and invalid data are identified and coded where practical.
COMMENT: (G)

1.5.2-6 Stability of Trend Data (SPDS)
Trend rates presented to the control room operator should not fluctuate as a result of minor fluctuations in data or oscillatory behavior which may be superimposed on a well-defined trend of the variable.
COMMENT: (G)

1.5.2-7 Indication of Non-Representative Trend Data (SPDS)
When a simple quantitative rate-of-change value is used, an indication should be provided to inform the control room operator when, as a result of minor fluctuations or oscillations, the rate value does not accurately represent the trend of the variable.
COMMENT: (G)

1.5.2-8 Operability Monitoring (SPDS)
The SPDS design incorporates an automatic or user-activated operability monitoring feature.
COMMENT: (G)

1.5.2-9 Indication of System Failure (SPDS)
The design incorporates a display of calendar date and time of day such that the display is updated only when the system is operating properly so that a static time would indicate a system failure.
COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.3. Format

1.5.3-1 Selection of Display Format (SPDS)
A manually operated switch or input from an alpha-numeric keyboard, touch panel, light pen, cursor, or equivalen arrangement is provided by the design to allow the control room operator to select the display format for the mode of plant operation.
COMMENT: (I)

1.5.3-2 Automatic Format Change (SPDS)
Automatic display format change occurs with a change in the mode of plant operation.
COMMENT: (G)

1.5.3-3 Indication of Automatic Change (SPDS)
There are provisions in the display to indicate to the control room operator that a change in the mode of plant operation has occurred.
COMMENT: (G)

1.5.3-4 Mode-Specific Display Formats (SPDS)
The design has a display format for each mode of plant operation.
COMMENT: (G)

1.5.3-5 Minimum Data Set (SPDS)
For each mode of operation, the displays contain the minimum set of indicators and data needed to assess the plant functions that are used to determine the plant's safety status.
COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.4. Coding

1.5.4-1 Color Coding (SPDS)
Color coding is used to indicate the approach to unsafe operation and to indicate unsafe operation.
COMMENT: (G)

1.5.4-2 Limit Marks (SPDS)
Limit marks are used for each critical plant variable displayed.
COMMENT: (G)

1.5.4-3 Pattern Coding (SPDS)
Patterns are used that noticeably distort when an unsafe condition is approached.
COMMENT: (G)

1.5.4-4 Color Coding of Change in Status (SPDS)
When color changes are used to indicate a change in functional or operating status, no more than three colors should be used, corresponding to two levels of change in severity of status.
COMMENT: (G)

1.5.4-5 Consistent Color Codes (SPDS)
The colors used in the SPDS display are consistent with color codes used elsewhere in the control room.
COMMENT: (G)

1.5.4-6 Color Coding Conflicts (SPDS)
Displays avoid conflicts between the use of color coding to enhance selective identification of displays, display elements and the use of color codes to enhance changes in the operating status of displays, display elements, or displayed variables.
COMMENT: (G)

1.5.4-7 Distinctiveness of Pattern Coding (SPDS)
When a pattern is used to enhance the control room operator's assessment of the safety status of the plant, the pattern for normal operating conditions has distinctive characteristics that distinguish it from the patterns produced by other conditions.
COMMENT: (G)

1.5.4-8 Use of Pattern Coding (SPDS)
Displays relying on pattern recognition to identify an abnormal condition are selected for variables that have small deviations about a steady-state value during normal operating conditions and that have distinctive variations from the steady state value during abnormal conditions.
COMMENT: (G)

1.5.4-9 Augmentation of Coding (SPDS)
Top level display formats based only on shape coding or only on color coding or on a combination of these are augmented with lower level display formats which are based on alphanumeric coding of data and information.
COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.5. Scaling

1.5.5-1 Automatic Rescaling (SPDS)

It is preferable that changes in scale for the purpose of maintaining an undistorted display for different operating conditions be made by a command by the control room operator rather than by automatic action of the display signal or data processing system.

COMMENT: (G)

1.5.5-2 Indication of Rescaling (SPDS)

A system that is designed to automatically change scaling alerts the control room operator that the change is being made.

COMMENT: (G)

1.5.5-3 Use of Non-Linear Scaling (SPDS)

When a non-linear relationship between the magnitude of the measured or derived value of the variable and the display element used to depict the value is used, it can be demonstrated that such a relationship is better understood by control room operators or that it will actually facilitate their interpretation of information.

COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.6. Workspace

1.5.6-1 Display Accessibility (SPDS)
The display is readily accessible to the following personnel, but not necessarily simultaneously:

Shift supervisor
Control room senior reactor operator
Shift technical advisor
One reactor operator

COMMENT: (G)

1.5.6-2 Operator Access (SPDS)
Member of the control room operating crew have physical access to the SPDS.
COMMENT: (G)

1.5.6-3 Lighting (SPDS)
Glare from normal of emergency lighting does not restrict the view of the SPDS from within the control room, and luminance levels and luminance contrast do not limit viewing the SPDS.
COMMENT: (G)

1.5.6-4 Display Visibility (SPDS)
The SPDS display is readable from the emergency station of the control room operator responsible for evaluating the safety status of the plant.
COMMENT: (G)

1.5.6-5 Display Position (SPDS)
The display system does not interfere with the crew's normal movement.
COMMENT: (G)

1.5.6-6 Interference with Other Displays (SPDS)
The display system does not interfere with full visual access to other control room operating systems and with displays important for safe operation.
COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.7. Display Formats
1.5.7.1. Normal Values

1.5.7.1-1 Normal Values (SPDS)
A bar chart should provide a reference to the normal operating value of each variable displayed.
COMMENT: (G)

1.5.7.1-2 Normal Ranges (SPDS)
The normal operating range of a variable on a bar chart is indicated when the operating range is a significant fraction of the total range.
COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.7. Display Formats
1.5.7.2. Deviation Bar Chart

1.5.7.2-1 Zero Reference (SPDS)
The zero reference is in the center of the deviation bar chart.
COMMENT: (G)

1.5.7.2-2 Normal Range (SPDS)
The range of normal conditions for positive or negative deviations represents no more than 10% of the total range provided to display that variable's deviation.
COMMENT: (G)

1.5.7.2-3 Indication of Magnitude (SPDS)
Some way to indicate the magnitude of each variable is provided when the deviation bar display is used as a primary SPDS display format because this information is not included in the deviation bar chart itself.
COMMENT: (G)

1.0 INFORMATION DISPLAY

1.5. Display of Safety Parameters

1.5.7. Display Formats

1.5.7.3. Circular Profile

1.5.7.3-1 Normal Profile (SPDS)

Under normal conditions, the profile is circular or regular.

COMMENT: (G)

1.0 INFORMATION DISPLAY
1.5. Display of Safety Parameters
1.5.7. Display Formats
1.5.7.4. Chernoff Faces

1.5.7.4-1 Use of Chernoff Faces (SPDS)
Chernoff faces are not used as the primary display format for SPDS.
COMMENT: (G)

2.0 OPERATOR INPUT AND CONTROL

2.1 Entering Information

2.1.1 General

2.1.1-1 Standardized Procedures (Tier 2 - Consistency)
Procedures for user actions should be standardized.
COMMENT: LOG ON and LOG OFF procedures, menu selection techniques, user input procedures, and error correction procedures are examples of user actions for which standardized conventions are required. (C)

2.1.1-2 Input units (Tier 2 - Meaningfulness)
Data should be entered in units which are familiar to the user.
COMMENT: (A)

2.1.1-3 Availability of information (Tier 2 - Task Compatibility)
Information necessary to select or enter a specific control action should be available to the user when selection of that control action is appropriate.
COMMENT: (A)

2.1.1-4 User memorization (Tier 2 - Memory Load)
The requirement to learn mnemonics, codes, special or long sequences, or special instructions should be minimized.
COMMENT: (A)

2.1.1-5 Data manipulation (Tier 2 - Memory Load)
The user should be able to manipulate data without concern for internal storage and retrieval mechanisms of the system.
COMMENT: (A)

2.1.1-6 Default Values (Tier 2 - Memory Load)
When likely default values can be defined for the data entries in a particular task, those default values should be offered to speed data entry.
COMMENT: (A,E)

2.1.1-7 Display of Default Values (Tier 2 - Memory Load)
On initiation of a data entry transaction, currently defined default values should be displayed in their appropriate data fields.
COMMENT: It may be helpful to mark default values in some way to distinguish them from new data entries. (A,E)

2.1.1-8 Single Method for Entering Data (Tier 2 - Minimizing User Actions)
Data entry transactions and associated displays should be designed so that a user can stay with one method of entry, and not have to shift to another.
COMMENT: As a positive example, minimize shifts from lightpen to keyboard entry and then back again. As a negative example, a user should not have to shift from one keyboard to another, or move from one work station to another, to accomplish different data entry tasks. (A,E)

2.1.1-9 Data Entered Only Once (Tier 2 - Minimizing User Actions)
A user should need to enter any particular data only once, and the computer should access those data if needed thereafter for the same task or for different tasks.
COMMENT: In effect, this recommendation urges integrated and flexible software design so that different programs can access previously entered data as needed. Requiring re-entry of data would impose duplicative effort on users and increase the possibility of entry errors. (A,E)

2.1.1-10 User Review of Prior Entries (Tier 2 - Minimizing User Actions)
When data entries made in one transaction are relevant to a subsequent transaction, the computer should retrieve and display them for user review rather

than requiring re-entry of those data.
COMMENT: (A,E)

2.1.1-11 Automatic Generation of Routine Data (Tier 2 - Minimizing User Actions)
For routine data that can be derived from existing computer records, the computer should access and enter such data automatically.
COMMENT: As a negative example, users should be required to identify a work station in order to initiate a transaction, nor to include other routine data such as current date and transaction sequence codes. Some data entry routines may be imposed in the interest of security, but at the risk of hindering a user in achieving effective task performance. (A,E)

2.1.1-12 Automatic Computation of Derived Data (Tier 2 - Minimizing User Actions)
Automatic computation of derived data should be provided sc that a user does not have to calculate and enter any number that can be derived from data already accessible to the computer.
COMMENT: Statistical descriptors such as sums, means, etc., can all be derived automatically by appropriate software. (A,E)

2.1.1-13 Automatic Entry of Redundant Data (Tier 2 - Minimizing User Actions)
If data are accessible to the computer that are logically related to other entries, the computer should retrieve and enter those redundant data items automatically.
COMMENT: As a negative example, a user should not have to enter both an item name and identification code when either one defines the other. When verification of previously entered data is required, usersshould be asked to review and confirm data items rather than re-enter them. Redundant entry may be needed for resolving ambiguous entries, for user training, or for security (e.g., user identification). (A,E)

2.1.1-14 Automatic Cross-File Updating (Tier 2 - Minimizing User Actions)
Automatic cross-file updating should be provided whenever necessary, so that a user does not have to enter the same data twice.
COMMENT: (A,E)

2.1.1-15 Easy Confirmation to Enter Default Values (Tier 2 - Minimizing User Actions)
Users should be provided with some simple means to confirm acceptance of a displayed default value for entry.
COMMENT: Similar techniques should be used when a user must review the accuracy of previously entered data. Simply tabbing past the default field may suffice. (A,E)

2.1.1-16 Minimal Shift Keying (Tier 2 - Minimizing User Actions)
Data entry transactions should be designed to minimize the need for shift keying.
COMMENT: Shift keying can be considered a form of double keying, which imposes a demand for extra user attention. Frequently used characters should be placed where they can be easily keyed. Conversely, frequent use of characters requiring shift keying should be avoided. (A,E)

2.1.1-17 Hierarchical process (Tier 2 - Minimizing User Actions)
When hierarchical levels are used to control a process or sequence, the number of levels should be minimized. Display and input formats should be similar within levels and the system should indicate the current positions within the sequence at all times.
COMMENT: (A)

2.1.1-18 Feedback During Data Entry (Tier 2 - Feedback)
Feedback should be displayed for all user actions during data entry; keyed entries should be displayed stroke by stroke.
COMMENT: For reasons of data protection, it may not be desirable to display passwords and other secure entries. (A,E)

2.1.1-19 Feedback for Completion of Data Entry (Tier 2 - Feedback)
The computer should acknowledge completion of a data entry transaction with a confirmation message if data entry was successful, or else with an error message.
COMMENT: Successful data entry should not be signaled merely by automatic erasure of entered data from the display, except possibly in the case of repetitive data entries. For single data entry transactions, it may be better if entered data is left on the display until the user takes an explicit action to clear the display. In a sequence of routine, repetitive data entry transactions, however, successful completion of one entry should result simply in regeneration of the initial (empty) data entry display, in order to speed the next entry in the sequence. (A,E)

2.1.1-20 Feedback for Repetitive Data Entries (Tier 2 - Feedback)
For a repetitive data entry task that is accomplished as a continuing series of transactions, successful entry should be indicated by regenerating the data entry display, automatically removing the just-entered data in preparation for the next entry.
COMMENT: Automatic erasure of entered data represents an exception to the general principle of control by explicit user action. In addition to erasure of entered data, a message confirming successful data entry might be displayed. Such a message may reassure uncertain users, especially in system applications where computer performance is unreliable. (E)

2.1.1-21 Clarifying Unrecognized Abbreviations (Tier 2 - Error Handling)
When the computer cannot recognize an abbreviated data entry, the user should be questioned as necessary to resolve any ambiguity.
COMMENT: This may occur when a user enters a misremembered abbreviation. (A,E)

2.1.1-22 Explicit ENTER Action (Tier 2 - General)
A user should be required to take an explicit ENTER action to initiate processing of entered data; processing should not be initiated as a side effect of some other action.
COMMENT: As a negative example, returning to a menu of control options should not by itself result in computer processing of data just keyed onto a display. However, in routine, repetitive data entry transactions, successful completion of one entry may automatically lead to initiation of the next. Deferring processing until after an explicit ENTER action will permit a user to review data and correct errors before computer processing; this is particularly helpful when data entry is complex and/or difficult to reverse. (A,E)

2.1.1-23 Entry via Primary Display (Tier 2 - General)
When data entry is a significant part of a user's task, entered data should appear on the user's primary display.
COMMENT: As a negative example, entry via typewriter is acceptable only if the typewriter itself, under computer control, is the primary display medium. When the primary display is basically formatted for other purposes, such as a graphic display for process control, a separate window on the display may have to be reserved for data entry. (A,E)

2.1.1-24 Compatibility with user skill (Tier 2 - General)
Controls should be compatible with the lowest anticipated user skill levels. Experienced users should have options which shortcut intervening steps necessary for inexperienced users.
COMMENT: (A)

2.1.1-25 Explicit CANCEL Action (Tier 2 - General)
A user should be required to take an explicit action in order to cancel a data entry.
COMMENT: Data cancellation should not be accomplished as a side effect of some other action. As a negative example, cas[illegible] interruptions of a data entry sequence, such as paging through forms, or detouring to HELP displays, shou[illegible] have the effect of erasing partially completed data entries. If a requested sequence control action implie[illegible] a more definite interruption, such as a LOG-OFF command, or a command to return to a menu display, then the user should be asked to confirm that action and alerted to the loss of any data entries that would result. (E)

2.1.1-26 User-Paced Data Entry (Tier 2 - General)
Users should be allowed to pace their data entry, rather than having the pace being controlled by

computer processing or external events.
COMMENT: The timing of user-paced data entry will fluctuate depending upon a user's momentary needs, attention span and time available. At maximum speed, user-paced performance is more accurate than that achieved by machine pacing. (A,E)

2.1.1-27 Entry of Corrections (Tier 2 - General)
The same explicit ENTER action should be required for entry of corrections as used for the original entry.
COMMENT: (A)

2.1.1-28 Editing During Entry (Tier 2 - General)
Users should be able to perform simple editing during data entry, without entering special editing modes.
COMMENT: For example, by use of destructive backspace to erase and retype characters to the immediate left of the cursor. (A)

2.1.1-29 Consistent Method for Data Change (Tier 2 - General)
In keyed data entry, users should always be allowed to change previous entries by delete and insert actions.
COMMENT: If data change is sometimes made by direct character substitution ("typeover"), then that option should also be consistently available. Using typeover, there is some risk of user confusion in replacement of an old value with a new one, during the transitional period when the item being changed is seen as a composite beginning with the new value and ending with the old. For example, form filling may require typeover to replace displayed characters such as underscores that act as field delimiters. (A)

2.1.1-30 Validation (Tier 2 - General)
Data entries should be validated by the system for correct format, legal value, or range of values. Where repetitive entry of data sets is required, data validation for each set should be completed before another transaction can begin.
COMMENT: (A)

2.1.1-31 Operator Confirmation of Destructive Entries (Tier 2 - General)
Operators should take explicit action to confirm a potentially destructive data/command entry before computer execution.
COMMENT: What constitutes "potentially destructive" requires definition in the context of each system operation. When data entries or changes will be nullified by an abort action, the operator should be requested to confirm the abort. (E)

2.1.1-32 Defaults for Sequential Entries (Tier 2 - General)
If a series of default values have been defined for a data entry sequence,users should be allowed to default all entries or to default until the next required entry.
COMMENT: Where a set of default values has been defined, a user may not wish to specify that each default value should be accepted for each data field individually. It might be quicker to accept the set of defaults by a single action. (A,E)

2.1.1-33 Character Entry via Single Keystroke (Tier 3 - Design Details)
Users should be allowed to enter each character of a data item with a single stroke of an appropriately labeled key.
COMMENT: As a negative example, when a keyboard is intended primarily for numeric input, with several letters grouped on each key such as a telephone keypad, users should be not be required to make alphabetic entries by double keying. Devices that involve complex keying methods for alphabetic entry (e.g., pressing more than one key, simultaneously or successively) require special user training and risk frequent data entry errors. When hardware limitations such as those of a telephone keypad seem to require double keying of alphabetic entries, data codes should be limited so that only single-keyed (numeric) entries are required. Alternatively, software to interrogate the user to resolve any ambiguities resulting from single-keyed alphabetic entries should be provided. (E)

2.1.1-34 Keeping Data Items Short (Tier 3 - Design Details)
For coded data, numbers, etc., data entries should be kept short so that the length of an individual item will not exceed 5-7 characters.
COMMENT: For coded data, lengthy items may exceed a user's memory span, inducing errors in both data entry and data review. Proper names, meaningful words, and other textual material are not coded data. Such items can be remembered more easily, and the length restriction recommended here need not apply. Coded data may include such items as badge numbers, payroll numbers, mail stops, equipment and part numbers, etc. (A,E)

2.1.1-35 Prompting Data Entry (Tier 3 - Design Details)
Prompting for the required formats and acceptable values for data entries should be provided.
COMMENT: Prompting is particularly needed for coded data entries. Menu selection may be appropriate for that purpose, because menu selection does not require the user to remember codes but merely to choose among displayed alternatives. Other methods of prompting include labeling data fields, such as Vendor (CE/GE/W) ___ and/or providing optional guidance displays. Prompting may not be needed by skilled users and indeed may hinder rather than help their performance in situations where display output is slow (as with Teletype displays); for such users prompting might be provided as an optional aid. (E)

2.1.1-36 Maintaining Context for Data Entry (Tier 3 - Design Details)
In a transaction involving extended data entry, a cumulative record of previous inputs should be displayed.
COMMENT: For example, in a multipage data entry display, the operator should not be required to recall data from page to page. (E)

2.1.1-37 Flexible Design for Data Entry (Tier 3 - Design Details)
When data entry requirements may change, some means for users (or a system administrator) to make necessary changes to data entry functions should be provided.
COMMENT: (E)

2.1.1-38 Large Pointing Area for Option Selection (Tier 3 - Design Details)
In selection of displayed alternatives, the acceptable area for pointing should be as large as consistently possible, including at least the area of the displayed label plus a half-character distance around the label.
COMMENT: The larger the effective target area, the easier the pointing action will be, and the less risk of error in selecting the wrong label by mistake. (E)

2.1.1-39 Aids for Entering Hierarchic Data (Tier 3 - Design Details)
If a user must enter hierarchic data, where some items will be subordinate to others, computer aids should be provided to help the user specify relations in the hierarchic structure.
COMMENT: For simple data structures, question-and-answer dialogues or form filling may suffice to maintain necessary data relations. For more complex data structures, such as those involved in graphic data entry, special techniques may be needed to help users specify the relations among data entries. (E)

2.1.1-40 Feedback when Changing Data (Tier 3 - Design Details)
If a user requests change (or deletion) of a data item that is not currently being displayed, the user should be offered the option of displaying the old value before confirming the change.
COMMENT: Displayed feedback will help prevent inadvertent data change, and is particularly useful in protecting delete actions. Like other recommendations intended to reduce error, it assumes that accuracy of data entry is worth extra effort by the user. For some tasks, that may not be true. Expert users may sometimes wish to implement data changes without displayed feedback, as in "global replace" transactions, accepting the attendant risk. (A,E)

2.1.1-41 Optional Abbreviation (Tier 3 - Design Details)
Optional abbreviation of lengthy data items should be allowed to minimize data entry keying by expert users, when that can be done without ambiguity.
COMMENT: (E)

2.1.1-42 Leading Zeros Optional (Tier 3 - Design Details)

For general numeric data, optional entry or omission of leading zeros should be allowed as equivalent alternatives.
COMMENT: If a user enters "56" in a field that is four characters long, the system should recognize that entry rather than requiring an entry of "0056". Special cases may represent exceptions to this rule, such as entry of serial numbers or other numeric identifiers. (A,E)

2.1.1-43 Decimal Point Optional (Tier 3 - Design Details)
Optional entry or omission of a decimal point at the end of an integer should be allowed as equivalent alternatives.
COMMENT: (E)

2.1.1-44 Upper and Lower Case Equivalent (Tier 3 - Design Details)
For coded data entry, upper and lower case letters should be treated as equivalent.
COMMENT: For data codes, users find it difficult to remember whether upper or lower case letters are required, and so the software design should not try to make such a distinction. For text entry, however, conventional use of capitalized letters should be maintained. (A,E)

2.1.1-45 Single and Multiple Blanks Equivalent (Tier 3 - Design Details)
Single and multiple blank characters should be treated as equivalent in data entry; users should not be requires to count blanks.
COMMENT: People cannot be relied upon to pay careful attention to such details. The computer should handle them automatically, e.g., ensuring that two spaces follow every period in text entry (if that is the desired convention), and spacing other data items in accord with whatever format has been defined. (A,E)

2.1.1-46 User Definition of Default Values (Tier 3 - Design Details)
Users should be permited to define, change or remove default values for any data entry field.
COMMENT: (A,E)

2.1.1-47 Temporary Replacement of Default Values (Tier 3 - Design Details)
Users should be allowed to replace any data entry default value with a different entry, without thereby changing the default definition for subsequent transactions.
COMMENT: (A,E)

2.1.1-48 Inserting (Tier 3 - Design Details)
When inserting words or phrases, items to be inserted should be displayed as the final copy will appear.
COMMENT: (A)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.2 Cursor Positioning and Control
2.1.2.1 General

2.1.2.1-1 Cursor Control - General (Tier 2 - General)
The user should be able to adjust the sensitivity of the cursor movement to be compatible with the required task and user skills.
COMMENT: (E)

2.1.2.1-2 Display of Cursor (Tier 2 - General)
The cursor should not move beyond the display boundaries and disappear from sight.
COMMENT: (E)

2.1.2.1-3 Compatible Control of Cursor Movement (Tier 2 - General)
Control actions for cursor positioning should be compatible with movements of the displayed cursor, in terms of control function and labeling.
COMMENT: For cursor control by key action, a key labeled with a left-pointing arrow should move the cursor leftward on the display; for cursor control by joystick, leftward movement of the control (or leftward pressure) should result in leftward movement of the cursor, etc. (A,C,E)

2.1.2.1-4 Easy Cursor Positioning (Tier 3 - Design Details)
Users should be provided with an easy, accurate means of positioning a displayed cursor to point at different display elements and/or display locations.
COMMENT: Cursor positioning is a frequent user action during graphic data entry. An easy means for controlling cursor movement is essential for efficient performance. (E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.2 Cursor Positioning and Control
2.1.2.2 Controlling Cursor Movement

2.1.2.2-1 Consistent positioning (Tier 2 - Consistency)
Where cursor positioning is incremental by discrete steps, the step size of cursor movement should be consistent horizontally (i.e., in both right and left directions), and vertically (in both up and down directions).
COMMENT: (E)

2.1.2.2-2 Cursor Control Key Functions (Tier 2 - General)
At the minimum, keys for cursor control should allow horizontal and vertical cursor movement.
COMMENT: Ideally, keys for cursor control should allow both horizontal and vertical movement, and movement along the diagonals. (D)

2.1.2.2-3 Cursor Movement (Tier 2 - General)
If the cursor is moved by depressing a key, releasing the key should cause the cursor to stop moving.
COMMENT: (E)

2.1.2.2-4 Responsive Cursor Control (Tier 2 - General)
For arbitrary position designation, moving a cursor from one position to another, the cursor control should permit both fast movement and accurate placement.
COMMENT: Ideally, when the user moves a pointing device the displayed cursor should appear to move instantly. Rough positioning should take no more than 0.5 seconds for full screen traversal. Fine positioning may require incremental stepping of the cursor, or a control device incorporating a large control/display ratio for small displacements, or a selectable vernier mode of control use. For any given cursor control action, the rate of cursor movement should be constant, i.e., should not change with time. Slow visual feedback of cursor movement can be particularly irritating when a user is repeatedly pressing a cursor control key, or perhaps holding the key down. In that case, slow feedback will cause the user to misjudge location and move the cursor too far. (E)

2.1.2.2-5 Precise Pointing (Tier 2 - General)
When fine accuracy of positioning is required, as in some forms of graphic interaction, the displayed cursor should include a point designation feature.
COMMENT: Precise pointing will also require a cursor control device capable of precise manipulation. Touch displays, for example, will not permit precise pointing. A cross may suffice (like cross-hairs in a telescope), or perhaps a notched or V-shaped symbol (like a gun sight). (E)

2.1.2.2-6 Selectable Rate Aiding (Tier 2 - General)
Rate aiding of the cursor movement (i.e., the speed of follower movement is proportional to the speed of input movement) should be user selectable on/off. The default should be not to have rate aiding (zero-order control-display relation).
COMMENT: (D)

2.1.2.2-7 Cursor Control at Keyboard (Tier 3 - Design Details)
When position designation is required in a task emphasizing keyed data entry, cursor control should be provided by some device integral to the keyboard (function keys, joystick, "cat", etc.).
COMMENT: Separately manipulated devices (lightpen, "mouse", etc.) will tend to slow the user. (A,E)

2.1.2.2-8 Location of cursor control keys (Tier 3 - Design Details)
If cursor movement is accomplished by depressing keys, the keys should be located on the main keyboard.
COMMENT: (E)

2.1.2.2-9 User Selectable Speed (Tier 3 - Design Details)
Users should be able to select at least two speeds (normal and fast) for the movement of the cursor when the keys for cursor control are held down.
COMMENT: (D)

2.1.2.2-10 Confirming Cursor Position (Tier 3 - Design Details)
For most graphics data entry, pointing should be a dual action, first positioning a cursor at a desired position, and then confirming that position to the computer.
COMMENT: An exception to this recommendation would be the free hand drawing of continuous lines ("path specification"), where a computer must store and display a series of cursor positions as they are input by the user. when the user initiates such a line-drawing sequence, a new datapoint might be recorded automatically whenever the cursor has been moved a certain distance (e.g., 1 mm) or when a certain time has elapsed (e.g., 0.5 s). During graphics data entry, a cursor will almost always be somewhere on the display, but not necessarily at a location inter ed by the user. In effect, a user needs some way to move the cursor around and some separate action to signal th puter when its position should be recorded. An interesting case of position confirmation is "n. .rbanding", which is a technique to aid line drawing. With rubberbanding, a user can designate the starting point for a line, then move the cursor to various possible end points while the computer continuously shows the line that would result if that end point were confirmed by the user. (E)

2.1.2.2-11 Variable Step Size (Tier 3 - Design Details)
When character size is variable, the incremental cursor positioning should vary correspondingly, with a step size matching the size of currently selected characters.
COMMENT: (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.2 Cursor Positioning and Control
2.1.2.3 Automatic Cursor Placement

2.1.2.3-1 Consistent Cursor Placement (Tier 2 - Minimizing User Actions)
On the initial appearance of a data entry display, the cursor should appear automatically at some consistent and useful location.
COMMENT: In a form-filling display, the cursor should be placed in the first entry field. (E)

2.1.2.3-2 Consistent HOME Position (Tier 2 - General)
When there is a predefined HOME position for the cursor, that position should be consistently defined on all displays of a given type.
COMMENT: The HOME position of the cursor should also be consistent in the different "windows" or sections of a partitioned display. For example, HOME might be in the upper left corner of a text display, or at the first field in a form-filling display, or at the center of a graphic display. (A,C,E)

2.1.2.3-3 Automatic Cursor Placement for Menus (Tier 2 - General)
On separate menu displays, when menu selection is by pointing, the system should place the cursor automatically at the first listed option. When menu selection is by code entry, the cursor should be automatically placed in the command entry area.
COMMENT: When menu selection is by code entry, for some applications it may increase the efficiency of sequence control if a null entry is recognized as a default to the first displayed option (assuming that the first option is the most likely choice). (E)

2.1.2.3-4 Cursor Placement for Pointing at Options (Tier 2 - General)
When users will select among displayed options by pointing, the cursor should be placed on the first (most likely) option at display generation.
COMMENT: (E)

2.1.2.3-5 Automatic Return of Cursor (Tier 3 - Design Details)
When the user is required to return to the origin or other specific screen location automatic return of the cursor should be provided.
COMMENT: (D)

2.1.2.3-6 Cursor Placement Following Error (Tier 3 - Design Details)
In addition to providing an error message, the location of a detected error should be marked by positioning the cursor at that point on the display, i.e., at that data field or command word.
COMMENT: Displaying the cursor at a non-routine position will help emphasize that an error has occurred, and direct the user's attention to the faulty entry. (E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.2 Cursor Positioning and Control
2.1.2.4 Cursor Control and Data Entry

2.1.2.4-1 Easy Cursor Movement to Data Fields (Tier 2 - Minimizing User Actions)
If a cursor must be positioned sequentially in predefined areas, such as displayed data entry fields, this should be accomplished by simple user action.
COMMENT: Automatic cursor advance is generally not desirable. Programmable tab keys are customarily used for this purpose. (A,E)

2.1.2.4-2 Explicit Activation (Tier 2 - General)
Users should be required to take a separate, explicit action, distinct from cursor positioning, for the actual entry (enabling, activation) of a designated position.
COMMENT: For line drawing or tracking tasks the need for rapid, continuous entry may override the need to reduce entry errors. (C,E)

2.1.2.4-3 Display Format Protection (Tier 2 - General)
When there are areas of a display in which data entries cannot be made (blank spaces, protected field labels, etc.), those areas should be insensitive to pointing actions, i.e., the cursor should be prevented from entering those areas.
COMMENT: Automatic format protection will generally make cursor positioning easier for a user, since the cursor will not have to be stepped through blank areas, and much routine cursor control can be accomplished with only casual reference to the display. When a user may have to modify display formats, then this automatic format protection can be provided as a general default option subject to user override. (A,E)

2.1.2.4-4 Cursor Movement (Tier 3 - Design Details)
Users should not have to frequently alter hand positions between a pointing device (such a joystick) to position cursors and the keyboard to edit or add text.
COMMENT: (A,E)

2.1.2.4-5 Free Cursor Movement (Tier 3 - Design Details)
For text editing, users should be allowed to move the cursor freely over a displayed page of text to specify items for change, and to make changes directly to the text.
COMMENT: Free cursor movement and changes made directly to the text are characteristics usually associated with so-called screen-based editors and not associated with line- or command-based editors. Screen-based editors are preferred by users and are potentially more efficient. (E)

2.1.2.4-6 Proportional Spacing (Tier 3 - Design Details)
If proportional spacing is used for displayed text, computer logic should make necessary adjustments automatically when the cursor is being positioned for data entry or data change.
COMMENT: Without automatic computer aids, a user probably will not handle proportional spacing accurately. (E)

2.1.2.4-7 Cursor Movement by Units of Text (Tier 3 - Design Details)
Users should be able to move the cursor by specific units of text, as well as one character at a time.

COMMENT: Cursor positioning will be easier if appropriate function keys can be provided. A SENTENCE key that allows a user to move directly to the next displayed sentence will be more convenient than some double-keying logic such as CONTROL-S. (E)

2.1.2.4-8 Tabbing within Rows (Tier 3 - Design Details)
During tabular data entry, users should be allowed to tab directly from one data field to the next, so that the cursor can move freely back and forth within a row (i.e., across columns).

COMMENT: ()

2.1.2.4-9 Tabbing within Columns (Tier 3 - Design Details)
During tabular data entry, users should be allowed to tab directly from one data field to the next, so that the cursor can move freely up and down a column.
COMMENT: (E)

2.1.2.4-10 Data Entry Independent of Cursor Placement (Tier 3 - Design Details)
An ENTER action for multiple data items should results in entry of all items, regardless of where the cursor is placed on the display.
COMMENT: A user may choose to move the cursor back to correct earlier data items, and may not move the cursor forward again. The computer should ignore cursor placement in such cases. (E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.2 Cursor Positioning and Control
2.1.2.5 Use of Multiple Cursors

2.1.2.5-1 Minimal Use of Multiple Cursors (Tier 2 - Task Compatibility)
Multiple cursors on a single display should be used only when they are justified by task requirements.
COMMENT: Multiple cursors may confuse a user, and so require special consideration if used in USI design. Multiple cursors might be useful to mark a user's place when manipulating data in multiple display windows. In graphic interaction, one cursor might be used for line drawing and a different cursor for alphanumeric data entry (labels, etc.). (A,E)

2.1.2.5-2 Multi Monitor/Multi Controller Cursor Characteristics (Tier 2 - General)
In a multitasking environment with multiple monitors, controllers, or cursors, the location of the active cursor should be obvious to the user.
COMMENT: If there are two pointing cursors -- one on each of two monitors -- the active cursor should be apparent to the user. If there is a single cursor that moves between two monitors, its path should be continuously trackable. As the cursor crosses from one monitor to the other it should either maintain its vertical coordinate for side by side monitors and horizontal for stacked monitors or should jump between uniquely specified locations on each screen. (D)

2.1.2.5-3 Distinctive Multiple Cursors (Tier 2 - General)
If multiple cursors are used, they should be visually distinctive from one another.
COMMENT: (A,E)

2.1.2.5-4 Compatible Control of Multiple Cursors (Tier 2 - General)
If multiple cursors are controlled by different devices, their separate controls should be compatible in operation.
COMMENT: Assume that one cursor is moved upward on a display by forward motion of a joystick. Then a second cursor should also be moved upward by forward motion -- perhaps by forward motion of a second joystick or by forward motion of a thumbwheel or other device. (A,E)

2.1.2.5-5 Distinctive Control of Multiple Cursors (Tier 2 - General)
If multiple cursors are controlled by a single device, a clear signal should be provided to the user to indicate which cursor is currently under control.
COMMENT: (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.3 Text Entry and Editing
2.1.3.1 General

2.1.3.1-1 Necessary Data Displayed (Tier 2 - Task Compatibility)
Whatever information a user needs for text entry/editing should be available for display, as an annotation to displayed text.
COMMENT: Required annotation will vary with the application. Some annotation may be so commonly needed that it should be continuously displayed -- e.g., document name, page number, indication of control mode (if any), etc. Other annotation might be displayed only at user request-- such as document status (date last changed, last printed, etc.) which might be displayed in an optional window overlay, and format control characters which might be visible in an optional display mode. For example, the user might wish to see format control characters, such as tab and margin settings. (A,E)

2.1.3.1-2 Adequate Display Capacity (Tier 2 - General)
Display capacity, i.e., number of lines and line length, should be adequate to support efficient performance of text entry/editing tasks.
COMMENT: For example, for text editing where the page format of subsequent printed output is critical, the user's terminal should be able to display full pages of text in final output form, which might require a display capacity of 50-60 lines or more. For general text editing where a user might need to make large changes in text, i.e., sometimes moving paragraphs and sections, a display capacity of at least 20 lines should be provided. Where text editing will be limited to local changes, i.e., correcting typos and minor rewording, as few as seven lines of text might be displayed. A single line of displayed text should not be used for text editing. During text editing, a user will need to see some displayed context in order to locate and change various text entries. Displaying only a small portion of text will make a user spend more time moving forward and back in a displayed document to see other parts, will increase load on the user's memory, and will cause users to make more errors. (A,E)

2.1.3.1-3 Control Entries Distinct from Text (Tier 2 - General)
If control entries are made by keying onto the display, such as by keyed menu selections or commands, they should be distinguishable from displayed text.
COMMENT: For example, keyed control entries might be made only in a reserved window in the display. The intent here is to help ensure that a user will not inadvertently enter controls as text, or vice versa. If a command entry is keyed into the body of a text display, perhaps at the end of the last sentence, then a user cannot be certain whether the computer will interpret the command as a text entry or as a control entry. In applications where the screen cannot display all possible format features (e.g., special fonts), format codes representing those features are usually displayed within the text. It is not practical in such cases to display format codes in a separate window, since a displayed code must mark the text that will be affected by the code. These codes should therefore be highlighted in some way to distinguish them from text. One way of avoiding the problem altogether is to use function keys rather than command entry to control text editing. To provide a general range of text editing functions, however, many keys will be needed. A practical design approach might be to adopt double-keying logic for all keys on a standard (QWERTY) keyboard, where control-F means FILE a document, control-G means GET a document, etc., and providing appropriate extra labels for those keys. (A,E)

2.1.3.1-4 Text Distinct from Annotation (Tier 2 - General)
Annotations to displayed text should be distinguishable from the text itself.
COMMENT: This recommendation refers to text annotations added by users, such as marginal notes on printed displays. Other annotation such as format control characters might be shown in a special display mode where text has been expanded to permit annotation between lines. For example, continuous annotation might be displayed in the top and/or bottom lines of a page, separated from the text by blank lines; optional annotation might be displayed in window overlays. (A,E)

2.1.3.1-5 Natural Units of Text (Tier 3 - Design Details)
Users should be allowed to specify segments of text in whatever units are natural for entry/editing.
COMMENT: For unformatted ("free") text, natural units will be characters, words, phrases, sentences, paragraphs,

and pages; for specially formatted text, such as computer program listings, allow specification of other logical units, including lines, subsections, sections, etc. (A,E)

2.1.3.1-6 Text Displayed as Printed (Tier 3 - Design Details)

Users should be allowed to display text exactly as it will be printed.

COMMENT: Accurate display is particularly necessary when the format of printed output is important, as when printing letters, tables, etc. Ideally, text displays should be able to represent all the features that are provided in printed output, including upper and lower case, underlining, bolding, subscripting, superscripting, special symbols, and different styles and sizes of type. When those features are important, the necessary display capability should be provided. For special formatting features that are not frequently used, it may be sufficient to use extra symbols to note text features that cannot be directly displayed. In that case, care should be taken that such annotation does not disturb the spacing of displayed text. This may require two display modes, one to show text spacing as it will be printed and the other to show annotations to the text. A corollary to this recommendation is that changes made to displayed text should appear as a user makes them. Some line-based editors show changes only after a document has been filed and later recalled for display, which does not represent good user interface design. (A,E)

2.1.3.1-7 Format Control by User (Tier 3 - Design Details)

Easy means for users to specify required format control features should be provided during text entry/editing, e.g., to specify margin and tab settings.

COMMENT: Required format features will vary depending on the application. The intent of this guideline is that all required format features should be easy to control. Any format features which are provided but are optional for the user's task should not be made easy to use at the expense of required format features. One convenient method of margin and tab control is to users should be allowed to mark settings on a displayed "ruler" that extends the width of a page and is continuously displayed at the top of the screen. (A,E)

2.1.3.1-8 Establishing Predefined Formats (Tier 3 - Design Details)

When text formats must follow predefined standards, the standard format should be provided automatically and not rely on users to remember and specify proper formats.

COMMENT: For example, standard formats might be required for letters, memos, or other transmitted messages. (A,E)

2.1.3.1-9 Storing User-Defined Formats (Tier 3 - Design Details)

When text formats cannot be predicted in advance, users should be able to specify and store for future use the formats that might be needed for particular applications.

COMMENT: For example, a special format might be adopted for generating a particular report at periodic intervals. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.3 Text Entry and Editing
2.1.3.2 Text Entry

2.1.3.2-1 Editing Capabilities During Text Entry (Tier 2 - General)
Users should be allowed to do at least some simple editing during text entry without having to invoke a separate edit mode.
COMMENT: For example, while entering text, users will need at least some capability for text selection (by cursor movement) and deletion. The intent of this guideline is not to endorse modeless over moded text editors. In fact, when experienced users perform editing tasks, a moded editor may offer some advantages. However if a moded editor is provided, users should be able to do some simple editing such as correcting typographical errors and making simple word changes without having to invoke that editor. When users will compose text on-line, consider providing a modeless editor rather than a moded editor. Modeless editors offer some advantages for text composition, when users will frequently alternate between text entry and editing. (A,E)

2.1.3.2-2 Consistent Word Spacing (Tier 3 - Design Details)
Unless otherwise specified by the user, entered text should be left-justified to maintain constant spacing between words, leaving right margins ragged if that is the result.
COMMENT: (A,E)

2.1.3.2-3 Hyphenation by Users (Tier 3 - Design Details)
In the entry/editing of text, automatic pagination and line breaks by the computer should keep words intact, and hyphenation should only be introduced where specified by users.
COMMENT: Where compound words have been hyphenated by a user, the computer might break the compound after a hyphen, for pagination or line breaks, unless otherwise specified by the user. Compound words formed with slashes (e.g., "entry/editing") might be treated in a similar manner. (A,E)

2.1.3.2-4 Auditory Signals for Alerting Users (Tier 3 - Design Details)
During text entry/editing, an auditory signal should be provided whenever it is necessary to draw a user's attention to the display.
COMMENT: A touch typist entering text from written copy will often not be looking at the display screen, and therefore may not notice visual indicators of errors or mode changes unless they are accompanied by auditory signals. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.3 Text Entry and Editing
2.1.3.3 Editing Text

2.1.3.3-1 Editing by Multiple Methods (Tier 1 - Use)
The user should be able to edit text, tables, and graphics by multiple methods.
COMMENT: Editing by multiple methods includes use of editing commands, menus, and command keystrokes. All editing procedures should be consistent in the dialogue structure and syntax, independent of the type of information being edited. (D)

2.1.3.3-2 Reversible Actions (Tier 2 - General)
Text editing logic should be designed so that any user action is immediately reversible.
COMMENT: Reversible actions are particularly important in a text editing environment because text formatting often involves experimentation with features such as underscoring, bolding, and spacing. If users know that they can reverse whatever they do, they will feel more free to delete text and experiment with formatting features. An UNDO capability is currently available in some interface designs. In some applications, however, this capability is provided through the use of an UNDO key which can only reverse the most recent control action. For text editing, users must be able to reverse such formatting features as centering and bolding at any time. Therefore, if control actions are to be made reversible, an UNDO action should be able to reverse more than the most recent command, perhaps by requiring the user to specify which command to undo, and/or to place the cursor at the location of the format feature that is to be reversed. As an example, if a user centers a heading and then decides it would look better flush against the left margin, an UNDO action should reverse the centering and move the heading back to its original location. Another example: if a user underlines a paragraph of text and then decides it should be in all capital letters instead, an UNDO action should reverse the underlining. The user should not be required to delete the paragraph and retype it just to erase the underscoring. When text segments have been deleted, it should be possible to retrieve more than the most recent deletion. Some systems do this by storing all deletions in a special file. Deleted text which the user wishes to retrieve can then be moved from the deletion file to the file in which the user is presently working. (A,E)

2.1.3.3-3 Editing Commands (Tier 2 - General)
Where editing commands are made by keying onto the display, the editing commands should be readily distinguishable from the displayed textual material.
COMMENT: (D)

2.1.3.3-4 Presentation Mode (Tier 2 - General)
Display mode rather than line mode should be used for text editing when the user's task requires extensive text entry/editing.
COMMENT: (D)

2.1.3.3-5 Confirming Actions in DELETE Mode (Tier 2 - General)
If a DELETE mode is used, any text specified by a user should be highlighted for deletion and the user should be required to confirm the DELETE action before the computer will process it.
COMMENT: Requiring a user to confirm actions in DELETE mode is particularly important when the control entries for cursor positioning (e.g., WORD, SENTENCE, PARAGRAPH, PAGE) are also used to specify text for deletion, which is often the case. Users will associate the specification of text units primarily with cursor positioning, which is the most frequent action in text editing. In a DELETE mode, after specifying text units for deletion, a user may press a PARAGRAPH key intending to move to the next paragraph but accidentally delete the next paragraph. Confirmation of DELETE actions will tend to prevent such errors. An alternative approach to this problem is not to provide a continuing DELETE mode, but instead require double keying to accomplish deletions. In a DELETE mode, a user might press a DELETE key followed by unlimited repetitions of a WORD key (or keys specifying other units of text). With double keying, the user would have to press DELETE before each selection of a text unit to be deleted. (A,E)

2.1.3.3-6 Undoing Deletions (Tier 2 - General)

Deleted data should be stored by the system to allow the user to undo the deletion and restore the deleted text.
COMMENT: The user should be able to restore the deleted text by a single action. (D)

2.1.3.3-7 Selecting Data for Editing (Tier 3 - Design Details)

Users should be able to select textual, graphical, and tabular information for specific editing functions by multiple methods, each requiring minimal simple actions to perform the selection.
COMMENT: Multiple methods are, forexample, with a cursor control device, step keys, and menu selection. (D)

2.1.3.3-8 Highlighting Selected Information (Tier 3 - Design Details)

Selected information should be visually distinct from non-selected items.
COMMENT: (D)

2.1.3.3-9 Minimum Amount of Selectable Data (Tier 3 - Design Details)

The minimum amount of alphanumeric data that users should be able to select is one character.
COMMENT: (D)

2.1.3.3-10 Unselecting Information (Tier 3 - Design Details)

Users should be able to unselect textual, tabular, or graphical information (i.e., remove the information from the selected state) with a single action.
COMMENT: Unselection should remove the perceptual cue indicating selection. (D)

2.1.3.3-11 Vertical Scrolling When Selecting Text (Tier 3 - Design Details)

If the selected text, table, or graphics area extends beyond the bottom of the displayed page, the screen should automatically scroll until the user stops selecting.
COMMENT: (D)

2.1.3.3-12 Non-Contiguous Blocks of Text (Tier 3 - Design Details)

Users should not be able to select non-contiguous blocks of text when cutting and pasting.
COMMENT: Cutting and pasting (operations which frequently follow selecting) is ambiguous with non-contiguous blocks, especially with respect to the spatial relation between the two non-contiguous blocks when they are pasted into a text file at a new location or into a new text file. (D)

2.1.3.3-13 Non-Contiguous Graphic Objects (Tier 3 - Design Details)

Users should be able to select multiple non-contiguous graphic objects using minimal actions.
COMMENT: Operations available for individual graphic objects should also be available for multiple selected objects. (D)

2.1.3.3-14 Inserting Text (Tier 3 - Design Details)

The text editor should operate in a consistent default mode.
COMMENT: For example, text could be always be inserted moving to the right from the cursor location and wrap to the next line when necessary (insert mode), or alternately, the editor could operate in overstrike mode. (D)

2.1.3.3-15 Replacing Text (Tier 3 - Design Details)

If text is selected, the editor should be in the overstrike mode.
COMMENT: Alphanumeric characters typed following selection of a string of characters should replace the selected text. (D)

2.1.3.3-16 Changing Physical Characteristics of Text (Tier 3 - Design Details)

The user should have the ability to change the physical characteristics of text.
COMMENT: Example physical characteristics to put under the user's control include font type, size, and capitalization; the ability to change the font style (e.g., by underlining, italicizing, and/or bolding characters or strings of characters), and/or to alter tab position in any part of a text file. (D)

2.1.3.3-17 Tabs (Tier 3 - Design Details)

A tab system should be available for paragraph indentation and moving the cursor to a preselected location.
COMMENT: The user should be able to set tabs at locations across a display, consistent with the spacing provided by the space bar. The symbols indicating the location of tabs should be invisible to the user by default but should become visible with a single action by the user (for example, by making a screen ruler appear on the display or displaying the tab symbols within the text field). (D)

2.1.3.3-18 Margins (Tier 3 - Design Details)
The user should have the ability to change margins for a text file.
COMMENT: This capability should include changing margins so that the user cannot view all of the characters in the horizontal line. Rationale: Users may need to have a double page size for the equivalent of a 14 x 17 page. (D)

2.1.3.3-19 Tab Controls (Tier 3 - Design Details)
For editing programs or tabular data, cursor tab controls or other provisions for establishing and moving readily from field to field should be provided.
COMMENT: (D)

2.1.3.3-20 Automatic Line Break (Tier 3 - Design Details)
For entry/editing of unformatted text, an automatic line break ("carriage return") should be provided when text reaches the right margin, with provision for user override.
COMMENT: For specially formatted text, such as computer program listings, users may need to control line structure themselves and hence need to override any automatic line break. Even when entering unformatted text, a user will sometimes wish to specify a new line at some particular point, if only for esthetic reasons. (A,E)

2.1.3.3-21 Automatic Pagination Aids (Tier 3 - Design Details)
Automatic pagination for text entry/editing should be provided, allowing users to specify the page size.
COMMENT: For short documents, automatic pagination may not be needed. (A,E)

2.1.3.3-22 Pagination (Tier 3 - Design Details)
If automatic repagination is not provided, a warning message should be presented to the user.
COMMENT: (A,E)

2.1.3.3-23 User Control of Pagination (Tier 3 - Design Details)
When automatic pagination is provided, users should be allowed to override that pagination in order to specify page numbers at any point in a document.
COMMENT: When producing a large document, a user may wish to split it into several separate text files for convenience in editing, and hence need to control the page numbering of those component sections. In general, a user will want flexibility in assembling different computer files to create a composite document. For example, a user might wish to number the first page of a document "23", or perhaps skip a page number in the middle of a document. (A,E)

2.1.3.3-24 Controlling Integrity of Text Units (Tier 3 - Design Details)
When automatic pagination is provided, users should be allowed to specify how many lines in a paragraph can stand alone at the bottom or top of a page ("widows" and "orphans"), and to specify any text that should not be divided between two pages, such as lists or tables.
COMMENT: (A,E)

2.1.3.3-25 Protecting Text During Page Overruns (Tier 3 - Design Details)
When a user is inserting text into a document that has already been paginated, no text should be lost if the user inserts more text than a page can hold.
COMMENT: It is difficult for a user to keep track of page size, particularly if the size of the display screen is less than the full page specified for printed text, which is often the case. A user will often not know when more text has been inserted into a page than there is room for. The computer should accommodate text insertions with automatic repagination. (A,E)

2.1.3.3-26 Head-and Foot-of File (Tier 3 - Design Details)
The means should be provided to readily move the cursor to the head or the foot (end) of the file.
COMMENT: (D)

2.1.3.3-27 Horizontal Scrolling (Tier 3 - Design Details)
The user should have the ability to shift the text information shown when the user cannot view all of the characters in the horizontal line.
COMMENT: This shift should be accomplished with a single action (e.g., by moving a scroll icon on a horizontal scroll bar). (D)

2.1.3.3-28 Display Window (Tier 3 - Design Details)
ROLL and SCROLL commands should refer to the display window, not the text/data.
COMMENT: That is, the display window should appear to the user to be an aperture moving over stationary text (D)

2.1.3.3-29 Buffer (Tier 3 - Design Details)
When inserting characters, words or phrases, items to be inserted should be collected in a buffer area and displayed in the prescribed insert area of the screen for subsequent insertion by user command.
COMMENT: (D)

2.1.3.3-30 Control Annotations (Tier 3 - Design Details)
Where special formatting features are indicated in the text by use of special codes or annotation, the insertion of the special annotation should not disturb the spacing of the displayed text and should not disturb formatting of graphs and tables or alignment of rows and columns.
COMMENT: (D)

2.1.3.3-31 User Confirmation of Editing Changes (Tier 3 - Design Details)
When a user signals completion of document editing, the user should be allowed to confirm that changes should be made to the original document, or else to choose alternative options.
COMMENT: A user will generally wish to replace the original document with its edited version. However, sometimes a user may decide that editing mistakes have been made, and wish to discard the new version while saving the original. Or a user might wish to save the new version as a separate document, while saving the original unchanged. Such decisions can be made best at the end of an editing session, when the user knows what has been accomplished, rather than before a session is begun. During text editing, the computer should always retain a copy of the original document until the user confirms that it should be changed. The original document should not be changed automatically as the user enters each editing change. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.3 Text Entry and Editing
2.1.3.4 Finding and Replacing Text

2.1.3.4-1 String Search (Tier 1 - Use)
Users should be allowed to specify a string of text and request the computer to advance (or back up) the cursor automatically to the next (or last previous) occurrence of that string.
COMMENT: An automatic string search capability will generally speed cursor placement in comparison with incremental positioning, particularly when moving over large portions of a document. Expert users may also wish to incorporate special characters in string search, including format control characters such as those for tabbing, bolding, etc. (A,E)

2.1.3.4-2 Global Search and Replace (Tier 1 - Use)
When systematic editing changes will be made throughout a long document, a "global search and replace" capability should be provided.
COMMENT: Global search and replace is where the system replaces all occurrences of one text string with another. Global search and replace could be designed in two different ways. One user might want the computer to make all changes automatically. Another user might want to review and confirm each change. Ideally, both options should be available. (A,E)

2.1.3.4-3 Upper and Lower Case Equivalent in Search (Tier 2 - General)
Unless otherwise specified by a user, upper and lower case letters should be treated as equivalent in searching text.
COMMENT: For example, "STRING", "String", and "string" should all be recognized/accepted by the computer when searching for that word. In searching for words, users will generally be indifferent to any distinction between upper and lower case. The computer should not compel a distinction that users do not care about and may find difficult to make. In situations when case actually is important, users should be allowed to specify case as a selectable option in string search. It may also be useful for the computer to ignore such other features as bolding, underlining, parentheses and quotes when searching text. (A,E)

2.1.3.4-4 Specifying Case in Search (Tier 2 - General)
When case is important, users should be allowed to specify case as a selectable option in string search.
COMMENT: Users may also wish to specify features such as bolding, underlining, and quotes when searching text. For example, when searching a document in which all the headings are capitalized, a user might wish to find a string only when it appears in a heading. (A,E)

2.1.3.4-5 Case in Global Search and Replace (Tier 2 - General)
If a global search and replace capability is provided, each time a string is replaced the case of the new string should match the case of the old string, unless otherwise specified by the user.
COMMENT: For example, if a word is replacing the first word in a sentence, the first letter of the new word should be capitalized; if it is replacing a word that is entirely in lower case, then the new word should also be in lower case. On occasion, however, a user might wish to replace an erroneous lower-case word ("Nrc") with a correctly capitalized version ("NRC"). (A,E)

2.1.3.5-1 Moving Text (Tier 1 - Use)
Users should be allowed to select and move text segments from one place to another within a document.
COMMENT: A user should not have to re-enter (i.e., rekey) text that is already available to the computer. One convenient method of allowing the user to both move and copy text is to provide a "cut and paste" facility in which the "cut" text remains in a storage buffer and can be "pasted" more than once. For copying, the user can cut text, paste it back into its original location, and paste it again at a new location. (A,E)

2.1.3.5-2 Pasting Text into a Graphical File and Vice Versa (Tier 1 - Use)
The user should be able to paste (1) alphanumeric data cut or copied from a text file or table into a graphical display and (2) graphical data into a text or tabular file.
COMMENT: (D)

2.1.3.5-3 Cutting Selected Data (Tier 2 - General)
Users should be able to cut only data that are currently selected.
COMMENT: (D)

2.1.3.5-4 Copying (Tier 2 - General)
Only data that are currently selected should be copied.
COMMENT: (D)

2.1.3.5-5 Cutting Grapical Objects and Areas of Graphical Displays (Tier 2 - General)
Users should be able to cut both graphical objects and areas of a graphical display.
COMMENT: (D)

2.1.3.5-6 Viewing Copied Data (Tier 2 - General)
Users should be able to view data after it has been copied prior to pasting.
COMMENT: (D)

2.1.3.5-7 Placing Cut Data in Compatible Data Files (Tier 2 - General)
Users should be able to insert copied data at any location in the current data file or other data files created with the same application.
COMMENT: Including in another file created using the same application. One implementation that would allow users to accomplish this is the use of a temporary editing buffer into which the system would place cut data. (D)

2.1.3.5-8 Placement of Pasted Data (Tier 2 - General)
The pasted data should be inserted in the text or table in the location immediately before the cursor and in a graphical file at the approximate location of the cursor.
COMMENT: At the end of the paste process, the cursor should have the same data following it in the text or table as before the process. (D)

2.1.3.5-9 Viewing Cut Data (Tier 3 - Design Details)
Users should be able to view data after it has been cut prior to pasting the data.
COMMENT: (D)

2.1.3.5-10 Pasting the Same Data More than Once (Tier 3 - Design Details)
Pasting the most recently cut or copied data should have no effect on a users' ability to paste the same data again.
COMMENT: That is to say, the user should be able to paste the most recently cut or copied data as many times as

he or she chooses. The data that can be pasted is only replaced when new data are cut or copied. (D)

2.1.3.5-11 Cutting Without a Gap in the Text (Tier 3 - Design Details)
The cut data should be removed from the text or tabular file which should be reconstituted without a gap where the text was removed.
COMMENT: The cursor should remain in the same location as prior to the cut. (D)

2.1.3.5-12 Cutting with a Gap in the Graphics (Tier 3 - Design Details)
A graphical file from which a graphical object was cut should be reconstituted to occupy the same amount of space as before the cut, with a gap where the object was removed.
COMMENT: (D)

2.1.3.5-13 Storing Frequently Used Text (Tier 3 - Design Details)
Users should be allowed to label and store frequently used text segments, and later to recall (copy into current text) stored segments identified by their assigned labels.
COMMENT: For example, much text processing involves repetitive elements specific to different applications, such as signature blocks, technical terms, long names, formulas or equations. (E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.3 Text Entry and Editing
2.1.3.6 Printing

2.1.3.6-1 Flexible Printing Options (Tier 2 - General)
In printing text, users should be allowed to select among available output formats (line spacing, margin size, etc.) and to specify the parts of a document to be printed; do not require that an entire document be printed.
COMMENT: For example, a user should be able to print just those portions of a document that have been changed, perhaps specifying just the first page, or page 17, or the last five pages, etc. This is particularly important when long documents will be edited. A user should not be required to print an entire 50-page document just because of a change to one page. (A,E)

2.1.3.6-2 Remote Printing (Tier 2 - General)
If information is printed remotely, print status messages should be displayed and screen contents should not be changed as a result of the print operation.
COMMENT: (A)

2.1.3.6-3 Information on Printing Status (Tier 2 - General)
The status of requests for printouts should be provided to users.
COMMENT: For example, the computer should acknowledge print requests immediately, and might provide a subsequent message to indicate when a printout has been completed if the printer is remote (unobservable) from the user's workstation. Also, if there is a queue of documents waiting for printout, a user should be able to get an estimate as to when a particular document will be printed. If a user is responsible for operating a local printer, the computer might display messages to alert the user of potential malfunctions, e.g., if its paper supply is exhausted, if the paper is not correctly loaded, etc. (A,E)

2.1.4-1 Grouping Data Fields (Tier 2 - Sequencing and Grouping)
Where no source documents or forms exist to support data entry, then form data fields should be logically grouped, by sequence and frequency of use, importance, and functional associations.
COMMENT: (A)

2.1.4-2 Transforming Units of Measurement (Tier 2 - Memory Load)
The user should not have to transform units at time of data entry.
COMMENT: (A)

2.1.4-3 Keystroke Not Required for Every Character Space (Tier 2 - Minimizing User Actions)
Users should not have to provide a keystroke for every character space reserved by the field.
COMMENT: (A)

2.1.4-4 Combined Entry of Related Data (Tier 2 - General)
Just one explicit entry action at the end of the transaction sequence should be required, rather than separate entry of each item.
COMMENT: Depending on form design, this practice might involve entering the entire form, or entry by page or section of a longer form. Form design should indicate to users just where explicit entry is required. Single entry of grouped data will generally permit faster input than item-by-item entry, and should prove more accurate as well. This practice permits user review and possible data correction prior to entry, and also helps the user understand at what point grouped data are processed. It will also permit efficient cross validation of related data items by the computer. (A,E)

2.1.4-5 Optional Versus Required Entry (Tier 2 - General)
Optional versus required data entries within fields on input forms should be distinct.
COMMENT: (A)

2.1.4-6 Data Field Labels (Tier 2 - General)
For each data field, an associated label should be displayed to help users understand what entries can be made.
COMMENT: (E)

2.1.4-7 Minimal Use of Delimiters (Tier 2 - General)
Whenever possible, entry of multiple data items should be allowed without keying special separator or delimiter characters.
COMMENT: For examples, hyphens, dollar signs, etc. This can be accomplished either by keying into predefined entry fields or by separating sequentially keyed items with blank spaces. In this context, tabbing from field to field is not considered to be keying a special delimiter character. When data items contain internal blanks, the entry fields with a predefined structure should be designed so that users will not have to key any internal delimiters. (A,E)

2.1.4-8 Standard Delimiter Character (Tier 2 - General)
When a field delimiter must be used for data entry, a standard character should be employed consistently for that purpose.
COMMENT: A special delimiter character that does not require shift keying should be used. A character that does not occur as part of any data entry (except possibly for entry of running text where its occurrence would not be ambiguous) should be used; for example, a slash (/) may be a good choice. (A,E)

2.1.4-9 Flexible Interrupt (Tier 2 - General)
When multiple data items are entered as a single transaction, as in form filling, the user should be allowed to REVIEW, CANCEL, or BACKUP and change any item before taking a final ENTER

action.
COMMENT: (A,E)

2.1.4-10 Variable Length Data Area (Tier 3 - Design Details)
Users should not have to remove unused underscores or otherwise enter keystrokes for each position within a variable length entry area.
COMMENT: (A)

2.1.4-11 Variable Length Field Entries (Tier 3 - Design Details)
For variable length field entries, automatic justification of the input data should be provided.
COMMENT: (A)

2.1.4-12 Left Justification of Alphanumeric Display Requirements (Tier 3 - Design Details)
Unless otherwise required by processing or display requirements, alphanumeric input should be left justified, and numeric input should be right justified for integer data or decimal point justified for decimal data.
COMMENT: (A)

2.1.4-13 Direct Pointing Devices for Selecting Fields (Tier 3 - Design Details)
In complicated forms with many fields, or when field entry will be less predictable (as in data base update), direct pointing devices, such as mouse or lightpen, should be available for selecting fields.
COMMENT: (A)

2.1.4-14 Tabbing to Advance to Subsequent Fields (Tier 3 - Design Details)
Where the number of fields is limited, screen traversal distances are short, and when data fields will be accessed sequentially, explicit tabbing should be available for advancing to subsequent fields.
COMMENT: (A)

2.1.4-15 Overwriting Characters (Tier 3 - Design Details)
Data entry by overwriting a set of characters within a field should be avoided.
COMMENT: (A)

2.1.4-16 Deferring Inputting Data (Tier 3 - Design Details)
When entry of data in a field is deferred or omitted, the system should identify the field by highlighting or other means. Before the data are filed or accessed, the user should be reminded that data have not been input.
COMMENT: (A)

2.0 OPERATOR INPUT AND CONTROL

2.1 Entering Information

2.1.5 Tabular Data Entry

2.1.5-1 Use of Tabular Displays (Tier 1 - Use)
When sets of data items must be entered sequentially, in a repetitive series, a tabular display format should be provided where data sets can be keyed row by row.
COMMENT: Row-by-row entry facilitates comparison of related data items, and permits potential use of a DITTO key for easy duplication of repeated entries. When the items in each data set exceed the capacity of a single row, tabular entry will usually not be desirable, unless there is a simple means for horizontal scrolling. (A,E)

2.1.5-2 Distinctive Label Formats (Tier 2 - General)
Distinctive formats should be provided for column headers and row labels, so that users can distinguish them from data entries.
COMMENT: (E)

2.1.5-3 Automatic Justification of Entries (Tier 2 - General)
Automatic justification of tabular data entries should be provided; a user should not have to enter blanks or other extraneous formatting characters to achieve proper justification.
COMMENT: As a negative example, if a user enters "56" in a field four characters long, the system should not interpret "56 __ __" as "5600". (A,E)

2.1.5-4 Significance of Numeric Values (Tier 3 - Design Details)
Numeric values should be displayed to level of significance required of the data regardless of the value of individual input data.
COMMENT: (A)

2.1.5-5 Maintaining Significant Zeros (Tier 3 - Design Details)
When a user must enter numeric values that will later be displayed, all significant zeros should be maintained ; zeros should not be arbitrarily removed after a decimal point if they affect the meaning of the number in terms of significant digits.
COMMENT: (A,E)

2.1.5-6 Aiding Entry of Duplicative Data (Tier 3 - Design Details)
For entry of tabular data, when entries are frequently repeated, users should be provided with some easy means to copy duplicated data.
COMMENT: For example, a DITTO capability will speed data entry, and should prove more accurate than requiring users to rekey duplicated data. (E)

2.1.5-7 Row Scanning Cues (Tier 3 - Design Details)
For long tables, those with many rows, some extra visual cue should be provided to help a user scan a row accurately across columns.
COMMENT: Visual aids for scanning rows are probably needed more when a user is reviewing and changing displayed data than for initial data entry. Such aids should be provided consistently, however, so that display formats for both data entry and review will be compatible. For example, a blank line might be inserted after every fifth row; or perhaps dots between columns in every fifth row might suffice. As an alternative, a displayed ruler which a user can move from one row to another may be used. (E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.6 Speech Input

2.1.6-1 Speech Input (Tier 1 - Use)
Spoken data input should be provided only when data entry cannot be accomplished through more reliable methods such as keyed entry or pointing.
COMMENT: Current speech recognition devices are not well developed and tend to be error prone. Thus there should be some good reason for choosing speech input over more conventional data entry methods. Speech input might be appropriate if a user cannot use his/her handsfor some reason. (E)

2.1.6-2 Limited Vocabulary for Speech Input (Tier 2 - Minimizing User Actions)
The vocabulary used for spoken data entry should be constructed so that only a few options are needed for any transaction.
COMMENT: To increase the likelihood that a user's valid entries are correctly identified by the system, the user's vocabulary should be predictable. This does not necessarily mean that the vocabulary must be small, though recognition systems that can only accommodate small vocabularies are more prevalent and less expensive. A vocabulary is predictable when a user's choice of inputs at any given time is small, so that the system will be more likely to make a correct match in interpreting an entry. (E)

2.1.6-3 Input Feedback (Tier 2 - Feedback)
Input feedback and simple error correction procedures should be provided for speech input.
COMMENT: (A)

2.1.6-4 Easy Error Correction for Speech Input (Tier 2 - Error Handling)
Feedback and simple error correction procedures should be provided for speech input, so that when a spoken entry has not been correctly recognized by the computer, the user can cancel that entry and speak again.
COMMENT: Simple error correction is particularly important with spoken data entry, since speech recognition systems are prone to error except under carefully controlled conditions. (E)

2.1.6-5 Alternative Entries for Speech Input (Tier 2 - General)
When speech input is the only form of data entry available, alternatives forms for critical entries should be allowed, so that if the system cannot recognize an entry after repeated attempts, another entry form can be substituted.
COMMENT: Because speech recognition systems are affected by normal variations in a user's voice, and by changes in the acoustic environment, a spoken entry that was accepted yesterday might not be accepted today. Thus for important entries a user should be able to use an alternative word. Spelling a word letter-by-letter is not an acceptable alternative, since speech recognition systems may have trouble correctly identifying similar sounding letters. For example, "Exit" might be defined as an acceptable substitute for "Finished". (E)

2.1.6-6 Non-Speech Activation (Tier 2 - General)
Speech recognition systems should have an external, non-speech means of activation and deactivation so that extraneous conversation is not taken as command input.
COMMENT: Additionally, if possible, a standby mode may be provided from which spoken commands to activate/deactivate may be invoked. External, non-speech means of activation and deactivation can include use of a keyboard. (D)

2.1.6-7 Vocabulary Items (Tier 2 - General)
The vocabulary items should (1) consist of words that are meaningful and familiar to the user; (2) be accoustically unique within a set; and (3) consist of 2-5 syllables.
COMMENT: Items of 2-5 syllables in length are generally better recognized than one-syllable items. (D)

2.1.6-8 Phonetically Distinct Vocabulary for Speech Input (Tier 2 - General)
The spoken entries needed for any transaction should be phonetically distinct from one another.

COMMENT: Words which are easily distinguished by one speech recognition system may be confused by another. (E)

2.1.6-9 PAUSE and CONTINUE Options for Speech Input (Tier 2 - General)
PAUSE and CONTINUE options should be provided for speech input, so that a user can stop speaking without having to log off the system.
COMMENT: A user may wish to stop speaking data for a time in order to answer a telephone or to speak with a fellow worker. Users should not have to log off the system every time they wish to say something that is not intended as an entry. (E)

2.1.6-10 User-Adjustable Rejection Levels (Tier 3 - Design Details)
The speech amplitude and rejection levels required for input should be user-adjustable.
COMMENT: (D)

2.1.6-11 Word Boundaries (Tier 3 - Design Details)
Where word boundaries (pauses between words) are required for system interpretation, boundaries of 100 milleseconds or more should be allowed by the system.
COMMENT: (A)

2.1.6-12 Confidence Rating (Tier 3 - Design Details)
A consistent scale and/or the associated confidence rating which symbolize the similarity of each spoken command to the recorded template should be available to the user.
COMMENT: (D)

2.1.6-13 Vocabulary Sets (Tier 3 - Design Details)
Application vocabularies should be divided into sets based on the hierarchy of the application and recognition accuracy requirements.
COMMENT: This improves recognition by reducing the number of choices that the recognizer has to consider to return the correct item. (D)

2.1.6-14 Testing the Recognition of Individual Vocabulary Items (Tier 3 Design Details)
The user should be able to test the recognition of any individual vocabulary item without the entire interactive system being on-line. Feedback on the word recognized and the corresponding confidence score should be available immediately after each use of a word.
COMMENT: (D)

2.1.6-15 Speaker-Dependent Voice Recognizer (Tier 3 - Design Details)
If an application functions with a speaker-dependent voice recognizer, the user should be able to retrain or update any or all vocabulary templates at any time.
COMMENT: A user's voice changes over time, even in the course of an hour of contiuous use. Several factors have the ability to alter the voice temporarily. To maintain good performance under these conditions, the user must have the ability to modify the template set. (D)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.7 Graphics Entry and Editing
2.1.7.1 General

2.1.7.1-1 Pointing (Tier 2 - General)
When graphic data entry involves frequent pointing on a display surface, the user interface should be designed so that actions for display control and sequence control are also accomplished by pointing, in order to minimize shifts from one entry device to another.
COMMENT: For example, in drawing a flow chart, a user should be able to link predecessor and successor elements directly by pointing at them, or by drawing lines between them, rather than by separately keyed entries. This recommendation implies extensive use of menus in the margins of a graphic display to permit direct selection of data attributes and control options by pointing. If screen capacity is too limited to permit simultaneous display of both graphic data and menus, then the designer might provide temporary superposition of menu windows on displayed data, or might provide some separate display device to show current options for control entry. Control entry via keyboard and/or function keys will be less satisfactory. If pointing is performed on some separate input device, such as a stylus on a digitizing tablet, then associated control actions should also be implemented via that device. For graphics software, a pointing action by a user can accomplish several different logical functions: specifying a displayed element ("pick" function); selecting a system-defined object, attribute or action ("button" or "choice" function); or indicating a location in the conceptual drawing space ("locator" function). A designer must distinguish among these functions, although most users will not. Alphabetic entry for titles, labels, and other annotation of graphic displays will be accomplished more quickly by conventional keyboard input than by pointing. (A,C,E)

2.1.7.1-2 Distinctive Cursor (Tier 2 - General)
The current cursor position should be indicated by displaying some distinctive cursor symbol at that point.
COMMENT: (A,C,E)

2.1.7.1-3 Zooming for Precise Positioning (Tier 2 - General)
When data entry requires exact placement of graphic elements, users should be allowed to request expansion of the critical display area ("zooming") to make the positioning task easier.
COMMENT: (A,C,E)

2.1.7.1-4 Displaying Current Attributes (Tier 2 - General)
During graphic data entry/editing, the selected attributes that will affect current actions should be displayed for ready reference by the user.
COMMENT: Users may forget what options have been chosen. Displayed reminders will be particularly important in situations where the consequences of a mistaken user action are difficult to reverse, e.g., where it may be hard to erase a wrongly drawn line. For example, when graphic attributes -- plotting symbols, character size, line type, color, etc. -- are chosen from displayed menus, it might suffice to highlight the currently selected menu options; alternatively, current selections might be shown in some sort of "reminder" window. A few attributes might be shown by the displayed cursor, i.e., by changing cursor shape, size or color depending upon current attribute selections. If rubberbanding is provided to aid line drawing, then that process itself would show the currently selected line type. In some applications, display cues may not be adequate to convey attribute information completely. There may not be sufficient room on the display. Or the attributes may derive from underlying models whose characteristics are too complex for simple display representation. In such cases, users should be able to request auxiliary display of such information to determine the operative context for current actions. (A,C,E)

2.1.7.1-5 Automatic Data Registration (Tier 2 - General)
Automatic registration or alignment of computer-generated graphic data should be provided, so that variable data are shown properly with respect to fixed background or map data at any display scale.
COMMENT: When users are required to enter data via some separate device such as a graphic tablet, rather than directly on the display surface, it may be necessary for a user to participate in some computer-prompted procedure for ensuring data registration. Such a procedure may prove error-prone, however, and should be considered an undesirable expedient. (A,C,E)

2.1.7.1-6 Highlighting Selected Elements (Tier 2 - General)
When a user has selected a displayed graphic element, that element should be highlighted in some way so that the user can anticipate the consequences of any proposed action involving that selection.
COMMENT: A dotted border might be displayed around a selected element, or perhaps a selected element might be displayed with video inversion to distinguish it from other elements. (A,E)

2.1.7.1-7 Changing Position (Translation) (Tier 2 - General)
When editing graphic data, users should be allowed to reposition selected elements on the display.
COMMENT: Repositioning displayed elements, whether done by "dragging" or "cut-and-paste", will usually prove easier than deleting an element and then recreating it from scratch in the desired location. A capability for moving elements will aid initial data entry as well as any subsequent editing of graphic data. If an element is moved visibly by dragging across the display, it is probably not necessary to depict it in complete detail in all of its intermediate positions. It might suffice to show it in simplified outline until its new position has been confirmed by the user (or perhaps until it remains in one position for a fixed interval of time), at which point its details could be filled in again by the computer. (A,D,E)

2.1.7.1-8 Selecting Graphic Elements (Tier 3 - Design Details)
Users should be provided some means for designating and selecting displayed graphic elements for manipulation.
COMMENT: For example, designation might be by pointing, in the case of a discrete element, or might require some sort of outlining action to delineate portions of a complex figure. (A,C,E)

2.1.7.1-9 Selecting from Displayed Attributes (Tier 3 - Design Details)
During graphic data entry, users should be allowed to specify attributes for displayed elements by selecting from displayed samples illustrating the available options.
COMMENT: For example, for line drawing a user might select from displayed samples of thick or thin, solid or broken, etc. A display of available attributes will serve as a helpful reminder to the user, and will eliminate the need to assign distinctive verbal labels to the various options. Samples of some attributes may be difficult to display. In complex graphics, for example, specification of line type might involve selection among "brushes", each of which has a "tip" defining the size and shape of the drawing area (a group of pixels) that the user can manipulate. Brushes might have squared tips to draw sharp lines, or rounded tips to draw lines with softer edges. By analogy with artistic painting, a "smear" brush might be provided to average or blend colors along its path. Selective erasure might be accomplished with a brush applying (returning to) the color of the display background. In most applications, the current selection of data attributes should remain in effect until a new selection is made. In some cases, e.g., following selection of an "erase" attribute, it may help the user if a selected attribute reverts automatically to a default value at the completion of a transaction sequence. (A,C,E)

2.1.7.1-10 Consistent Method for Attribute Selection (Tier 3 - Design Details)
When editing graphic data, users should be allowed to change display attributes by whatever means were used to select those attributes in the first place.
COMMENT: Many editing changes will be made during data entry, rather than as separate later actions, and thus it is important that entry and editing actions be consistent. For example, if line type is selected initially from a menu of displayed attributes, then changing a line type should also be accomplished via menu selection. (A,E)

2.1.7.1-11 Selecting Colors (Tier 3 - Design Details)
If users may select colors as an attribute of graphic elements, they should be allowed to specify colors directly by pointing at displayed samples, rather than requiring them to name the colors.
COMMENT: If many colors are available, users with normal vision can choose from displayed samples more reliably than from a list of color names. For color-blind users, however, it might be helpful to add names/labels to the displayed samples. If only a few colors are available, their names can probably be used reliably. For more elaborate graphic art, it may be helpful to users should be allowed to mix their own colors by sequential selection (i.e., cursor placement), either in a displayed palette or directly in a graphic image. Such color mixing could permit user control of saturation, brightness, and opacity/transparency, as well as hues. (A,E)

2.1.7.1-12 Changing Attributes (Tier 3 - Design Details)
When entering or editing graphic data, users should be allowed to change display attributes for selected graphic elements.
COMMENT: For example, if a figure was created initially with dashed lines, then a user should be able to select the figure, or portions of it, and change the dashed lines to solid lines by specifying that alternative attribute. If it is easy to change attributes, reversing earlier data entry decisions, then the process of composing graphic displays will be generally easier. Another approach to changing an attribute might be to rely on general editing capabilities, i.e., to delete the element in question (perhaps using an UNDO command for an element just created) and then redraw it. But a capability for specifying attribute change directly, without element deletion and reentry, will often be helpful. (A,E)

2.1.7.1-13 Moving Selected Objects (Tier 3 - Design Details)
Only objects that have been selected should be movable within the display.
COMMENT: (D)

2.1.7.1-14 Changing Size (Tier 3 - Design Details)
When editing graphic data, users should be able to change the size (scale) of any selected element on the display, rather than delete and recreate the element in a different size. Types of resizing should include simultaneous resizing of both x and y dimensions and changing only one dimension.
COMMENT: (C,D)

2.1.7.1-15 Changing Orientation (Rotation) (Tier 3 - Design Details)
Only objects that have been selected should be able to be reoriented.
COMMENT: (D)

2.1.7.1-16 Multiple Methods of Reorienting Objects (Tier 3 - Design Details)
Users should be able to reorient objects by multiple methods.
COMMENT: For example, by direct manipulation, or selection of a menu command. (D)

2.1.7.1-17 Continuous Motion Rotation (Tier 3 - Design Details)
The rotation of an object to a new orientation should involve a smooth and continuous motion of an outline of the object.
COMMENT: (D)

2.1.7.1-18 Direction of Rotation (Tier 3 - Design Details)
Users should be able to rotate objects clockwise or counterclockwise.
COMMENT: (D)

2.1.7.1-19 Deleting Elements (Tier 3 - Design Details)
When editing graphic data, users should be allowed to delete selected elements from the display.
COMMENT: Deletion/erasure will help when mistakes are made during data entry, as well as in any subsequent editing of graphic data. Deletion should be implemented as a reversible action. A general UNDO capability might suffice to reverse deletions. A more extended reversibility might be provided by saving deleted elements in a computer scrap basket from which they can be retrieved any time during a work session in case a deletion is discovered to be a mistake. (A,E)

2.1.7.1-20 Easy Storage and Retrieval (Tier 3 - Design Details)
Easy means for saving and retrieving graphic displays or their component elements at different stages in their creation should be provided .
COMMENT: A user should not have to create a graphic image more than once. Once a graphic element has been created, a user should be able to save it for possible re-use. As a protective measure, a user might wish to save different versions of a graphic display at successive stages during its creation, in order to return to an earlier state if later results seem unsatisfactory. During creation, the elements added to a graphic display can be interrelated in complex ways, and thus stepwise deletion of unwanted elements could prove a difficult process. An UNDO command might be helpful for deleting some of the most recently added elements. But storage and subsequent retrieval of interim versions of the display may be more helpful for a foresighted user. (A,C,E)

2.1.7.1-21 Naming Displays and Elements (Tier 3 - Design Details)
Users should be allowed to name graphic displays or designated elements, in order to aid storage and retrieval or manipulation during graphic data entry/editing; and provide means for a user to review a current "catalog" of named elements.
COMMENT: Standard displays and graphic components might be assigned names automatically by the computer, but users will still need a capability to assign their own names to interim versions of displays in creation, or to various elements of those displays. In either case, users may forget what names have been assigned; some "catalog" of currently named elements will serve as a helpful reminder. For currently displayed material, pointing may be more convenient than naming for the designation of selected elements; but names will certainly aid the retrieval of stored material. (A,E)

2.1.7.1-22 Aids for Entering Hierarchic Data (Tier 3 - Design Details)
Computer aids for entering graphic data in an organized hierarchic structure should be provided when such entry is required.
COMMENT: For example, for entering map data, a user might have to specify different levels of data storage for a city's name and location, its municipal boundaries, its major road patterns, its street names and house numbers, etc.; computer aids could help that process. (E)

2.1.7.1-23 Automatic Data Valiuation (Tier 3 - Design Details)
When graphic data represent relations among real objects, appropriate computer logic based on models of physical probability should be provided to validate data entries.
COMMENT: If inconsistencies of data entry cannot be resolved immediately, the computer might keep track of unresolved questions pending receipt of further data. If data indicate that a military land unit has been reported in the middle of a lake, the computer should call that discrepancy to the user's attention. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.7 Graphics Entry and Editing
2.1.7.2 Plotting Data Points

2.1.7.2-1 Automated Data Plotting (Tier 2 - General)
When complex graphic data must be entered quickly, computer aids should be provided to automate that process.
COMMENT: Users can create simple graphics or edit stored graphic material fairly quickly, but they can only create complex graphic displays much more slowly. A variety of computer aids can be provided to help enter graphic data. Entry of detailed drawings and/or photographic imagery can be accomplished via a video camera and high-resolution digitizer, perhaps with facilities for a user to edit that process. (A,E)

2.1.7.2-2 Plotting Stored Data (Tier 2 - General)
Automated plotting of computer-stored data should be provided at user request, with provision for subsequent editing by a user.
COMMENT: For example, a computer might plot the data values from two arrays in a line graph, or three-dimensional data in XYZ coordinates. In many applications, data intended for graphic display will already be stored in the computer. In such cases a user might specify the graphic format required and edit elements in the resulting display output, without actually having to re-enter the data. When users do have to enter data for graphic display, they might choose form filling or tabular entry for efficiency in the initial input of data and then invoke graphic capabilities for subsequent data editing. In either case, it is important that previously entered data should be accessible for graphic processing. (A,E)

2.1.7.2-3 Computer Derivation of Graphic Data (Tier 2 - General)
When graphic data can be derived from data already available in the computer, machine aids should be provided for that purpose.
COMMENT: For example, a computer might fit a smoothed curve through plotted data values, filter out points when drawing a densely defined curve, rescale graphs, invert graphs by exchanging X- and Y-values, convert graphs to show cumulative curves, calculate and display various statistical measures of data distribution, produce a contour plot from gridded data with linear interpolation, plot map contours from latitude-longitude coordinates, calculate bearings, distances, and areas on maps, plot perspective views of objects defined in plan views, plot specified cross-sections of displayed objects, calculate a parts list for a designed assembly, identify critical paths and float time in network scheduling charts, etc. The machine capacity for generating graphic data by computation will far exceed a user's capabilities in both speed and accuracy. (A,E)

2.1.7.2-4 Predefined Graphic Formats (Tier 3 - Design Details)
When graphic data must be plotted in predefined standard formats, templates or skeletal displays for those formats should be provided to aid data entry.
COMMENT: In many applications, it may help to provide flexibility so that general prestored formats can be modified by a user and then saved for subsequent use. For example, sample displays might be stored in the computer to aid in creating standard graphs such as bar graphs, or standard diagrams such as organization charts, or page layouts for typesetting, or maps drawn to different scales or with different projections. (A,E)

2.1.7.2-5 Aids for Graph Construction (Tier 3 - Design Details)
When graphs must be constructed for data plotting, computer aids should be provided for that purpose.
COMMENT: For example, construction aids might include stored templates of different kinds of graphs, prompts to guide users in the definition of scale axes, and aids for format control such as automatic centering of axis labels if requested by a user. Computer aids for graph construction should be designed to allow flexibility in their use. A user should be allowed to position labels and other graphic elements at will, except where operational requirements may impose fixed formats. (A,E)

2.1.7.2-6 Aids for Scaling (Tier 3 - Design Details)
Computer aids should be provided to help users specify appropriate scales for graphic data entry.

COMMENT: The computer should handle scaling automatically, subject to review and change by a user. The computer might provide a general template for the plotting scale and prompt the user as necessary to define the scale more exactly, including specification of the origin, linear or logarithmic axes, scale intervals, minimum and maximum values, and labels for axes. In the process of defining scales the computer might impose rules to ensure that the resulting graphic displays are designed to permit effective information assimilation by their users, e.g., displaying scales with conventional direction, so that numbers increase in value from left to right, or from bottom to top. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.7 Graphics Entry and Editing
2.1.7.3 Drawing Lines and Figures

2.1.7.3-1 Drawing Lines (Tier 1 - Use)
When line drawing is required, users should be provided with aids for drawing straight line segments.
COMMENT: Some applications may require drawing continuous lines freehand. (A,C,E)

2.1.7.3-2 Drawing Figures (Tier 1 - Use)
When a user must draw figures, computer aids should be provided for that purpose.
COMMENT: For example, a user might select from a stored set of standard forms -- rectangles, circles, etc. -- and edit those to create figures or the component elements of figures, rather than having to draw each figure from scratch. Much graphic construction can either be aided in some way (by templates, tracing techniques, grid gravity, etc.), or can employ machine generation of computed or stored forms, often followed by user editing of those forms. A great many different figures can be created by combining simple elements or by specifying geometric parameters (e.g., conic sections). Computer aids that allow such shortcuts can speed figure drawing and make the process more accurate. In some applications, such as constructing organization charts, figures may repeat a number of standard elements. In such cases computer aids can be provided to make the production of figures almost routine. Computer logic might be provided to allow a user to create a rectangle simply by designating two opposite corners, or a circle by first specifying its center and then any point on its circumference, with rubberbanding to show the result of any current selection. Some capability for freehand drawing may be needed, particularly in the creation of graphic art, but freehand drawing will not provide sufficient precision for many applications. (A,C,E)

2.1.7.3-3 Zooming (Tier 1 - Use)
Critical or difficult graphic drawing tasks should be supported by a "zooming" function to enlarge critical display areas.
COMMENT: (A,E)

2.1.7.3-4 Stored Models (Tier 2 - General)
When drawings are variations on a common theme, a computer model that will allow users to create particular instances by entering appropriate parameters should be provided .
COMMENT: (A,E)

2.1.7.3-5 Grid Reference for Alignment (Tier 2 - General)
When graphic elements are created with vertical and horizontal alignment, a reference grid should be provided at user-request to aid that alignment.
COMMENT: A reference grid might be displayed merely as a visual aid. In some instances, however, where repeated graphic elements must be aligned in regular fashion, it may be helpful to use a grid to position graphic elements automatically at its intersections. An example might be the construction of organization charts with repeating rows of boxes connected by line segments. "Grid gravity" might be provided automatically during graphic entry, based on "gravity field" connection of drawn lines to grid points, or might be invoked as a separate editing command by a user. A grid suitable for aiding data entry may not prove equally helpful for subsequent interpretation of data on the completed display. Therefore, after a graphic image has been composed, the user should decide whether or not to include the reference grid in the finished display. (A,E)

2.1.7.3-6 Changing Grid Intervals (Tier 2 - General)
When a reference grid is displayed to aid graphic data entry, users should be allowed to change the grid intervals in either or both directions.
COMMENT: For different applications, a user may wish to work with a fine grid or a coarse grid, depending on the quantizing interval of the data being plotted. (A,E)

2.1.7.3-7 Aiding Line Connection (Tier 3 - Design Details)
When line segments must join or intersect, computer logic should be provided to aid such

connection.
COMMENT: An effective computer logic to aid line connection is to provide a so-called "gravity field" surrounding each line segment, so that if a line-drawing cursor is moved within that field the cursor's new line will be extended automatically to intersect the already-displayed line. Note that a "gravity field" need not itself be displayed; users will soon learn to infer its extent by its effect in aiding cursor placement. Because users often seek to join line segments at their ends, it may help to enlarge the zone of attraction at the end of each displayed line to facilitate such end-to-end connection. The concept of "gravity field" can also be used to align drawn line segments with points in a reference grid, as well as with each other. (A,E)

2.1.7.3-8 Specifying Line Relations (Tier 3 - Design Details)

For precise drawing, users should be allowed to draw lines by specifying their geometric relations with other lines.
COMMENT: For example, in computer-aided design, a user might wish to create a new line by declaring it parallel with (or perpendicular to) an existing line. (A,E)

2.1.7.3-9 Constraint for Vertical and Horizontal Lines (Tier 3 - Design Details)

When graphic elements are created with vertical and horizontal lines, users should be allowed to specify appropriate constraints during line drawing.
COMMENT: Here computer logic is invoked to interpret casual freehand gestures by a user as if they were carefully drawn -- the electronic equivalent of a draftsman's T-square. Thus a roughly vertical motion by a user could create an exactly vertical line in computer storage and display. In applications where orthogonal lines predominate, it may be helpful to make constrained drawing the norm, while allowing users to specify free-form drawing as an exception. (A,E)

2.1.7.3-10 Rubberbanding (Tier 3 - Design Details)

When lines must be drawn at arbitrary positions, lengths and angles, a rubberbanding capability should be provided, in which the computer displays a tentative line extending from a designated start point to whatever is the currently proposed end point.
COMMENT: This technique permits users to enter or change a line segment rapidly and with confidence by designating its starting point and then simply moving the cursor to the desired end-point, thus placing the "rubberband" line in its intended position. A similar capability should be provided to aid entry/editing of specified outline figures. A rectangle might be rubberbanded by fixing one corner and moving the opposite corner. A circle might be rubberbanded to desired size by fixing its center and changing the extension of its radius. (A,E)

2.1.7.3-11 Alternative Methods for Drawing Figures (Tier 3 - Design Details)

In applications requiring a general capability for drawing figures, a choice of methods should be provided for specifying graphic elements.
COMMENT: For example, a straight line might usually be created by specifying two points, but sometimes it might be easier to specify one point plus a constraint that the line be parallel (perpendicular, tangent) to some other line. A circle might usually be created by specifying its center and a point on its circumference; but sometimes it might be easier to specify a circle by other means -- e.g., by two ends of its diameter, or by three points on its circumference, or by its center plus a constraint that it be tangent to some other figure, or by inscribing it within a square. An ellipse might usually be created by specifying two foci and a point on its perimeter, but sometimes it might be easier to specify its center and draw its long and short axes, or it might be inscribed within a rectangle. A regular polygon might usually be created by specifying the end points of one edge and the number of sides, but it also might be specified by its center and one vertex and the number of its sides. (A,E)

2.1.7.3-12 Automatic Figure Completion (Tier 3 - Design Details)

In applications where design rules have been previously defined, computer aids to complete automatically any details of graphic data entry covered by those rules should be provided.
COMMENT: For example, the computer might automatically add dimensional annotation to drafted figures, or when drawing or editing a polygon, the computer might automatically maintain closure if additional vertices are specified, rather than requiring the user to close the figure manually. In computer-aided design, if the flanges of connected components are designed with arcs of standard radius, then a user might draw those joints square and ask the computer to round them. A computer might create perspective drawings automatically from plan and elevation data, with hidden parts eliminated. In drawing flow charts, a computer might automatically add the arrow to a

connecting line, depending upon the direction in which the line was drawn (or the sequence in which its points were designated). (A,E)

2.1.7.3-13 Enlargement for Symbol Drawing (Tier 3 - Design Details)

In applications where users may create special symbols, a capability for drawing (or changing) a symbol in large scale should be provided , with automatic reduction by the computer to the needed size.

COMMENT: For example, enlargement might aid in specifying shapes to be used for plotting points or for map symbols, or in designing icons or the letters in a font. When drawing symbols in large scale, a rough sketch may suffice, requiring less dexterity from a user. The desirable degree of scale expansion will depend upon symbol complexity, and can probably be determined by testing. Some designers recommend a 20x20 grid to provide an enlarged pixel representation, on which a user can add or delete pixels to create a symbol. (A,E)

2.1.7.3-14 Copying Elements (Tier 3 - Design Details)

Users should be allowed to copy a selected graphic element in order to duplicate it elsewhere or create a repeating pattern.

COMMENT: Many graphic displays contain repeating elements; copying an element already created may prove quicker than redrawing that element from scratch. In creating patterns, a user will often need to specify a reference point in the original element and then specify where that point should be placed for each copy of that element. In some special applications, it might help to provide an optional kind of copying capability called "instancing" in which a user can choose to copy a graphic element from a stored template, and then all copies (or instances) will be changed automatically whenever that original template is changed. (A,E)

2.1.7.3-15 Rotating Elements (Tier 3 - Design Details)

When editing graphic data that depict objects, users should be allowed to rotate a selected element on the display, in order to show it in different orientations.

COMMENT: Rotation of a displayed element will usually prove easier than deleting an element and then recreating it from scratch in the desired orientation. A capability for rotating an element will aid initial data entry as well as any subsequent editing of graphic data. (A,E)

2.1.7.3-16 Reflection of Elements (Tier 3 - Design Details)

When users must create symmetric graphic elements, a means for specifying a reflection (mirror image) of existing elements should be provided .

COMMENT: Many graphic displays contain symmetric figures where if one side has been drawn the other side might be created quickly as a reflected copy of the first, perhaps with some subsequent modification by the user. Users will need some means for specifying the desired reflection plane, which for practical purposes should probably be constrained to a choice between left-right and up-down reflection. (A,E)

2.1.7.3-17 Grouping Elements (Tier 3 - Design Details)

Users should be allowed to designate a group of elements to which graphic editing operations will be applied in common.

COMMENT: For example, a user might carefully position two elements with respect to each other, and then wish to move both of them together while preserving their relative positions. Grouping elements might be a temporary action, intended for just a few successive editing operations, or it might be specified more permanently via some sort of "make group" command. (A,E)

2.1.7.3-18 Merging Elements (Tier 3 - Design Details)

In the special case when a drawn object can be created by the junction or disjunction of other graphic elements, computer aids should be provided for merging those elements by boolean combination.

COMMENT: For example, in showing the junction of two objects comprising the components of some more complex object, a computer might calculate and draw their intersection, automatically dealing with overlapped data sets and concealed contours. This technique can represent the intersection of solid objects and also the result of drilling holes in an object. (A,E)

2.1.7.3-19 Filling Enclosed Areas (Tier 3 - Design Details)

When area coding is required, users should be allowed to fill an enclosed area with a selected attribute (color, shading or cross-hatching) by a simple specification action, rather than by having to trace over the area involved.

COMMENT: For example, for many applications, it may suffice if a user can simply point at one of several displayed attributes (color patches, brightness levels, hatching patterns) and then point at the area to be filled. A user might wish to shade the bars of a bar chart, or the wedges in a pie chart, or the various components of a drawn diagram or picture. (A,E)

2.0 OPERATOR INPUT AND CONTROL

2.1 Entering Information

2.1.8 Data Validation

2.1.8-1 Automatic Data Validation (Tier 1 - Use)
Software for automatic data validation should be provided to check any item whose entry and/or correct format or content is required for subsequent data processing.
COMMENT: (A,E)

2.1.8-2 Stroke-By-Stroke Echo (Tier 2 - General)
Data being entered through a keyboard should be echoed on the screen on a stroke by stroke basis, except when applied to passwords or other security measures .
COMMENT: (A)

2.1.8-3 System Validation (Tier 2 - General)
Where possible, when a command entry does not meet validation logic, a cautionary message should be displayed asking the user to confirm data entry.
COMMENT: For example, during reactivity control, the following type message may be displayed: "A negative value has been entered in the field 'Control Rods.' Please enter a positive number between 1 and 32." (A)

2.1.8-4 Data Verification by User Review (Tier 2 - General)
When verification of prior data entries is required, users should be allowed to review and confirm the data, rather than requiring re-entry of the data. For special verification, as when computer processing has detected doubtful and/or discrepant data entries, the user should be alerted with an appropriate advisory message.
COMMENT: For routine verification, data review by the user will be quicker than re-entry, with less risk of introducing new errors. (E)

2.1.8-5 Cross Validation of Related Data (Tier 2 - General)
For the entry of related data items, automatic cross validation should be provided to ensure that the data set is logically consistent.
COMMENT: Such cross checking is a significant advantage of on-line data processing, providing computer aids to help users detect logical errors. (E)

2.1.8-6 Displaying Default Values (Tier 2 - General)
Currently operative default values should be displayed for data entry, so that users can review and confirm them for computer processing.
COMMENT: (E)

2.1.8-7 Non-Disruptive Error Messages (Tier 2 - General)
If data validation detects a probable error, an error message should be displayed to the user at the completion of data entry; do not interrupt an ongoing transaction.
COMMENT: (A,E)

2.1.8-8 Timely Validation of Sequential Transactions (Tier 3 - Design Details)
In a repetitive data entry task, the data for one transaction should be validated and the user should be allowed to correct errors before beginning another transaction.
COMMENT: This is particularly important when the task requires transcription from source documents, so that a user can detect and correct entry errors while the relevant document is still at hand. (A,E)

2.1.8-9 Optional Item-by-Item Validation (Tier 3 - Design Details)
Optional item-by-item data validation within a multiple-entry transaction should be provided .
COMMENT: This capability, which might be termed an "interim ENTER," may sometimes help a novice user who is uncertain about the requirements imposed on each data item. (A,E)

2.1.8-10 Deferral of Required Data Entry (Tier 3 - Design Details)
If a user wishes to defer entry of a required data item, the user should be required to enter a special symbol in the data field to indicate that the item has been temporarily omitted rather than ignored.
COMMENT: (E)

2.1.8-11 Reminder of Deferred Entry (Tier 3 - Design Details)
If a user has deferred entry of required data but then requests processing of entries, that omission should be signaled to the user and immediate entry of missing items or perhaps further deferral should be allowed.
COMMENT: (E)

2.1.8-12 User Validation (Tier 3 - Design Details)
The user should be able to obtain a paper copy (virtual screen dump) of the contents of alphanumeric or graphic displays.
COMMENT: (A)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.9 Error Prevention and Correction
2.1.9.1 General

2.1.9.1-1 Consistent Procedures (Tier 2 - Consistency)
Clear and consistent procedures for different types of transactions should be provided, particularly those involving data entry, change and deletion, and error correction.
COMMENT: Consistent procedures will help users develop consistent habits of operation, reduce the likelihood of user confusion and error, and are especially important for any transaction that risks data loss. (E)

2.1.9.1-2 Appropriate Ease or Difficulty of User Actions (Tier 2 - General)
The ease of user actions should match desired ends; frequent or urgent actions should be easy to take, but make potentially destructive actions should be sufficiently difficult so that they require extra user attention.
COMMENT: (E)

2.1.9.1-3 Control by Explicit User Action (Tier 2 - General)
The computer should change data only as a result of explicit actions by a user, and not initiate changes automatically.
COMMENT: The aim here is to preserve clarity of system operation for the user. In effect, a computer should not initiate data changes unless requested (and possibly confirmed) by a user. Exceptions - 1) In an operations monitoring situation, a computer might accept data changes automatically from external sources (sensors), if appropriate software is incorporated to ensure validation and protection of the input data. 2) A computer might perform cross-file updating automatically, following data change by a user. (E)

2.1.9.1-4 Appropriate Response to All Entries (Tier 2 - General)
The interface software should deal appropriately with all possible control entries, correct and incorrect.
COMMENT: For certain routine and easily recognized errors, such as trying to tab beyond the end of a line, a simple auditory signal ("beep") may be sufficient computer response. If a user selects a function key that is invalid for a particular transaction, no action should result except display of an advisory message indicating what functions are appropriate at that point. (E)

2.1.9.1-5 Prompting Command Correction (Tier 2 - General)
If an element of a command entry is not recognized, or logically inappropriate, users should be prompted to correct that element rather than requiring re-entry of the entire command.
COMMENT: A faulty command can be retained in the command entry area of the display, with the cursor automatically positioned at the incorrect item, plus an advisory message describing the problem. (E)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.9 Error Prevention and Correction
2.1.9.2 Correcting Data/Command Entries

2.1.9.2-1 Acknowledging Corrections (Tier 2 - Feedback)
All error corrections by the user should be acknowledged by the system either by indicating a correct entry has been made or by another error message.
COMMENT: (C)

2.1.9.2-2 UNDO to Reverse Control Actions (Tier 2 - Error Handling)
Any user action should be immediately reversable by an UNDO command. UNDO itself should be reversible, so that a second UNDO action will do again whatever was just undone.
COMMENT: Even with an UNDO capability, however, a user may make an irretrievable mistake, if succeeding actions intervene before a prior destructive action is noticed. If a user is overhasty in confirming a destructive action, and realizes the mistake right away (i.e., before taking another action), then an UNDO action might be taken to reverse the damage. (E)

2.1.9.2-3 User Review and Editing of Entries (Tier 2 - General)
For all inputs, whether data entries or commands, users should be allowed to edit composed material before requesting computer processing.
COMMENT: Input editing will allow users to correct many errors before computer processing. When an error is detected, a user will be able to fix it by editing, i.e., without having to retype any correct items (which might introduce further errors). (E)

2.1.9.2-4 Display of Erroneous Entries (Tier 2 - General)
Computer-detected errors, as well as the associated error message, should be displayed continuously until the error is corrected.
COMMENT: (C)

2.1.9.2-5 Immediate Error Correction (Tier 2 - General)
When a data entry error is detected by the computer, the user should be allowed to make an immediate correction.
COMMENT: It is helpful to correct data entry errors at the source, i.e., while a user still has the entry in mind and/or source documents at hand. When a user cannot correct an entry, as when transcribing from a source document that itself contains an error, it may help to allow the user to defer entry of the wrong item. Alternatively, the user might wish to cancel the transaction. (E)

2.1.9.2-6 Editing Entries After Error Detection (Tier 2 - General)
Following error detection, users should be allowed to edit entries so that they must rekey only those portions that were in error.
COMMENT: If a user must re-enter an entire data set to correct one wrong item, s/he may make new errors in previously correct items. (E)

2.1.9.2-7 Explicit Entry of Corrections (Tier 2 - General)
Users should be required to take an explicit ENTER action for computer processing of error corrections; this should be the same action that was taken to enter the data originally.
COMMENT: (E)

2.1.9.2-8 Error Message Content (Tier 2 - General)
Error messages should specifically describe the error and available remedies in language that reflects the user's point of view, not the programmer's.
COMMENT: Error messages should explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition. Where clear inference is not possible, probable helpful inference(s) may be offered. (C)

2.1.9.2-9 Automated Correction Aid (Tier 2 - General)
When inappropriate or unrecognized commands are detected, a list of permissible commands, or commands predicting what the user is attempting should be provided .
COMMENT: (D)

2.1.9.2-10 Flexible BACKUP for Error Correction (Tier 2 - General)
Users should be allowed to BACKUP easily to previous steps in a transaction sequence in order to correct an error or make any other desired change.
COMMENT: For example, a user might wish to BACKUP through the defined sequence of a question-and-answer dialogue in order to change a previous answer. (E)

2.1.9.2-11 Errors in Stacked Commands (Tier 3 - Design Details)
If an error is detected in a stacked series of command entries, the computer should either consistently execute to the point of error, or else consistently require users to correct errors before executing any command.
COMMENT: In most applications, partial execution will probably prove desirable. The point here is that an interface design decision should be made and then followed consistently. (E)

2.1.9.2-12 Partial Execution of Stacked Commands (Tier 3 - Design Details)
If only a portion of a stacked command can be executed, the user should be notified and provided appropriate guidance to permit correction, completion, or cancellation of the stacked command.
COMMENT: Note that stacked commands can fail because of error in their composition, or for other reasons such as unavailability of required data. (E)

2.1.9.2-13 Spelling Errors (Tier 3 - Design Details)
Commands should not be named in such a way that misspelling and other common errors could produce valid system commands or initiate transactions different from those intended.
COMMENT: When possible, the system should recognize common misspellings of commands and execute the commands as if spelling had been correct. Computer- corrected commands, values, and spellings should be displayed and highlighted for user confirmation. (C)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.9 Error Prevention and Correction
2.1.9.3 Confirming Entries

2.1.9.3-1 User Confirmation of Destructive Entries (Tier 2 - General)
When a control entry will cause any extensive change in stored data, procedures and/or system operation, and particularly if that change cannot be easily reversed, the user should be notified and confirmation of the action should be required before implementing it.
COMMENT: This guideline applies to replacing or destroying any data file, any disk, or other stored data. The guideline does not apply to editing of words, numbers, or text lines within a document or data form or to editing of graphical elements within a graphical data file. (E)

2.1.9.3-2 Confirmation Message Content (Tier 2 - General)
Confirmation me iges should be simple, positive, and direct.
COMMENT: (D)

2.1.9.3-3 User Warned of Potential Data Loss (Tier 2 - General)
The prompt for a CONFIRM action should warn users explicitly of any possible data loss.
COMMENT: (Bad) CONFIRM DELETE (Good) CONFIRM deletion of entire FEEDWATER file?? (E)

2.1.9.3-4 Verification of Deletion (Tier 2 - General)
If a complete file is to be deleted. sufficient information, (name, description, size, date established, data last changed, etc.) should be displayed to verify the file for deletion.
COMMENT: (A)

2.0 OPERATOR INPUT AND CONTROL
2.1 Entering Information
2.1.9 Error Prevention and Correction
2.1.9.4 Protecting Data

2.1.9.4-1 Protection from Computer Failure (Tier 1 - Use)
Automatic measures should be provided to minimize data loss from computer failure.
COMMENT: An automatic capability is needed because users cannot be relied upon to remember to take necessary protective measures. Though not strictly a feature of user interface design, reliable data handling by the computer will do much to maintain user confidence in the system. Conversely, data loss resulting from computer failure will weaken user confidence, and reduce user acceptance where system use is optional. For example, depending upon the criticality of the application, different protective measures may be justified, including periodic automatic archiving of data files, maintenance of transaction logs for reconstruction of recent data changes, or even provision of parallel "backup" computing facilities. (E)

2.1.9.4-2 Protection from Interrupts (Tier 2 - General)
When a proposed user action will interrupt a current transaction sequence, automatic means to prevent data loss should be provided ; if potential data loss cannot be prevented, the user should be warned.
COMMENT: Do not interrupt without user confirmation. Some interrupt actions such as BACKUP, CANCEL, or REVIEW, will by their definition cause only limited data change, and so need no special protection. However, if an interrupt action may cause extensive data change (e.g., RESTART, LOG-OFF), then the user should be required to confirm that action before processing. If a user should interrupt a series of changes to a data file, then the computer might automatically save both the original and the changed versions of that file for subsequent user review and disposition. (E)

2.1.9.4-3 Protection from Data Change (Tier 2 - General)
When data must not be changed, users should not be permitted to change controlled items.
COMMENT: It is not enough simply to instruct users not to make changes in displayed data. (E)

2.1.9.4-4 Explicit Action to Select Destructive Modes (Tier 2 - General)
Users should take explicit action to select any operational mode that might result in data loss; the computer should not establish destructive modes automatically.
COMMENT: In many applications, it may be better not to provide any destructive mode. Instead of providing a DELETE mode, for example, require that DELETE be a discrete action subject to confirmation by the user when the requested data deletion is extensive. (E)

2.1.9.4-5 Warning Users of Potential Data Loss (Tier 2 - General)
For conditions which may require special user attention to protect against data loss, an explicit alert and/or warning message should be provided to prompt appropriate user action.
COMMENT: (E)

2.1.9.4-6 Safe Defaults (Tier 2 - General)
If automatic defaults are provided for control entries, those defaults should protect against data loss or at least not contribute to the risk of data loss.
COMMENT: For example, requesting a printout of filed data, one control option might be to delete that file after printing; the default value for such a destructive option should automatically be set to NO whenever the printing options are presented to a user for selection. (E)

2.1.9.4-7 Protecting Physical Controls (Tier 2 - General)
If activation of function keys (and other control devices) may result in data loss, they should be located separately and/or physically protected to reduce the likelihood of accidental activation.
COMMENT: (E)

2.1.9.4-8 Disabling Unneeded Controls (Tier 2 - General)

When function keys and other devices are not needed for current control entry, and especially when they may have destructive effects, they should be temporarily disabled by the software so that they cannot be activated by a user.
COMMENT: Some means should also be provided to help users distinguish currently active from disabled controls, such as brightening (active) or dimming (disabled) their associated labels. If labeling is adequate, then user selection of a disabled control need produce no response. If adequate labeling cannot be provided, then user selection of a disabled control should produce an advisory message that the control is not currently active. (E)

2.1.9.4-9 Preventing Data Loss at LOG-OFF (Tier 2 - General)

When a user requests LOG-OFF, pending transactions should be checked and if any pending transaction will not be completed, or if data will be lost, an advisory message requesting user confirmation should be displayed.
COMMENT: A user may sometimes suppose that a job is done before taking necessary implementing actions. (E)

2.1.9.4-10 Displaying Data to be Changed (Tier 3 - Design Details)

If a user requests change (or deletion) of a stored data item that is not currently being displayed, both the old and new values should be displayed so that the user can confirm or nullify the change before the transaction is completed.
COMMENT: For proposed deletion of significant amounts of data, such as entire files, it will probably not be feasible to display all of the data. In such instances, sufficient information should be provided so that the user can identify those files s/he has selected for deletion. The user should be clearly warned of the potential data loss and required to confirm the destructive action before it will be executed. This practice will tend to prevent inadvertent change, including changes resulting in loss of needed data. User attempts at selective data change without displayed feedback will be prone to error. (E)

2.1.9.4-11 Distinctive File Names (Tier 3 - Design Details)

When data files may be deleted (or overwritten) by name, the names of different files should distinctive.
COMMENT: In many applications, file naming is a user option, and distinctive naming will depend on user judgment. The computer might provide an advisory message if a proposed new file name is similar (e.g., identical in the first 5 letters) to the name of an existing file. (E)

2.1.9.4-12 Feedback for Mode Selection (Tier 3 - Design Details)

When the result of user actions will be contingent upon prior selection among differently defined operational modes, a continuous indication of the current mode should be provided, particularly when user inputs in that mode might result in data loss.
COMMENT: A user cannot be relied upon to remember prior actions. Thus any action whose results are contingent upon previous actions can represent a potential threat to data protection. For example, if a DELETE mode is being used to edit displayed data, some indication of that mode should be continuously displayed to the user. (E)

2.1.9.4-13 Multiple Users (Tier 3 - Design Details)

When two or more users have simultaneous read access or data processing results from multiple user-computer interfaces, the operation by one person should not interfere with the operations of another person.
COMMENT: Provisions should be made so that the pre-empted user can resume operations at the point of interference without information loss. (A)

2.1.9.4-14 Protection from Interference by Other Users (Tier 3 - Design Details)

Data should be protected from inadvertent loss caused by the actions of other users.
COMMENT: When one user's actions can be interrupted by another user, as in defined emergency situations, that interruption should be temporary and nondestructive. The inter[illegible] user should subsequently be able to resume operation at the point of interruption without data loss. Wh[illegible]ple users review, enter, or modify data in a system, they should be able to review and browse data cha[illegible]tries made by other users. In systems where information handling requires the coordinated action of multi[illegible]sers, it may be appropriate that one user can change

data that will be used by others. But when multiple users will act independently, then care should be taken to ensure that they will not interfere with one another. (E)

2.1.9.4-15 Segregating Real from Simulated Data (Tier 3 - Design Details)
When simulated data and system functions are displayed or provided (perhaps for user training), real data should be protected and real system use should be clearly distinguished from simulated operations.
COMMENT: (E)

2.1.9.4-16 Data Entry/Change Transaction Records (Tier 3 - Design Details)
In situations where unauthorized data changes may be possible, users (or a system administrator) should be able to request a record of data entry/change transactions.
COMMENT: Transaction records might be maintained for purposes of user guidance as well as for data protection. (E)

2.0 OPERATOR INPUT AND CONTROL

2.2 Operator Dialogue

2.2.1 General

2.2.1-1 Interactive control (Tier 2 - Consistency)
General design objectives for interactive control should include consistency of control action, minimized need for control actions, and minimized memory load on the user, with flexibility of interactive control to adapt to different user needs.
COMMENT: As a general principle, the user who should decide what needs doing and when to do it. The selection of dialogue types should be based on anticipated task requirements and user skills. Different types of dialogue imply differences in system response time for effective cooperation. Estimated relative requirements for user training and for system response time are given below. Dialogue Type Question and Answer Menu Selection Form Filling Function Keys Command Language Natural/Query Language Graphic Interaction Required User Training None None Moderate Moderate High ModerateHighTolerable Speed of System Response Moderate (.5 to less than 2 secs) Very Fast (less than .2 secs) Slow (greater than 2 secs) Very Fast (less than .2 secs) Moderate/Slow (.5 to greater than 2 secs) Fast (.2 to less than .5 secs) Very Fast(less than .2 secs) (C)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.2 Sequence Control

2.2.2-1 Consistent User Actions (Tier 2 - Consistency)
Sequence control actions should be consistent in form and consequences.
COMMENT: Similar means to accomplish ends that are similar should be employed from one transaction to the next, from one task to another, throughout the user interface. In particular, there should be some standard, consistent routine for a user to initiate and terminate the transaction sequences that comprise different tasks. Users should not be required to learn different command names to terminate different tasks, or remember to terminate one task by command and another by function key. (A,E)

2.2.2-2 Consistent Display of Context Information (Tier 2 - Consistency)
Information displayed to provide context for sequence control should be distinctive in location and format, and consistently displayed from one transaction to the next.
COMMENT: (A,E)

2.2.2-3 Format Consistency (Tier 2 - Consistency)
Display and input formats should be similar within levels and the system should indicate current positions within a sequence.
COMMENT: (A)

2.2.2-4 Context Definition (Tier 2 - Consistency)
Formats should be consistent from one frame to the next.
COMMENT: (A)

2.2.2-5 Wording Consistent with User Guidance (Tier 2 - Consistency)
The wording and required format of control functions should be consistently refelected in the wording of user guidance, including all labels, messages, and instructional material.
COMMENT: For example, (Good) To delete a paragraph, press DELETE and then PARAGRAPH. (Bad) If a paragraph must be erased, press DELETE and then PARAGRAPH. For example, when the computer displays a file name, that name should be shown in a format that would be acceptable if the name were included in a command entry. For example, if a user must complete a control form to specify printer settings, the words used as labels on that form should also be used in any error messages and HELP displays which may guide that process. (E)

2.2.2-6 Consistent Terminology for Sequence Control (Tier 2 - Consistency)
For instructional material, such as display labeling, on-line guidance, and other messages to users, consistent terminology should be used to refer to sequence control.
COMMENT: (E)

2.2.2-7 Logical Transaction Sequences (Tier 2 - Task Compatibility)
When designing a sequence of related transactions for some information handling task, task requirements should be employed to ensure that those transactions will constitute a logical unit or subtask from a user's viewpoint, and to determine what control options users will need at any point.
COMMENT: A logical unit to the user is not necessarily the same as a logical unit of the computer software that mediates the transaction sequence. It might be, for example, that a user should enter ten items of data in a single transaction, because those data all come from one particular paper form, even though the computer will use five of those items for one purpose and five items for another in its subsequent internal processing. (A,E)

2.2.2-8 Minimal User Actions (Tier 2 - Minimizing User Actions)
Control actions should be simple, particularly for real-time tasks requiring fast user response; control logic should permit completion of a transaction sequence with the minimum number of actions.
COMMENT: For example, a user should be able to print a display by simple request, without having to take a series of other actions first, such as calling for the display to be filed, specifying a file name, then calling for a print

of that named file. Another example, for long, multipage displays, it should be possible to request a particular page directly, without having to take repetitive NEXT PAGE or PREV PAGE actions. A destructive action will be less likely to be taken by mistake, if it is designed to be different or distinctive, requiring extra user actions. (A,E)

2.2.2-9 Flexible Sequence Control (Tier 2 - Flexibility of Use)

Flexible means of sequence control should be provided so that users can accomplish necessary transactions involving data entry, display, and transmission, or can obtain guidance as needed in connection with any transaction.

COMMENT: For example, in scanning a multipage display the user should be able to go forward or back at will. If user interface design permits only forward steps, so that the user must cycle through an entire display series to reach a previous page, that design is deficient. (A,E)

2.2.2-10 Periodic Feedback (Tier 2 - Feedback)

When system functioning requires the user to stand-by, periodic feedback should be provided to indicate normal system operation.

COMMENT: (D)

2.2.2-11 Feedback for Control Entries (Tier 2 - Feedback)

The computer should acknowledge every control entry immediately; for every action by the user there should be some apparent reaction from the computer.

COMMENT: In particular, the absence of computer response is not an acceptable means of indicating that a control entry is being processed. "Immediately" as used in this guideline must be interpreted in relation to the response time requirements of different dialogue types. For example, execution of a requested transaction might produce an immediately apparent result, as when a user requests NEXT PAGE and the next page is displayed. A message might indicate completion of a transaction, as when a user requests a printout at a remote facility and the computer displays a confirming message "RAD WASTE file has been sent to printer"; or, a message might indicate that execution is in progress or deferred, as when a user enters data and the computer displays an interim message "RAD WASTE file is being updated." A message might indicate that the control entry requires correction or confirmation, as when a user requests a file display and the computer displays an error message "RAD WASTE file not recognized." (E)

2.2.2-12 Indicating Completion of Processing (Tier 2 - Feedback)

When processing in response to a control entry is lengthy, the user should be given some positive indication of subsequent completion, and appropriate related information.

COMMENT: If a user is currently involved in some new transaction, then completion of processing for a prior transaction should be indicated by nondisruptive display of an appropriate advisory message. If the outcome of a completed transaction may imply the need for further user action, that should be indicated to the user. (E)

2.2.2-13 User Initiative in Sequence Control (Tier 2 - General)

Users should be allowed to take initiative and control their interaction with the computer; user requirements should be anticipated and appropriate user control options and computer responses should be provided in all cases.

COMMENT: In most applications, a user should be able to interrupt or terminate any transaction once it has been initiated. Users will sometimes change their minds and decide that an initiated transaction is not what was wanted after all. Software logic should be "bulletproofed" to anticipate every possible action by a user, no matter how improbable, providing an appropriate computer response for random (or even malicious) inputs as well as for correct entries and likely errors. In particular, a dialogue should never reach a dead end with no further action available to the user. If a user makes an entry inappropriate to current processing logic, the computer should simply display an advisory message that the input cannot be recognized and indicate the available options as to what can be done next. (A,E)

2.2.2-14 User-Paced Sequence Control (Tier 2 - General)

Users should be allowed to pace control entries, rather than requiring users to keep pace with computer processing or external events.

COMMENT: User pacing will let control entries be made in accord with a user's current needs, attention span, and time available. (A,E)

2.2.2-15 Control by Explicit User Action (Tier 2 - General)
Users should be allowed to control transaction sequencing by explicit action; computer processing should be deferred until an explicit user action has been taken.
COMMENT: For example, when a user is keying an extended data entry, the computer should not interrupt the user to require immediate correction of any entry error, but instead should wait for the user's ENTER action. Also, when a user is composing a command to accomplish some transaction, the computer should not interrupt the user by responding as soon as it recognizes a partial entry but instead should wait for the user's ENTER action. In automated process control applications, emergency conditions may take precedence over current user transactions, and a computer-generated warning might interrupt user actions. In routine, repetitive data entry transactions, successful completion of one entry may lead automatically to initiation of the next. If the computer interrupts a user, it pre-empts the initiative in sequence control, in effect forcing the user into an error correction (or some other) sequence conceived by the interface designer, and not necessarily a sequence that would be chosen by the user. In general, computer detection of problems with current user entries can be negotiated at the conclusion of a transaction, before it is implemented. Nondisruptive alarms or advisory messages can be displayed to report computer monitoring of external events so that the user can choose when to deal with them. (E)

2.2.2-16 Control Matched to User Skill (Tier 2 - General)
The means of sequence control should be compatible with user skills, permitting simple step-by-step actions by beginners, but permitting more complex command entry by experienced users.
COMMENT: Most systems will have users with varying levels of experience. Any particular user may become more expert with increasing experience, or perhaps less expert after a long period of disuse. Accommodating users of varying experise requires a mixture of different dialogue types, with some means for smooth transition from one mode of dialogue to another. For instance, as a user comes to learn menu codes, s/he might be allowed to enter those codes without necessarily displaying a menu, i.e., those codes might also serve as commands. (E)

2.2.2-17 Compatibility with User Expectations (Tier 2 - General)
The results of any control entry should be compatible with user expectations, so that a change in the state or value of a controlled element is displayed in an expected or natural form.
COMMENT: For example, a control entry of NEXT PAGE should show the next frame of a current display, and should not jump off to some other internally defined "page" in the computer's data base. When the completion of a control entry is indicated by a special function key, that key should be labeled ENTER (or some functionally equivalent word) and should result in computer acknowledgment of the entry. (D,E)

2.2.2-18 Distinctive Display of Control Information (Tier 2 - General)
All displays should be designed so that features relevant to sequence control are distinctive in position and/or format.
COMMENT: Relevant features include displayed options, command entry areas, prompts, advisory messages, and other displayed items (titles, time signals, etc.) whose changes signal the results of control entries. (A,E)

2.2.2-19 Highlighting Selected Data (Tier 2 - General)
When a user is performing an operation on some selected display item, that item should be highlighted.
COMMENT: This practice will help avoid error, if a user has misunderstood or perhaps forgotten which item was selected. (A,E)

2.2.2-20 Display of Operational Mode (Tier 2 - General)
When context for sequence control is established in terms of a defined operational mode, users should be reminded of the current mode and other pertinent information.
COMMENT: For example, if text is displayed in an editing mode, then a caption might indicate EDIT as well as the name of the displayed text; if a DELETE mode is selected for text editing, then some further displayed signal should be provided. (A,E)

2.2.2-21 Upper and Lower Case Equivalent (Tier 2 - General)
For interpreting user-composed control entries, upper and lower case letters should be treated as

equivalent.
COMMENT: Users find it difficult to remember whether upper or lower case letters are required, and so the interface design should not try to make such a distinction. (E)

2.2.2-22 Log-on (Tier 3 - Design Details)
When users must log-on to a system, log-on should be a separate procedure that is completed before a user may select any operational options.
COMMENT: (E)

2.2.2-23 Log-on Frame (Tier 3 - Design Details)
The log-on frame should appear as soon as possible on the display with no additional user involvement.
COMMENT: (A)

2.2.2-24 Log-on Delays (Tier 3 - Design Details)
Log-on delays should be accompanied by an advisory message to tell the user status and when the system will become available.
COMMENT: (A)

2.2.2-25 Immediate Start of Productive Work (Tier 3 - Design Details)
After completing the sign-on process, the user should be able to start productive work immediately.
COMMENT: (A)

2.2.2-26 Log-off (Tier 3 - Design Details)
If there are pending actions and the user requests a log-off, the system should inform the user that these actions will be lost.
COMMENT: (A)

2.2.2-27 Saving Open Files in Automatic Log-off (Tier 3 - Design Details)
Where possible, in the event of automatic log-off, open files should be saved to some defined file name.
COMMENT: For example by concatenation of Users Name + Date. (E)

2.2.2-28 Automatic Logoff (Tier 3 - Design Details)
Interactive timesharing systems should allow some specified time between keyboard actions before automatic log-off unless a longer period is requested by the user.
COMMENT: (A)

2.2.2-29 Audible Signal for Automatic Logoff (Tier 3 - Design Details)
An audible signal should be presented at specified intervals prior to automatic log-off.
COMMENT: (A)

2.2.2-30 Appropriate Computer Response Time (Tier 3 - Design Details)
The speed of computer response to user control entries should be appropriate to the transaction involved.
COMMENT: In general, the response should be faster for those transactions perceived by a user to be simple. For example, computer response to a likely control entry, such as NEXT PAGE, should be within 0.5-1.0 second; response to other simple entries should be within 2.0 seconds; error messages should be displayed within 2-4 seconds. (E)

2.2.2-31 Defining Context for Users (Tier 3 - Design Details)
The sequence control software should be designed to maintain context for the user throughout the series of transactions comprising a task.
COMMENT: Where appropriate, the results of previous entries affecting present actions should be displayed, and currently available options indicated. (A,E)

2.2.2-32 Context Established by Prior Entries (Tier 3 - Design Details)
The sequence control software should interpret current control actions in the context of previous entries and not require users to re-enter data.
COMMENT: For example, if data have just been stored in a named file, users should be able to request a printout of that file without having to re-enter its name. If transactions involving contextual interpretation would have destructive effects (e.g., data deletion), then the interpreted command should be displayed first for user confirmation. (A,E)

2.2.2-33 Displayed Context (Tier 3 - Design Details)
If the consequences of a control entry will differ depending upon context established by a prior action, then some continuous indication of current context should be displayed for reference by the user.
COMMENT: For example, if activating a DELETE key establishes a mode, so that subsequent selection of a PAGE key will erase a page of data rather than simply advancing to display the next page, then some indication of that established DELETE mode should be displayed to the user. (A,E)

2.2.2-34 Record of Prior Entries (Tier 3 - Design Details)
Users should be permitted to request a summary of the results of prior entries to help determine present status.
COMMENT: Summarizing prior entries will be particularly helpful in tasks where transaction sequences are variable, where a user must know what was done in order to decide what to do next. Summarizing prior entries may not be needed for routine transactions if each step identifies its predecessors explicitly, although even in those circumstances a user may be distracted and at least momentarily become confused. (A,E)

2.2.2-35 Display of Control Parameters (Tier 3 - Design Details)
Users should be allowed to review any control parameter(s) that is currently operative.
COMMENT: A capability for parameter review is helpful even when a user selects all parameters personally. Users will sometimes be forgetful, or may become confused, particularly if their activities are interrupted for any reason. (A,E)

2.2.2-36 Indicating Control Lockout (Tier 3 - Design Details)
If control entries must be delayed pending computer processing of prior entries, then the delay should be indicated to the user.
COMMENT: For example, if processing delay results in control lockout, that could be signaled by disappearance of the cursor from the display, or perhaps by a notable change in the shape of the cursor, accompanied by an auditory signal. In some applications it may be desirable to ensure that the keyboard and other control devices are automatically locked until the user can begin a new transaction. This would be true when processing the current transaction will affect the results of subsequent user actions. In other applications, it may be possible to permit users to continue work while previous transactions are still being processed. Deletion or change of a displayed cursor in itself may not be a sufficient indicator of keyboard lockout. Auditory signals will be particularly helpful to a skilled touch-typist, who may not look at the display when transcribing data entries. Following control lockout, computer readiness to accept further entries should be indicated to the user. (E)

2.2.2-37 Interrupt to End Control Lockout (Tier 3 - Design Details)
In situations where control lockout does occur, an auxiliary means of control entry should be provided , such as a special function key, to abort a transaction causing extended lockout.
COMMENT: Such an interrupt capability will be especially helpful if a user recognizes that an error has been made and wants to stop an unneeded transaction, acting like an UNDO command. (E)

2.2.2-38 Display Average System Response Time (Tier 3 - Design Details)
Average system response time, if affected by the number of on-line users, should be displayed at time of log-on.
COMMENT: This message should not be in code but should contain specific information concerning current response time and the periods when response time is relatively quick (e.g., "Average response to simple commands is 10 to 15 seconds (s); system response time is usually 1 to 2 seconds between 1100 and 1200 and after 1600

hours"). (A)

2.2.2-39 Control by Simultaneous Users (Tier 3 - Design Details)
When several users must interact with the system simultaneously, control entries by one user should not interfere with those of another.
COMMENT: This requires careful interface design for applications where joint, coordinated actions must be made by a group of users. (A,E)

2.2.2-40 Flexible Design for Sequence Control (Tier 3 - Design Details)
When sequence control requirements may change, which is often the case, some means for the user (or a system administrator) to make necessary changes to control functions should be provided.
COMMENT: Sequence control functions that may need to be changed include those represented in these guidelines, namely, the types of dialogue that are provided, procedures for transaction selection and interrupt, methods for context definition and error management, and alarm control. (E)

2.2.2-41 Hierarchical Levels (Tier 3 - Design Details)
When hierarchical levels are used control a process or sequence, the number of levels should be minimized.
COMMENT: (A)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.3 Transaction Selection

2.2.3-1 Organization and Labeling of Listed Options (Tier 2 - Sequencing and Grouping)
The general options list should show control entry options grouped,labeled and ordered in terms of their logical function, frequency and criticality of use, following the general guidelines for menu design.
COMMENT: (A,E)

2.2.3-2 Provide Further Available Action (Tier 2 - Consistency)
Transactions should never leave the user without further available action and should provide next steps or alternatives.
COMMENT: For example, "Continue", "Abort", "Go to Main directory", etc. (A)

2.2.3-3 Consistent CONTINUE Option (Tier 2 - Consistency)
At any step in a defined transaction sequence, if there is only a single appropriate next step, then a consistent control option to continue to the next transaction should be provided .
COMMENT: For example: CONTINUE or NEXT or STEP might be suitable names for this option. If data entry is involved, then Users should be required to take an explicit ENTER action to signal data entry, rather than simply selecting CONTINUE. (A,E)

2.2.3-4 Displaying Option Codes (Tier 2 - Consistency)
When users must select options by code entry, the code associated with each option should be displayed in a consistent and distinctive manner.
COMMENT: For example, in many applications an equal sign can be used to designate option codes, such as N = Next page, P = Prev page, etc. (E)

2.2.3-5 Consistent Order in Entry Stacking (Tier 2 - Consistency)
For control entry stacking, entries should be required to be in the same order as they would normally be made in a succession of separate control entry actions.
COMMENT: (E)

2.2.3-6 Standard Delimiter in Entry Stacking (Tier 2 - Consistency)
If punctuation other than spaces is needed to separate entries in a stacked control entry, a single standard symbol should be used for that purpose.
COMMENT: For example: A slash (/) may be a good choice. Whatever symbol is adopted as a delimiter for control entries should preferably be the same as any delimiter that might be used when making data entries. Note that even when a standard symbol is consistently used to punctuate stacked entries, entry will be slower and less accurate than if only spaces are used for punctuation. (A,E)

2.2.3-7 Task-Oriented Wording for Options (Tier 2 - Meaningfulness)
Task-oriented wording for control options should be used to reflect the user's view of the current transaction.
COMMENT: (A,E)

2.2.3-8 Computer processing constraints (Tier 2 - Task Compatibility)
The sequence of transaction selection should generally be dictated by user choices and not by internal computer processing constraints.
COMMENT: (C)

2.2.3-9 Indicating Appropriate Control Options (Tier 2 - Task Compatibility)
Users should be provided a list of the control options that are specifically appropriate for any transaction.

COMMENT: Transaction-specific options might be listed in the working display if there is space for them. Otherwise, they might be displayed in an overlay window at user request. Control options that are available for almost any transaction should be treated as implicit options, which need not be included in a list of transaction-specific options unless they are particularly appropriate to the current transaction. (A,E)

2.2.3-10 Prompting Control Entries (Tier 2 - Task Compatibility)

Users should be provided with whatever information may be needed to guide control entries at any point in a transaction sequence, by incorporating prompts in a display and/or by providing prompts in response to requests for HELP.

COMMENT: (A,E)

2.2.3-11 User-Specified Transaction Timing (Tier 2 - Task Compatibility)

When appropriate to task requirements, users should be allowed to specify transaction timing.

COMMENT: For example, when a requested transaction should start or should be completed, or the periodic scheduling of repeated transactions. In many applications users will wish specified transactions performed as quickly as possible. In some applications, however, users may have good reasons to delay initiation (or completion) of transactions. For example, a user might wish to specify that a requested data analysis routine be deferred until some later hour, to ensure that interim updates to the data will be taken into account. A user might prepare a number of messages for transmittal, but specify that actual transmission be deferred until a later time. A user might wish to specify that a request for a large printout be deferred to take advantage of reduced overnight rates, but specify a printout deadline to ensure delivery by 0800 the next morning. (A,E)

2.2.3-12 Options List/Prompting (Tier 2 - Memory Load)

Information that the user needs to perform transactions should be displayed, without burdening short and long term memory.

COMMENT: (A)

2.2.3-13 Minimize Mneumonics, Codes, etc. (Tier 2 - Memory Load)

The requirement to learn mnemonics, codes, special or long sequences, and special instructions should be minimized.

COMMENT: (A)

2.2.3-14 User Control in Transaction Selection (Tier 2 - Flexibility of Use)

Users should be allowed to select transactions; computer processing constraints should not dictate sequence control.

COMMENT: For example, a user who wants to interrupt a current activity should not be required by the computer to complete some long sequence of useless transactions. When a logical sequence of transactions can be determined in advance, interface design might encourage and help a user to follow that sequence. Guidance may be desirable though constraint is not. (A,E)

2.2.3-15 General List of Control Options (Tier 2 - Flexibility of Use)

A general list of basic control options should be provided and always be available to serve as a "home base" or consistent starting point for control entries.

COMMENT: Return to this starting point can be accomplished by an OPTIONS function key, or by an explicit control option on every display, or by a generally available implicit option. Such a capability may be helpful even when all dialogue is user-initiated. It might be the general menu for a menu selection dialogue, or might be a standard starting point for composing command entries. However a user should not be required to return to a display of general options in order to make a control entry. If a user remembers option codes or commands, ideally those control entries could be made from any point in a transaction sequence. (A,E)

2.2.3-16 Stacked Control Entries (Tier 2 - Flexibility of Use)

Users should be allowed to key a sequence of commands or option codes as a single "stacked" control entry.

COMMENT. In particular, users should be allowed to enter stacked entries from any menu so that an experienced user can make any specific control entry without having to view subsequent menus. Control entry stacking may be helpful when a user is being prompted to enter a series of parameter values, and knows what several succeeding prompts will request and what values to enter. Control entry stacking will permit a transition from simple step-by-step control entry by novice users, as in menu selection and question-and-answer dialogues, to the entry of extended command-language statements by experienced users; entry stacking is especially helpful in time-shared systems where computer response to any user entry may be slow. (A,E)

2.2.3-17 User Definition of Macro Commands (Tier 2 - Flexibility of Use)
Users should be allowed to assign a single name to a defined series of control entries, and then to use that named "macro" for subsequent command entry.
COMMENT: In this way users can make frequently required but complicated tasks easier to accomplish, when the interface designer has failed to anticipate a particular need. (A,E)

2.2.3-18 Only Available Options Offered (Tier 2 - General)
Only control options that are actually available for the current transaction should be offered to users.
COMMENT: If certain options are not yet implemented, as during system development, or are not available for any other reason, those should be annotated on the display. (A,E)

2.2.3-19 Indicating Control Defaults (Tier 2 - General)
When control is accomplished by keyed command or option code entries and a default is defined for a null control entry, the default should be indicated to the user.
COMMENT: The point here is that when defaults are defined, and when t... m one transaction to another, then users should be informed of the current default logic. For example, "Pre... ER to see more options." If a consistent default is adopted throughout interface design, that default need not be explicitly indicated for each individual transaction. Here the phrase "null control entry" refers to pressing an ENTER key without first keying a command or option code (and without any accompanying data). It does not refer to defaults for optional parameters that might accompany a valid control entry, whose values might be displayed only at user request. It is not necessary that any defaults be defined for null control entries. In such cases, the computer might simply respond "ENTER alone is not recognized here." (A,E)

2.2.3-20 Cursor Placement for Pointing at Options (Tier 3 - Design Details)
When users will select among displayed options by pointing, the cursor should be placed on the first (most likely) option at display generation.
COMMENT: (E)

2.2.3-21 Cursor Placement for Keyed Entry of Options (Tier 3 - Design Details)
When users must select options by keyed entry of a corresponding code, the cursor should be placed in the control entry area at display generation.
COMMENT: (E)

2.2.3-22 Abbreviation in Entry Stacking (Tier 3 - Design Details)
For control entry stacking, command names, their abbreviations, or option codes should be accepted just as if those control entries had been made separately.
COMMENT: In some applications, it might prove helpful if the computer were to display its interpretation of a stacked entry for user review and confirmation. (A,E)

2.2.3-23 Minimal Punctuation of Stacked Entries (Tier 3 - Design Details)
Users should be allowed to stack control entries without any punctuation other than spaces between words or option codes.
COMMENT: (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.4 Transaction Interrupts

2.2.4-1 User Interruption of Transactions (Tier 2 - Flexibility of Use)
Flexibility in sequence control should be provided by allowing a user to interrupt or cancel a current transaction, in ways appropriate to task requirements.
COMMENT: (A,E)

2.2.4-2 Distinctive Interrupt Options (Tier 2 - General)
If different kinds of user interrupt are provided, each interrupt function should be designed as a separate control option with a distinct name.
COMMENT: As a negative example, it would not be good to have a single INTERRUPT key which has different effects depending upon whether it is pushed once or twice; users would be confused by such an expedient and uncertain about what action has been taken and its consequences. (A,E)

2.2.4-3 User Transaction Interrupts (Tier 2 - General)
User interrupts and aborts should not modify or remove stored or entered data.
COMMENT: (A)

2.2.4-4 CANCEL Option (Tier 3 - Design Details)
If appropriate to sequence control, a CANCEL option should be provided which will have the effect of erasing any changes just made by the user and restoring the current display to its previous version.
COMMENT: For example, in a sequence of related data entries, on several display frames, CANCEL might erase ("clear") data in the current frame as a convenient way to begin keying corrected data, rather than having to erase each data item individually. (A,E)

2.2.4-5 BACKUP Option (Tier 3 - Design Details)
If appropriate to sequence control, a nondestructive BACKUP option should be provided which will have the effect of returning to the display for the last previous transaction.
COMMENT: For example, in a sequence of related data entries, on several display frames, BACKUP might return to the previous frame, where data items could then be erased by CANCEL or could be edited individually. Such a BACKUP capability will prove feasible only in the software design of well-defined transaction sequences, but will prove helpful when it can be provided. (A,E)

2.2.4-6 REVIEW Option (Tier 3 - Design Details)
If appropriate to sequence control, a nondestructive REVIEW option should be provided which will have the effect of returning to the first display in a defined transaction sequence, permitting the user to review a sequence of entries and make necessary changes.
COMMENT: For example, in a sequence of related data entries, on several display frames, REVIEW might return to the first frame, from which data could be reviewed and edited as needed throughout the sequence of frames. REVIEW is an extension of the BACKUP capability, and is useful only in well-defined transaction sequences such as step-by-step data entry in a question-and-answer dialogue. (A,E)

2.2.4-7 RESTART Option (Tier 3 - Design Details)
If appropriate to sequence control, a RESTART option should be provided which will have the effect of canceling any entries that may have been made in a defined transaction sequence and returning to the beginning of the sequence.
COMMENT: For example, in a sequence of related data entries, on several display frames, RESTART might erase all data entries in the sequence and return to the first frame. When data entries or changes will be nullified by a RESTART action, users should be required to CONFIRM the RESTART. A RESTART action combines the functions of REVIEW and CANCEL, and is relevant only to well-defined transaction sequences. (A,E)

2.2.4-8 END Option (Tier 3 - Design Details)

If appropriate to sequence control, an END option should be provided which will have the effect of concluding a repetitive transaction sequence.
COMMENT: For example, in a repetitive sequence of data entries, where completing one transaction cycles automatically to begin the next, END might break the cycle and permit the user to select other transactions. (A,E)

2.2.4-9 PAUSE and CONTINUE Options (Tier 3 - Design Details)
If appropriate to sequence control, PAUSE and CONTINUE options should be provided which will have the effect of interrupting and later resuming a transaction sequence without any change to data entries or control logic for the interrupted transaction.
COMMENT: For example, a user might wish to interrupt a current task to read an incoming message. Or, in the interests of data protection, as a "security pause", a user might wish to blank a current display to prevent its being read by some casual visitor. (A,E)

2.2.4-10 Indicating PAUSE Status (Tier 3 - Design Details)
If a PAUSE option is provided, some indication of the PAUSE status should be displayed whenever that option is selected by a user, and prompt the CONTINUE action that will permit resumption of the interrupted transaction.
COMMENT: (A,E)

2.2.4-11 SUSPEND Option (Tier 3 - Design Details)
If appropriate to sequence control, a SUSPEND option should be provided which will have the effect of preserving current transaction status when a user leaves the system, and permitting resumption at that point when the user later logs back onto the system.
COMMENT: In the interests of data protection, a SUSPEND option might require special user identification procedures at subsequent log-on, to prevent unauthorized access to suspended transactions. (A,E)

2.2.4-12 Indicating SUSPEND Status (Tier 3 - Design Details)
If a SUSPEND option is provided, some indication of the SUSPEND status should be displayed whenever that option is selected by a user, and at subsequent log-on prompt the user in those procedures that will permit resumption of the suspended transaction.
COMMENT: (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.5 Transaction Dialogue
2.2.5.1 Command Language

2.2.5.1-1 Layered Command Language (Tier 2 - Sequencing and Grouping)

A command language should be designed so that its functions are organized in groups (or "layers") for ease in learning and use.

COMMENT: For example, a user should be able to display the next of a set of received messages with some simple command such as READ NEXT, although a complete command to retrieve any message might include potential specification of which message, from which message list, in which format, to which output device. The fundamental layer of the language should be the easiest, allowing use of the system by people with little training and/or limited needs. Successive layers of the command language can then increase in complexity for users with greater skills. In effect, simple versions of commands can be recognized by defaulting all of the optional parameters. Control forms might be used to display default options for complicated commands. (A,C,E)

2.2.5.1-2 General List of Commands (Tier 2 - Consistency)

A general list of basic commands, with appropriate command format guidance, should be provided to serve as a "home base" or consistent starting point for composing command entries.

COMMENT: Such a general list of commands might provide more comprehensive user guidance than is possible when prompting command entry from a working display. (A,E)

2.2.5.1-3 Standard Display Area for Command Entry (Tier 2 - Consistency)

When command language is used for sequence control, a command entry area in a consistent location should be provided on every display, preferably at the bottom.

COMMENT: Adjacent to the command entry area there should be a display window reserved for prompting entries, for recapitulation of command sequences (with scrolling to permit extended review), and to mediate question-and-answer dialogue sequences (i.e., prompts and responses to prompts). (A,C,E)

2.2.5.1-4 Consistent Wording of Commands (Tier 2 - Consistency)

All words in a command language, and their abbreviations, should be consistent in meaning from one transaction to another, and from one task to another.

COMMENT: As a negative example, EDIT should not be used in one place, MODIFY in another, UPDATE in a third, all referring to the same kind of action. Commands should be congruent with one another, following natural language patterns; if one command is UP, its complement should be DOWN; other natural complements include RIGHT-LEFT, FORWARD-BACK, IN-OUT, PUSH-PULL, RAISE-LOWER, etc. (A,C,E)

2.2.5.1-5 Standard Techniques for Command Editing (Tier 2 - Consistency)

Users should be allowed to edit erroneous commands with the same techniques that are employed to edit data entries.

COMMENT: Consistent editing techniques will speed learning and reduce errors. (A,C,E)

2.2.5.1-6 Familiar Wording (Tier 2 - Meaningfulness)

Words for a command language should reflect the user's point of view, and correspond to the user's operational language.

COMMENT: For example, to transfer a file, the assigned command should be something like TRANSFER, MOVE, or SEND, and not some jargon term like PIP. (C,E)

2.2.5.1-7 Meaningful Command Names (Tier 2 - Meaningfulness)

Command names should be meaningful, and specifically describe the functions being implemented.

COMMENT: Functions should not be arbitrarily assigned letters as command names, e.g., the letter D preceded by a special key such as CONTROL might be a LOG-OFF command. In such cases, when command names are not real words that describe system functions, users will have difficulty learning to use the system. If users are permitted to enter abbreviations rather than complete command names, users should be able to determine the command name represented by the abbreviation. Otherwise, a short abbreviation may seem an arbitrary code. For instance, a prompt might read "To DELETE a record, enter D" rather than "To erase a record, enter D." (E)

2.2.5.1-8 Functional Wording (Tier 2 - Meaningfulness)
A command language should be designed so that a user can enter commands in terms of functions desired, without concern for internal computer data processing, storage and retrieval mechanisms.
COMMENT: For example, users should be able to request display of a data file by name alone, without any further specification such as that file's location in computer storage. Where file names are not unique identifiers, the computer should be programmed to determine whatever further context is necessary for identification. Or perhaps the computer should ask the user to designate a "directory" defining the subset of files of current interest. (E)

2.2.5.1-9 Guidance Information (Tier 2 - Memory Load)
Users should be able to request guidance information necessary to determine required parameters or options in a command entry, or to determine available options for an appropriate command.
COMMENT: (C)

2.2.5.1-10 Command Language (Tier 1 - Use)
Command-language dialogues should be used for tasks involving a wide range of control entries, where users may be highly trained and will use the system frequently.
COMMENT: Command language should also be employed for tasks where control entries may be mixed with data entries in arbitrary sequence. (E)

2.2.5.1-11 Minimal Punctuation (Tier 2 - Flexibility of Use)
Users should be allowed to enter commands without any punctuation other than the spaces between words.
COMMENT: Command entry will be faster and more accurate when spaces are used rather than any other kind of punctuation. (A,C,E)

2.2.5.1-12 Abbreviation of Commands (Tier 2 - Flexibility of Use)
Users should be allowed to abbreviate commands.
COMMENT: For example, if a "P" uniquely identifies a print command (i.e., no other commands start with "P") then a user should be able to enter PRINT, or PR, or P, or any other truncation to initiate printing. As a corollary, misspelled command entries should also be tolerated, within the limits of computer recognition. The computer can interrogate a user as necessary to resolve ambiguous entries. (A,C,E)

2.2.5.1-13 Recognizing Command Synonyms (Tier 2 - Flexibility of Use)
The computer should recognize a variety of synonyms for each word defined in the command language.
COMMENT: For example, the words "mail", "post", and "transmit" might be accepted synonyms for the command "send". What synonyms are frequently employed can be determined by analysis of user error records in prototype testing. Infrequent users may need to relearn command names each time they use the system. For those users, time spent learning commands is not worthwhile considering that they will seldom use those commands. (E)

2.2.5.1-14 User-Assigned Command Names (Tier 2 - Flexibility of Use)
A command language should have flexibility to permit a user to assign personal names to files, frequently used commands, etc.
COMMENT: Frequently used commands should be easy for a user to enter. For users who must move back and forth between different systems with differently defined command languages, some flexibility in command naming will permit those users to establish their own consistent terminology. Before users can be allowed to adopt their own assigned command names, the computer must check those names to prevent duplication. A potential risk of increased flexibility is increased confusion, if users forget what names they have specified for commands and data files. The computer should maintain a current index of command and file names for on-line user reference. (E)

2.2.5.1-15 Command Stacking (Tier 2 - Flexibility of Use)
Users should be allowed to key a series of commands at one time ("command stacking").
COMMENT: This practice will allow experienced users to by-pass prompting sequences. Command stacking will

reduce the extended memory load on users. Command stacking may also be much faster than separate entry of commands, in systems where input/output processing is overloaded by multiple users. (E)

2.2.5.1-16 User Definition of Macro Commands (Tier 2 - Flexibility of Use)
Users should be allowed to assign a single name to a defined series of commands and then use that named "macro" for subsequent command entry.
COMMENT: In this way users can make a frequent but complicated task easier to accomplish, when the interface designer has failed to anticipate that particular need. (C,E)

2.2.5.1-17 User-Requested Prompts (Tier 2 - Flexibility of Use)
Users should be allowed to request computer-generated prompts as necessary to determine required parameters in a command entry, or to determine available options for an appropriate next command.
COMMENT: For example, using a HELP function key, or perhaps simply keying a question mark in the command entry area, would be satisfactory methods to request prompting. (C,E)

2.2.5.1-18 Replacing Erroneous Commands (Tier 2 - Error Handling)
If a user makes a command entry error, after the error message has been displayed the user should be allowed to enter a new command.
COMMENT: A user should not be forced to correct and complete an erroneous command. In considering a command entry error message, a user may decide that the wrong command was chosen in the first place, and wish to substitute another command instead. (E)

2.2.5.1-19 Correcting Command Entry Errors (Tier 2 - Error Handling)
If a command entry is not recognized, the user should be allowed to revise the command rather than rejecting the command outright.
COMMENT: Misstated commands should not simply be rejected. Instead, software logic should guide users toward proper command formulation. (A,E)

2.2.5.1-20 Reviewing Destructive Commands (Tier 2 - Error Handling)
If a command entry may have disruptive consequences, the user should be required to review and confirm a displayed interpretation of the command before it is executed.
COMMENT: (A,C,E)

2.2.5.1-21 Distinctive Meaning for Commands (Tier 2 - General)
Words in a command language should be distinctive from one another, and emphasize significant differences in function.
COMMENT: In general, commands should not have semantically similar names, such as SUM and COUNT, or ERASE and DELETE, or QUIT and EXIT. (C,E)

2.2.5.1-22 Interpreting Misspelled Commands (Tier 2 - General)
Where the set of potential command entries is well defined, the computer should recognize and execute common misspellings of commands, rather than requiring re-entry.
COMMENT: (E)

2.2.5.1-23 User Definition of Macro Commands (Tier 2 - General)
The programming should not accept a user designated macro name that is the same as an existing command name.
COMMENT: (C)

2.2.5.1-24 Distinctive Spelling for Commands (Tier 3 - Design Details)
Words and abbreviations in a command language should have distinctive spelling, so that simple spelling errors will be recognized as such rather than invoking a different command.
COMMENT: As a negative example, if one command name is DELETE, abbreviated DEL, then another command should not be named DELIVER with an abbreviation of DELR. Instead, ERASE could be substituted for DELETE, or SEND for DELIVER. When a system has only a few commands, all of those commands should be distinctive.

When a system has many commands, it may not be possible to ensure that each is distinctive. In that case, it is important to ensure that any commands which are destructive or time-consuming are made distinctive. (E)

2.2.5.1-25 Recognizing Alternative Syntax (Tier 3 - Design Details)
The computer should recognize probable alternative forms of command syntax.
COMMENT: For example, the computer might accept alternative methods of specifying a document, such as "memo 3", "memo3", or simply "3"; users might be allowed to use different punctuation and/or to list command modifiers in different orders. (E)

2.2.5.1-26 Standard Delimiter (Tier 3 - Design Details)
If command punctuation other than spaces is required, a single standard delimiter symbol should be used for that purpose.
COMMENT: Command punctuation other than spaces may be required as a delimiter to distinguish optional parameters, or to separate entries in a stacked command. For example, a slash (/) might be a good choice. Whatever symbol is adopted as a delimiter for command entries should preferably be the same as any delimiter that might be used when making data entries. Note, however, that even if some single delimiter is specified for consistent use in command punctuation, command entry will be slower and less accurate than if no delimiter at all were required. (E)

2.2.5.1-27 Ignoring Blanks in Command Entry (Tier 3 - Design Details)
Single and multiple blanks between words should be treated as equivalent when processing command entries.
COMMENT: People cannot readily distinguish one blank space from several, and so the computer should not impose such a distinction. (A,E)

2.2.5.1-28 Graphic Examples in Guidance Information (Tier 3 - Design Details)
Where possible, guidance information should be accompanied with graphic examples of command content and syntax.
COMMENT: (C)

2.2.5.2-1 Direct Manipulation (Tier 1 - Use)
A capability for direct manipulation of displayed objects should be provided as a means of sequence control.
COMMENT: For example, rather than compose a command or select a function key to file a document, a user might move a displayed icon representing the document to superimpose it on another icon representing a file. In sequence control by direct manipulation, the techniques for selecting and moving displayed objects would be similar to those described in guidelines for graphic data entry. An extension of this idea is the use of "embedded menus" in which various items within a working display are highlighted in some way to indicate that they can be selected to obtain further information. (D,E)

2.2.5.2-2 When to Use Direct Manipulation (Tier 1 - Use)
Direct manipulation should be used primarily in tasks with actions and objects that lend themselves to pictographic representation, and in which the actions and objects need not be modified for the successful interpretation of the command by the system.
COMMENT: (D)

2.2.5.2-3 Fast Computer Response with Direct Manipulation (Tier 1 - Use)
Direct manipulation should be used when the computer response is relatively fast.
COMMENT: (D)

2.2.5.2-4 Supplementary Verbal Labels
(Tier 2 - Meaningfulness)
If icons are used to represent control actions in menus, a verbal label should be displayed with each icon to help assure that its intended meaning will be understood.
COMMENT: A redundant verbal label might help make the meaning clear to a user who is uncertain just what a displayed icon means. (C,E)

2.2.5.2-5 Highlighting the Selected Item (Tier 2 - Feedback)
Selection of an icon, menu, or application-specific capability from a function area should be acknowledged by highlighting the selected item.
COMMENT: (D)

2.2.5.2-6 Feedback for Manipulation of an Icon (Tier 2 - Feedback)
If the completion of the action commanded by manipulation of an icon has a result that is visible to the user, feedback should be communicated by the completion of the commanded action.
COMMENT: If the completion of the command has no visible result, feedback should be communicated by a message. (D)

2.2.5.2-7 Commands that Cannot be Completed (Tier 2 - Feedback)
The system should acknowledge a command that cannot be completed by a message indicating non-completion of the command and an appropriate error message.
COMMENT: (D)

2.2.5.2-8 Graphic Display of Control Context (Tier 2 - General)
Graphic means for displaying to users the context of current control actions should be provided.
COMMENT: For example, a graphic representation of the currently selected values of functions, elements and attributes affecting control actions might help reduce user errors in sequence control. Graphic techniques might be used to display the scope of a proposed control action, such as outlining a passage of text (or other group of display elements) currently selected for deletion. (E)

2.2.5.2-9 Graphic Display of Control Prompting (Tier 2 - General)

Graphic means should be provided for displaying to users prompting aids and other guidance pertaining to current control actions.

COMMENT: For example, a guidance display providing a graphic representation of keypad layout with notes explaining the various key functions might help a novice user to learn the control options available via function keys. A graphic representation of logical combinations specified in query formulation might help reduce errors in the use of query language. (E)

2.2.5.2-10 Selecting and Dragging (Tier 2 - General)

The system should use two principal direct manipulation actions: selecting and dragging.

COMMENT: Selecting should involve two steps: (1) indicating the object or action to be selected (e.g., moving a pointing cursor or other follower to an icon or function area) and (2) indicating to the system that the icon and its associated function are required through the performance of a specific, well-defined selection action by the user (e.g., "clicking" a cursor control device button). Dragging should involve moving a selected icon or the cursor. Moving the cursor or dragging an icon can be accomplished by any of several cursor manipulation devices. (D)

2.2.5.2-11 Consequences of Dragging (Tier 2 - General)

The consequences of dragging should be contingent on the nature of the object that is dragged and where the object is placed at the termination of dragging.

COMMENT: For example, dragging a data file icon to a 'statistics' icon might cause the data to be analyzed; Dragging the file icon to a disk icon might copy the file into that disk; Dragging an icon to an unoccupied portion of the screen might simply move the icon and has no effect on the object. (D)

2.2.5.2-12 Other Primary Features of Direct Manipulation Dialogue (Tier 2 - General)

In addition to using icons to represent objects and actions, other primary features of the direct manipulation dialogue should include (1) windows for containing the data files, (2) menus for additional objects and actions that are not easily represented by pictographic icons.

COMMENT: (D)

2.2.5.2-13 Opening an Icon (Tier 3 - Design Details)

A user should be able to open an icon with a single unique action.

COMMENT: E.g., pressing on a specific button of a cursor control device or a double click on the cursor control device button. Note: A "double click" is defined by two clicks within 700 ms of each other.) (D)

2.2.5.2-14 Size of Icons (Tier 3 - Design Details)

Items on the screen that are selectable should be a minimum of 5 mm on a side and separated by at least 3 mm.

COMMENT: (D)

2.2.5.3-1 Form Filling for Data Entry (Tier 1 - Use)
Form filling should be used for tasks where some flexibility in data entry is needed, such as the inclusion of optional as well as required items, and/or where computer response may be slow.
COMMENT: (C,E)

2.2.5.3-2 Form Filling for Control Entry (Tier 1 - Use)
Form filling should be provided as an aid for composing complex control entries.
COMMENT: For example, for a complex data retrieval request, a displayed form might indicate the various control parameters that could be specified. For a print request, a displayed form might help a user invoke the various format controls that are available. (C,E)

2.2.5.3-3 Defaults for Control Entry (Tier 1 - Use)
Form filling should be used as a means of displaying default values for the parameters in complex control entries.
COMMENT: Default parameters permit users to compose potentially complicated control entries by relatively simple actions. If defaults have been defined, they should be indicated to users. A displayed form permits a user to review (and confirm or change) default control values, just as a user might review displayed defaults for data entry. When only a few control parameters are involved, it may be feasible simply to prompt users with guidance messages rather than by displaying a control form. (A,E)

2.2.5.3-4 Consistent Format for Control Forms (Tier 2 - Consistency)
Forms for control entry should be consistent in format; their design should generally conform to guidelines for the design of data entry forms.
COMMENT: (A,C,E)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.5 Transaction Dialogue
2.2.5.4 Function Keys

2.2.5.4-1 Function Keys for Critical Control Entries (Tier 1 - Use)
Function keys should be provided for tasks requiring only a limited number of control entries, or for use in conjunction with other dialogue types as a ready means of accomplishing critical entries that must be made quickly without syntax error.
COMMENT: (A,D,E)

2.2.5.4-2 Function Keys for Frequent Control Entries (Tier 1 - Use)
Function keys should be provided for frequently required control entries.
COMMENT: For example, commonly used function keys include ENTER, PRINT, NEXT PAGE, PREV PAGE, OPTIONS, etc. When frequently used options are always available via function keys, they need not be included in displayed menus. (A,D,E)

2.2.5.4-3 Function Keys for Interim Control Entries (Tier 1 - Use)
Function keys should be provided for interim control entries, i.e., for control actions taken before the completion of a transaction.
COMMENT: For example, function keys will aid such interim actions as DITTO, CONFIRM, and requests for PRINT, or HELP, and also interrupts such as BACKUP, CANCEL, etc. Interim control refers to an action taken by a user while working with displayed data, e.g., while still keying data entries or changes, etc. Function keys will aid interim control entries partly because those entries may be frequent. (E)

2.2.5.4-4 Distinctive Location (Tier 2 - Sequencing and Grouping)
Function keys should be grouped in distinctive locations on the keyboard to facilitate their learning and use; frequently used function keys should be placed in the most convenient locations.
COMMENT: (A,E)

2.2.5.4-5 Layout Compatible with Use (Tier 2 - Sequencing and Grouping)
The layout of function keys should be compatible with their importance.
COMMENT: Keys for emergency functions should be given a prominent position and distinctive coding (e.g., size and/or color); physical protection should be provided for keys with potentially disruptive consequences (A,E)

2.2.5.4-6 Consistent Assignment of Function Keys (Tier 2 - Consistency)
If a function is assigned to a particular key in one transaction, that function should be assigned to the same key in other transactions.
COMMENT: For example, a SAVE key should perform the same function at any point in a transaction sequence. (D,E)

2.2.5.4-7 Consistent Functions in Different Operational Modes (Tier 2 - Consistency)
When a function key performs different functions in different operational modes, equivalent or similar functions should be assigned to the same key.
COMMENT: For example, a particular key might be used to confirm data changes in one mode, confirm message transmission in another, etc. As a negative example, a key labeled RESET should not be used to save data in one mode, dump data in another, and signal task completion in a third. (A,E)

2.2.5.4-8 Consistent Logic for Double Keying (Tier 2 - Consistency)
If double (control/shift) keying is used, the logical relation between shifted and unshifted functions should be consistent from one key to another.
COMMENT: Consistency in the underlying logic for double keying will help a user to learn the functions associated with different keys. For example, one consistent logic might be that shifted and unshifted functions are opposite, so that if a particular key moves the cursor forward then that key when shifted would move the cursor

backward. Another possible logic might be that shifted and unshifted functions are related by degree, so that if a particular key deletes a single displayed character then that key when shifted would delete a word. (A,E)

2.2.5.4-9 Feedback for Function Key Activation (Tier 2 - Feedback)
When function key activation does not result in any immediately observable natural response, users should be provided with some other form of computer acknowledgment.
COMMENT: Temporary illumination of the function key will suffice, if key illumination is not used for other purposes such as indicating available options. Otherwise an advisory message should be displayed. (A,E)

2.2.5.4-10 Indicating Active Function Keys (Tier 2 - Feedback)
If some function keys are active and some are not, the current subset of active keys should be indicated in some noticeable way, suc as by brighter illumination.
COMMENT: This practice will speed user selection of function keys. (E)

2.2.5.4-11 Multiple Presses of Function Key (Tier 2 - Feedback)
Pressing a function key in a sequence of key presses unrelated to the function should result in a message asking the user if he or she meant to select that function.
COMMENT: It should not result in the action normally produced by the key until the user responds positively to the question. (D)

2.2.5.4-12 Single Key for Continuous Functions (Tier 2 - General)
When a function is continuously available, that function should be assigned to a single key.
COMMENT: (A,E)

2.2.5.4-13 Single Keying for Frequent Functions (Tier 2 - General)
Keys controlling frequently used functions should permit single key action and should not require double (control/shift) keying.
COMMENT: (A,D,E)

2.2.5.4-14 Logical Pairing of Double-Keyed Functions (Tier 2 - General)
If double (control/shift) keying is used, the functions paired on one key should be logically related.
COMMENT: For example, if a particular function key moves the cursor to the upper left corner of a display screen, then that same key when shifted might be used to move the cursor to the bottom right corner of the screen. As a negative example, a function key that moves the cursor should not be used when shifted to delete displayed data. (A,E)

2.2.5.4-15 Distinctive Labeling of Function Keys (Tier 3 - Design Details)
Each function key should be labeled informatively to designate the function it performs; labels should be sufficiently different from one another to prevent user confusion.
COMMENT: As a negative example of confusingly similar labeling, two keys should not be labeled ON and DN. (D,E)

2.2.5.4-16 Labeling Multifunction Keys (Tier 3 - Design Details)
If a key is used for more than one function, the function currently available should always be indicated to the user.
COMMENT: If a key is used for just two functions, depending upon defined operational mode, then alternate illuminated labels might be provided on the key to indicate which function is current. In those circumstances, it is preferable that only the currently available function is visible, so that the labels on a group of keys will show what can be done at any point. If key function is specific to a particular transaction, an appropriate guidance message on the user's display should be provided to indicate the current function. (E)

2.2.5.4-17 Easy Return to Base-Level Functions (Tier 3 - Design Details)
If the functions assigned to a set of keys change as a result of user selection, the user should be provided with an easy means to return to the initial, base-level functions.
COMMENT: In effect, multifunction keys can provide hierarchic levels of options much like menu selection dialogues, with the same need for rapid return to the highest-level menu. For some applications, it may be desirable

to automate the return to base-level assignment of multifunction keys, to occur immediately on completion of a transaction and/or by time-out following a period of user inaction. (A,E)

2.2.5.4-18 Disabling Unneeded Function Keys (Tier 3 - Design Details)

When function keys are not needed for any current transaction, they should be temporarily disabled under computer control; users should not be required to apply mechanical overlays for this purpose.

COMMENT: If a user selects a function key that is invalid for the current transaction, no action should result except display of an advisory message indicating what functions are available at that point. (E)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.5 Transaction Dialogue
2.2.5.5 Macros and Programmable Function Keys

2.2.5.5-1 Communication Among Users About Macros (Tier 2 - Meaningfulness)
Users who have macros and/or programmable function keys should be provided with information that aids communication.
COMMENT: For example, a list of the macro names and functions that they could make available to other users with whom they will communicate. (D)

2.2.5.5-2 Restricting User Definable Macros and Programmable Keys (Tier 2 - Task Compatibility)
The use of user definable macros and programmable function keys should be restricted.
COMMENT: The advantages may outweigh the disadvantages for some tasks (e.g., software development or modification) whereas, for other tasks (e.g., application specific software) the disadvantages may outweigh the advantages. (D)

2.2.5.5-3 User Restricted Modifying of Defined Macros (Tier 2 - General)
A user should be restricted from modifying a macro or programmable function key as defined by a different originating user.
COMMENT: (D)

2.2.5.5-4 No Duplication of Macro Names (Tier 2 - General)
Users should not be allowed to duplicate macro names; an error message should be provided to the user when he or she attempts to have a macro with a previously-used name.
COMMENT: (D)

2.2.5.5-5 Index of Macros (Tier 3 - Design Details)
Users should have access to an index of their macros and programmable function keys with their respective composition of commands.
COMMENT: (D)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.5 Transaction Dialogue
2.2.5.6 Menu Selection

2.2.5.6-1 Menu Selection (Tier 1 - Use)
Menu selection should be used for tasks that involve choice among a constrained set of alternative actions, that require little entry of arbitrary data, where users may have little training, and where computer response is relatively fast.
COMMENT: For exam... displayed menus are commonly used for function selection in text processing, in graphic interaction, and a multitude of other applications. Menus should be used when users have little or no typing skills. Menus should be used when the system has a limited keyboard. Lengthy menus are often formatted as separate displays. Task-specific menus, however, can sometimes be incorporated effectively along with data displays, to provide a short list of appropriate control options. Menu selection is, of course, a generally good means for control entry by untrained users. Menus can be used in conjunction with other dialogue types, depending upon task requirements. (B,C,D,E)

2.2.5.6-2 Menu Selection by Keyed Entry (Tier 1 - Use)
When menu selection is a secondary (occasional) means of control entry, and/or only short option lists are needed, then selection by keyed entry should be provided.
COMMENT: An option might be selected by keying an associated code which is included in the displayed menu listing. Alternatively, if menu labels can be displayed near a screen margin, then an option might be selected by pressing an adjacent multifunction key. (A,E)

2.2.5.6-3 Explicit Option Display (Tier 1 - Use)
When control entries for any particular transaction will be selected from a small set of options, those options should be displayed in a menu added to the working display, rather than requiring a user to remember them or to access a separate menu display.
COMMENT: A complete display of control options will sometimes leave little room for display of data. If an extensive menu must be added to a working data display, provide that menu as a separate window that can temporarily overlay displayed data at user request, but can then be omitted again by further user action. (A,E)

2.2.5.6-4 No One Menu Item Menus (Tier 1 - Use)
Menus should not be used in cases where there is only one menu item.
COMMENT: The use of menus for two menu items should be avoided in most cases. Methods other than menu selection for the input of one or two items are available (e.g., dialogue boxes). (D)

2.2.5.6-5 Systematic Organization of Items on Menu Bar (Tier 2 - Screen Organization)
The categories listed across the menu bar should be organized systematically.
COMMENT: For example, the categories on the left side of the menu bar might be system functions that apply across all (or most) applications. The categories on the right side of the menu bar might be those that are specific to the currently-active application. Within this general spatial layout, both the system-wide and specific categories would be ordered from left -- the category containing the most frequently used actions -- to right -- the category containing the least frequently used. (D)

2.2.5.6-6 Logical Ordering of Menu Options (Tier 2 - Sequencing and Grouping)
Menu options should be displayed in a logical order.
COMMENT: If no logical structure is apparent, then the options should be displayed in order of their expected frequency of use, with the most frequent listed first. (A,C,D,E)

2.2.5.6-7 Logical Grouping of Menu Options (Tier 2 - Sequencing and Grouping)
A menu should indicate logically related groups of options, rather than an undifferentiated string

of alternatives.
COMMENT: For example, in vertical listing of options, subordinate categories might be indented. Logical grouping of menu options will help users learn system capabilities. When logical grouping requires a trade-off against expected frequency of use, that trade-off should be resolved consistently for those functions throughout the menu structure. (A,C,E)

2.2.5.6-8 Logical Ordering of Grouped Options (Tier 2 - Sequencing and Grouping)
If menu options are grouped in logical subunits, those groups should be displayed in a logical order; if no logical structure is apparent, then display the groups in the order of their expected frequency of use.
COMMENT: (A,E)

2.2.5.6-9 Standard Area for Code Entry (Tier 2 - Consistency)
When menu selection is accomplished by code entry, a standard command entry area (window) should be provided where users enter the selected code; that entry area should be in a fixed location on all displays.
COMMENT: In a customary terminal configuration, where the display is located above the keyboard, command entry should be at the bottom of the display, in order to minimize user head/eye movement between the display and the keyboard. Experienced users might key coded menu selections in a standard area identified only by its consistent location and use. If the system is designed primarily for novice users, however, that entry area should be given an appropriate label, such as "ENTER choice here: ___." (A,C,D,E)

2.2.5.6-10 Consistent Location for Menus (Tier 2 - Consistency)
Pop-up, pull-down, and windowed menus should be displayed in consistent screen locations for all modes, transactions, and sequences.
COMMENT: (C)

2.2.5.6-11 Consistent Location of Menu Bar (Tier 2 - Consistency)
Menu bars should be placed at a consistent location in all displays.
COMMENT: For example, at the top of each display. (D)

2.2.5.6-12 Menu Options Worded as Commands (Tier 2 - Consistency)
The wording of menu options should consistently represent commands to the computer, rather than questions to the user.
COMMENT: Wording options as commands will permit logical selection by pointing, will facilitate the design of mnemonic codes for keyed entry, and will help users learn commands in systems where commands can be used to by-pass menus. Wording options as commands implies properly that the initiative in sequence control lies with the user. Wording options as questions implies initiative by the computer. For example, for option selection by pointing, a "+" (or some other special symbol) might be used consistently to distinguish a selectable control option from other displayed items, e.g., (Good) +PRINT (Bad) PRINT?. For option selection by code entry, the code for each option should be consistently indicated, e.g., (Good) p = Print (Bad) Print? (Y/N). (E)

2.2.5.6-13 Option Wording Consistent with Command Language (Tier 2 - Consistency)
If menu selection is used in conjunction with or as an alternative to command language, the wording and syntactic organization of displayed menu options should correspond consistently to defined elements and structure of the command language.
COMMENT: Where appropriate, cumulative sequences of menu selections should be displayed in a command entry area until the user signals entry of a completely composed command. (C,E)

2.2.5.6-14 Consistent Display of Menu Options (Tier 2 - Consistency)
When menus are provided in different displays, they should be designed so that option lists are consistent in wording and ordering.
COMMENT: As a negative example, if +PRINT is the last option in one menu, the same print option should not be worded +COPY at the beginning of another menu. (A,D,E)

2.2.5.6-15 Format Consistency (Tier 2 - Consistency)
Where ordering cannot be determined by the above, alphabetic ordering should be used.
COMMENT: (C)

2.2.5.6-16 Consistent Coding of Menu Options (Tier 2 - Consistency)
If letter codes are used for menu selection, those letters should be consistently used in designating options from one transaction to another.
COMMENT: Different codes for the same action will tend to confuse users and impede learning. The same code for different actions will tend to induce user errors, especially if those actions are frequently taken. However, this practice may be tolerable when selections are seldom taken, and then always taken from labeled alternatives. As a negative example, the same action should not be given different names (and hence different codes) at different places in a transaction sequence, such as f = Forward and n = Next. Another negative example, the same code should not be given to different actions q = Quit and q = Queue. (A,E)

2.2.5.6-17 Key Coded Menu Selection (Tier 2 - Consistency)
The code associated with each option should be displayed in a consistent and distinctive manner.
COMMENT: (C)

2.2.5.6-18 Consistent Design of Hierarchic Menus (Tier 2 - Consistency)
The display format and selection logic of hierarchic menus should be consistent at every level.
COMMENT: (A,E)

2.2.5.6-19 User Requested Menus: Pull-Downs and Pop-Ups (Tier 1 - Use)
User requested menus should be used whenever possible.
COMMENT: Among the types of user-requested menus, pull-down menus provide two advantages over pop-up menus: (1) the menu bar serves as a useful mnemonic aid, showing the user the command categories available in the menu, and (2) gaining visual access to the menu items within a category, selecting the item, and removing the menu can be accomplished with a minimal number of actions. The primary advantage of a pop-up menu over a pull-down menu is that, depending on the specific implementations, the user may have immediate access to the menu at the screen location of the selection action. The ideal user-requested menu design would provide the user with a reminder of the menu categories and would the user should be allowed to select an item with few actions and little movement of a cursor on the screen. (D)

2.2.5.6-20 Programmable Keys (Tier 2 - Consistency)
If menu items are selectable via activation of programmable function keys, the arrangement of the menu list should be compatible with the arrangement of the keys to the greatest degree possible.
COMMENT: (D)

2.2.5.6-21 Menu Color (Tier 2 - Consistency)
The same color for menus should be used within the same group.
COMMENT: (B)

2.2.5.6-22 Explanatory Title for Menu (Tier 2 - Meaningfulness)
An explanatory title should be provided for each menu that reflects the nature of the choice to be made.
COMMENT: EXAMPLE: (Good) Organizational Role: r = Responsible a = Assigned p = Performing. (Bad) Select: r = Responsible a = Assigned p = Performing. (E)

2.2.5.6-23 Letter Codes for Menu Selection (Tier 2 - Meaningfulness)
If menu selections are made by keyed codes, each code should be the initial letter or letters of the displayed option label, rather than assigning arbitrary letter or number codes.
COMMENT: For example, (Good) m = Male f = Female (Bad) 1 = Male 2 = Female. Options might be numbered when a logical order or sequence is implied. When menu selection is from a long list, the line numbers in the list might be an acceptable alternative to letter codes. (A,C,E)

2.2.5.6-24 Complete Display of Menu Options (Tier 2 - Task Compatibility)
A menu should be designed to display all options appropriate to any particular transaction.
COMMENT: A familiar set of general control options (i.e., options that are always implicitly available) may be omitted from individual displays; such general options might be selected by requesting a general menu, or perhaps by function key or command entry. (A,E)

2.2.5.6-25 Menu Options Dependent on Context (Tier 2 - Task Compatibility)
A menu should be designed to display only those options that are actually available in the current context for a particular user.
COMMENT: If a user selects a displayed option, and is then told that option is not actually available, an undesirable element of unpredictability has been introduced into the interface design. Users may become uncertain and confused about sequence control. (A,C,E)

2.2.5.6-26 Visual Representation of Path (Tier 2 - Memory Load)
The user should be able to access a visual representation of his or her path through a hierarchy of menus.
COMMENT: For example, if a user progresses through a series of permanent menus, an icon showing the previous menus and current menus, as well as menu selections, might be displayed. If a user progresses through a series of pull down menus, the previous menus might remain displayed with the selected item highlighted and the association between that item and the subsequent menu would be represented by a close spatial relation (e.g., a walking menu). (D)

2.2.5.6-27 General Menu (Tier 2 - Minimizing User Actions)
A general menu of basic options should be provided as the top level in a hierarchic menu structure, a "home base" to which a user can always return as a consistent starting point for control entries.
COMMENT: Return to the general menu might be accomplished by an OPTIONS function key, or by an explicitly labeled option on every display, or by a generally available implicit option. (A,E)

2.2.5.6-28 Hierarchic Menus for Sequential Selection (Tier 2 - Minimizing User Actions)
When menu selection must be made from a long list, and not all options can be displayed at once, a hierarchic sequence of menu selections should be provided rather than one long multipage menu.
COMMENT: Where a long list is already structured for other purposes, such as a list of customers, a parts inventory, a file directory, etc., it might be reasonable to the user should be required to scan multiple display pages to find a particular item. Even in such cases, however, an imposed structure for sequential access may prove more efficient, as when a user can make preliminary letter choices to access a long alphabetic list. Beginning users may learn faster and understand better a menu permitting a single choice from all available options, when those can be displayed on one page. However, a single long menu that extends for more than one page will hinder learning and use. (A,C,E)

2.2.5.6-29 Minimal Steps in Sequential Menu Selection (Tier 2 - Minimizing User Actions)
When users must step through a sequence of menus to make a selection, the hierarchic menu structure should be designed to minimize the number of steps required.
COMMENT: This represents a trade-off against the need for logical grouping in hierarchic menus. The number of hierarchic levels should be minimized, but not at the expense of display crowding. (E)

2.2.5.6-30 Return to Higher-Level Menus (Tier 2 - Minimizing User Actions)
Users should have to take only one simple key action to return to the next higher level in hierarchic menus.
COMMENT: This action could be considered analogous to the BACKUP option proposed as an interrupt for sequence control. (A,C,D,E)

2.2.5.6-31 Return to General Menu (Tier 2 - Minimizing User Actions)
Users should have to take only one simple key action to return to the general menu at the top level in hierarchic menus.

COMMENT: This action could be considered analogous to the REVIEW option proposed as an interrupt for sequence control. (A,C,D,E)

2.2.5.6-32 Stacking Menu Selections (Tier 2 - Minimizing User Actions)

Users should be able to combine a series of selections into a single "stacked" entry.

COMMENT: If necessary, stacked sequential entries might be separated by some character, such as a space, slash, comma or semicolon. It would be preferable, however, if they were simply strung together without special punctuation. Computer interpretation of an unpunctuated string will require letter codes (by preference) or fixed-digit number codes for option selection. (C,D,E)

2.2.5.6-33 By-Passing Menu Selection with Command Entry (Tier 2 - Minimizing User Actions)

Experienced users should be able to by-pass a series of menu selections and make an equivalent command entry directly.

COMMENT: In effect, a command entry might specify an option anywhere in a hierarchic menu structure, permitting a user to jump down several levels, or to move directly from one branch to another. If a command by-passes only a portion of the complete menu sequence, and so does not yet specify a complete control entry, then display the appropriate next menu to guide completion of the control entry. (A,C,E)

2.2.5.6-34 Menu Selection by Pointing (Tier 2 - Flexibility of Use)

When menu selection is the primary means of sequence control, and especially if choices must be made from extensive lists of displayed control options, option selection by direct pointing should be provided.

COMMENT: If a capability for direct pointing is not provided (e.g., if pointing involves separate manipulation of a mouse, or cursor positioning by key action), then for long menus it may prove faster to permit menu selection by keying associated option codes. Pointing directly at a displayed option guarantees good display-control compatibility. Users do not have to note associated option codes and enter them by key actions. (C,E)

2.2.5.6-35 Feedback for Menu Selection (Tier 2 - Feedback)

When a user has selected and entered a control option from a menu, if there is no immediately observable natural response then the computer should display some other acknowledgment of that entry.

COMMENT: An explicit message might be provided. In some applications, however, it may suffice simply to highlight the selected option label (e.g., by brightening or inverse video) when that would provide an unambiguous acknowledgment. (A,D,E)

2.2.5.6-36 Command Completion Feedback (Tier 2 - Feedback)

In addition to the indication that the system has received the menu-based command, feedback about completion of the command should also be communicated.

COMMENT: Completion of the action commanded by the menu item will be sufficient feedback, provided that the action has a result that is visible to the user. However, if the completion of the menu item has no visible result, the additional feedback that the command was completed should be communicated by a message in the Message Area. (D)

2.2.5.6-37 Acknowledgement of Selection from Keyboard (Tier 2 - Feedback)

When a menu item is chosen by a keyboard entry there should be some acknowledgement from the system that the item has been chosen.

COMMENT: E.g., by highlighting the menu item. (D)

2.2.5.6-38 Indicating Current Position in Menu Structure (Tier 2 - Feedback)

When hierarchic menus are used, the user should have some indication of current position in the menu structure.

COMMENT: One possible approach would be to recapitulate prior (higher) menu selections on the display. If routine display of path information seems to clutter menu formats, then a map of the menu structure might be provided at user request as a HELP display. (A,C,E)

2.2.5.6-39 Activation of Pull-down and Pop-Up Menus (Tier 2 - General)
Pull-down and pop-up menus should be activated by only a specific user action that requests the display of the menu.
COMMENT: Menus should not appear simply because the cursor has passed over the menu title. (D)

2.2.5.6-40 Function of Menu Should Be Evident (Tier 2 - General)
Menus should be designed so that the function of the menu is evident to the user.
COMMENT: (D)

2.2.5.6-41 Menu Accessibility (Tier 2 - General)
When using a menu system, the user at all times should have access to the main menu.

COMMENT: The user should not have to backtrack to return to the starting level in a hierarchical menu system. This capability can be provided by dedicating a program function key, touch field, or a cursor entry field to display the main menu. (B)

2.2.5.6-42 Single-Column List Format (Tier 2 - General)
When multiple menu options are displayed in a list, each option should be displayed on a new line, i.e., format the list as a single column.
COMMENT: Displaying options in several columns may be used where shortage of display space dictates a compact format; if there are only a few options, those might be displayed in a single row. An interesting exception could be made for hierarchic menus, where a high-level menu might be shown in the left column of a display, accompanied by a lower-level menu in the right column whose options change to reflect whatever selection is currently made from the high-level menu. A single column format will aid scanning, especially for novice users. (A,C,D,E)

2.2.5.6-43 Single Selection Per Menu (Tier 2 - General)
Each menu display should permit only one selection by the user.
COMMENT: (A,E)

2.2.5.6-44 Easy Selection of Important Options (Tier 2 - General)
The structure of hierarchic menus should permit immediate user access to critical or frequently selected options.
COMMENT: (A,E)

2.2.5.6-45 Non-selection of Conflicting Menu Items (Tier 2 - General)
Users should not be able to select menu items that are in conflict.
COMMENT: Menu items that are in conflict might be, for example, two different font sizes in a text input task. Users should, however, be able to select multiple menu items that are not in conflict (e.g., a font size and font type in text input). Each menu item selection would be a separate transaction with the system. (D)

2.2.5.6-46 Non-selectable Menu Items (Tier 2 - General)
When menu items are not selectable they should be identified as such to the user.
COMMENT: (D)

2.2.5.6-47 Menus Distinct from Other Displayed Information (Tier 2 - General)
If menu options are included in a display that is intended also for data review and/or data entry, the menu options should be distinct from other displayed information.
COMMENT: For example, menu options might be located consistently in the display and incorporate some consistent distinguishing feature to indicate their special function, perhaps beginning with a special symbol such as a plus sign (+NEXT, +BACK, etc.). An interesting variation in menu design is the use of "embedded menus, in which various items within a working display are highlighted in some way to indicate that they can be selected to obtain further information. (A,E)

2.2.5.6-48 Breadth and Depth of Menu Items (Tier 2 - General)
Menus should have a limited number of items in breadth and in depth.

COMMENT: Moderate menu breadth (e.g., number of menus in a menu hierarchy, number of menu categories in a menu bar, or number of pop-up menus) and depth (e.g., number of items per menu or, in menu bars, per menu category) should be facilitated by the use of a hierarchical menu structure whereby the selection of items from one menu (the parent) activates a second menu (the child) with further options. The parent menu should remain visible during the selection of the child menu. The number of levels in the hierarchy should be limited (for example, to no more than three). (D)

2.2.5.6-49 Hierarchic Menus (Tier 2 - General)

Hierarchic menus should be organized and labeled to guide operators within the hierarchic structure.

COMMENT: Operators will learn menus more quickly if a map of the menu structure is provided as HELP. (E)

2.2.5.6-50 Distinct Subordinate Menus (Tier 2 - General)

If hierarchical branching is used, each subordinate menu should be visually distinct from each previous superordinate menu. Examples include the display of level numbers, a graphical stacking effect, etc.

COMMENT: Successful user operations depend on a knowledge of context. The user needs to know the levels from which the current display menu came and how far down in the hierarchy the current menu is. (D)

2.2.5.6-51 Dual Activation for Pointing (Tier 2 - General)

If menu selection is accomplished by pointing, dual activation should be provided, in which the first action designates the selected option, followed by a separate second action that makes an explicit control entry.

COMMENT: For example, on a touch display, the computer might display a separate ENTER box that can be touched by a user to indicate that the cursor has been properly positioned. The two actions of cursor placement and entering should be compatible in their design implementation. If the cursor is positioned by keying, then an ENTER key should be used to signal control entry. If the cursor is positioned by lightpen, provide a dual-action "trigger" on the lightpen for cursor positioning and control entry. This recommendation for dual activation of pointing assumes that accuracy in selection of control entries is more important than speed. In some applications that may not be true. (C,E)

2.2.5.6-52 Large Pointing Area for Option Selection (Tier 2 - General)

If menu selection is accomplished by pointing, as on touch displays, the acceptable area for pointing should be as large as consistently possible, including at least the area of the displayed option label plus a half-character distance around that label.

COMMENT: The larger the effective target area, the easier the pointing action will be, and the less risk of error in selecting a wrong option by mistake. (A,E)

2.2.5.6-53 Highlighting When Cursor Passes Over Item (Tier 2 - General)

For all types of menus, menu items that are available to be selected should be highlighted whenever the cursor passes over them and the selection button is down.

COMMENT: As soon as the cursor passes outside the boundaries of the menu item the item should return to its normal state. Unavailable options should not highlight when the cursor passes over them. (D)

2.2.5.6-54 Control Options Distinct from Menu Branching (Tier 3 - Design Details)

The display of hierarchic menus should be formatted so that options which actually accomplish control entries can be distinguished from options which merely branch to other menu frames.

COMMENT: In some applications, it may prove efficient to design "hybrid" menus which display one branch of the menu hierarchy elaborated to include all of its control options while other branches are simply indicated by summary labels. In such a hybrid menu, it will help orient users if options that accomplish control actions are highlighted in some way to distinguish them from options which will result in display of other frames of the hierarchic menu. (A,E)

2.2.5.6-55 Number of Options (Tier 3 - Design Details)

Each menu option list should have 4 to 8 options; menus with less than 3 options should be

avoided.
COMMENT: (C)

2.2.5.6-56 No Scrolling in Menus (Tier 3 - Design Details)
All menu items should be visible to the user without scrolling.
COMMENT: This guideline applies to permanent menus, as well as for pop-up or pull-down menus when they are popped-up or pulled-down, respectively. (D)

2.2.5.6-57 Height of Menu Bar (Tier 3 - Design Details)
The height of a menu bar should be sufficient to contain standard text characters which serve as menu category labels, as well as space above and below the text characters.
COMMENT: (D)

2.2.5.6-58 Category Labels on Menu Bar (Tier 3 - Design Details)
Category labels on menu bars should be centered in the vertical dimension. Horizontally, category labels on the menu bar should be separated by enough space to be distinguishable as separate items, i.e., by at least two standard character widths.
COMMENT: One standard character width would be required to separate adjacent words in a multiword category. To indicate separate categories, more than one width would be needed. (D)

2.2.5.6-59 Labeling Grouped Options (Tier 3 - Design Details)
If menu options are grouped in logical subunits, each group should have a descriptive label that is distinctive in format from the option labels themselves.
COMMENT: Although this practice might sometimes seem to waste display space, it will help provide user guidance. Moreover, careful selection of group labels may serve to reduce the number of words needed for individual option labels. (D,E)

2.2.5.6-60 Keyboard Entry Code (Tier 3 - Design Details)
If menu items are selectable by keyboard entry the code should be closely related to the menu item. (D)
COMMENT: For example, the keyboard entry might be composed of the first letter of the option label.

2.2.5.6-61 Equivalent Keyboard Commands (Tier 3 - Design Details)
When equivalent keyboard commands are provided, they should be displayed as part of the menu option label.
COMMENT: (C)

2.2.5.6-62 Numbering Options for Codes (Tier 3 - Design Details)
Arbitrary numbers or codes should not be used for keyed entry. Numbering options might be used when the list of items is particularly long, but this should be avoided.
COMMENT: (D)

2.2.5.6-63 No Scrolling on Menu Bar (Tier 3 - Design Details)
The number of categories listed on the menu bar should not exceed the length of the bar. That is to say, reading the menu bar should not require scrolling.
COMMENT: (D)

2.2.5.6-64 After Selection of an Item (Tier 3 - Design Details)
When a pull-down or pop-up menu item has been selected, the menu should revert to its hidden state as the selected command is carried out.
COMMENT: (D)

2.2.5.6-65 ON/OFF Menu Items (Tier 3 - Design Details)
For menu items that can be in an "On" or "Off" state, the "On" state should be indicated by making the item perceptually distinct.
COMMENT: (D)

2.2.5.6-66 Selection of ON/OFF Items (Tier 3 - Design Details)
Selection of menu items with "On" and "Off" states should change their state.
COMMENT: (D)

2.2.5.6-67 Permanent Menus (Tier 3 - Design Details)
When permanent menus are used, there should be one standard design for the input prompt that is used across all applications.
COMMENT: For example, "ENTER CHOICE: __". Permanent menus may be used in cases where there is no pointing device available (although their use is not restricted to this case). Consequently, some type of code (number or letter) is usually entered through the keyboard to indicate a menu item choice. (D)

2.2.5.6-68 Permanent Menus Minimized (Tier 3 - Design Details)
The use of permanent menus should be minimized.
COMMENT: Because they require dedicated display space and more paging activity (because the application must return the user to the main menu page at every task change). However, permanent menus might be used (1) whenever it is beneficial to examine every option in detail or (2) when the amount of text in each menu item is large. (D)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.5 Transaction Dialogue
2.2.5.7 Natural Language

2.2.5.7-1 Constrained Natural Language (Tier 1 - Use)

A constrained form of natural language dialogue should be used in applications where task requirements are broad ranging and poorly defined.

COMMENT: Computer processing of natural language is now being developed on an experimental basis. Current capabilities permit computer recognition of constrained forms of "natural" language, with some limits on vocabulary and syntax. Such constrained natural languages might be considered akin to command languages, with the drawback that they are probably not as carefully designed. (E)

2.0 OPERATOR INPUT AND CONTROL
2.2 Operator Dialogue
2.2.5 Transaction Dialogue
2.2.5.8 Query Language

2.2.5.8-1 Query Language (Tier 1 - Use)
Query language dialogue should be used for tasks emphasizing unpredictable information retrieval.
COMMENT: (C,E)

2.2.5.8-2 Coherent Representation of Data Organization (Tier 2 - Consistency)
One single representation of the data organization should be used in query formulation, rather than multiple representations.
COMMENT: For example, if different queries will access different data bases over different routes, a user should not necessarily need to know this. (A,C,E)

2.2.5.8-3 Natural Organization of Data (Tier 2 - General)
A query language should reflect a data structure or organization perceived by users to be natural.
COMMENT: For example, if a user supposes that all data about a particular person are stored in one place, then the query language should permit such data to be retrieved by a single query, even though actual computer storage might carry the various data in different files. (A,C,E)

2.2.5.8-4 Task-Oriented Wording (Tier 2 - General)
The wording of a query should simply specify what data are requested; a user should not have to tell the computer how to find the data.
COMMENT: This objective has been called "nonprocedurality", meaning that a user should not have to understand computer procedures for finding data. (A,C,E)

2.2.5.8-5 Flexible Query Formulation (Tier 3 - Design Details)
Users should be allowed to employ alternative forms when composing queries, corresponding to common alternatives in natural language.
COMMENT: For example, when quantifying a query, a user should be able to employ equivalent forms, such as "over 50", "more than 50", "51 or more". (A,E)

2.2.5.8-6 Minimal Need for Quantifiers (Tier 3 - Design Details)
A query language should minimize the need for quantifiers in query formulation.
COMMENT: For example, negative quantifiers ("no", "none", "zero", etc.) are particularly difficult for users to deal with; other potentially confusing quantifiers include indefinite ("some", "any") and interrogative ("how many") forms. People have difficulty in using quantifiers. If a query language does require quantifiers, it may be helpful to allow a user to select the desired quantifier from a set of sample queries worded to maximize their distinctiveness. (A,E)

2.2.5.8-7 Logic to Link Queries (Tier 3 - Design Details)
A query language should include logic elements that permit users to link sequential queries as a single entry.
COMMENT: For example, common links for query formulation include "and", "or", etc. However a query language should be designed so that it does not require logical links. Some logical quantifiers ("greater than", "less than", etc.) may confuse users. (A,C,E)

2.2.5.8-8 Confirming Large-Scale Retrieval (Tier 3 - Design Details)
If a query will result in a large-scale data retrieval, the user should be required to confirm the transaction or else take further action to narrow the query before processing.
COMMENT: In this regard, it may be helpful to permit a user to set some upper bound for data output, in effect to define what constitutes a "large-scale" retrieval. It may help a user to decide whether to confirm or modify a pending query, if the user can request a partial display of the currently specified data output. (A,C,E)

2.2.5.9-1 Question-and-Answer Dialogue (Tier 1 - Use)
Question-and-answer dialogues should be used for routine data entry tasks, where data items are known and their ordering can be constrained, and where computer response is expected to be moderately fast.
COMMENT: Brief question-and-answer sequences can be used to supplement other dialogue types for special purposes, such as for LOG-ON sequences, or for resolving ambiguous control or data entries. Where computer response to any single user entry may be slow, then the aggregate time required to process a series of questions and answers may be very slow. In such a case, form filling may be used as an alternative dialogue type, where the user can enter a set of related "answers" as a single transaction. (C,D,E)

2.2.5.9-2 Unlimited Room for Answers (Tier 1 - Use)
The system should accept as much information from the user as he or she provides in an answer.
COMMENT: If the information that the system requests is constrained, a data form should be used. (D)

2.2.5.9-3 Request for Information (Tier 2 - General)
The system should provide the user with a specific request for information.
COMMENT: (D)

2.2.5.9-4 Questions Displayed Singly (Tier 2 - General)
Each question should be displayed separately; users should not be required to answer several questions at once.
COMMENT: A user may become confused in trying to deal with several questions at once, particularly if the number of questions is variable from one transaction to another. (A,C,D,E)

2.2.5.9-5 Stacking Related Questions (Tier 2 - General)
The system should be able to stack questions and their associated answers if a series of questions were concerned with the same topic.
COMMENT: (D)

2.2.5.9-6 Contextual Information Should Be Supplied (Tier 3 - Design Details)
The system should provide the user with contextual information required for answering the question.
COMMENT: For example, if the only answer that the system would accept were a percentage, the question should be followed by "(%)". The answer area should follow the contextual information. (D)

2.2.5.9-7 Recapitulating Prior Answers (Tier 3 - Design Details)
When a series of computer-posed questions are interrelated, answers to previous questions should be displayed when those will provide context to help a user answer the current question.
COMMENT: Another way to request a related series of user entries is to use a form-filling dialogue rather than question-and-answer. (A,C,E)

2.2.5.9-8 Removing and Recalling Questions (Tier 3 - Design Details)
The user should have the ability to remove a question and answer from the screen or recall a question and answer to the screen.
COMMENT: (D)

2.2.5.9-9 Sequence Compatible with Source Documents (Tier 3 - Design Details)
When questions prompt entry of data from a source document, the question sequence should match the data sequence in the source document.

COMMENT: (A,C,E)

2.2.5.9-10 Question Mark Delimiter (Tier 3 - Design Details)

A question mark should be the delimiter of the questions and answer dialogue.

COMMENT: In general, space for answering the question should be provided closely following the question mark. However, when additional information needed for the answer follows the question, the space for answering the question should be placed after the additional information. (D)

2.0 OPERATOR INPUT AND CONTROL

2.3 Display Control

2.3.1 General

2.3.1-1 Display Control (Tier 1 - Use)
Users should be able to tailor information displays by controlling data; selection, coverage, updating, and suppression. Users should be able to specify data for display.
COMMENT: (A)

2.3.1-2 Panning with Free Cursor Movement (Tier 1 - Use)
In applications where a user moves a cursor freely about a page of displayed data, panning should be adopted rather than scrolling as the conceptual basis of display framing.
COMMENT: (E)

2.3.1-3 Continuous Text Data (Tier 1 - Use)
Paging and windowing should not used when searching through continuous text data.
COMMENT: (A)

2.3.1-4 Single Frame Display of Critical Data (Tier 2 - Screen Organization)
Critical data requiring integrated display for effective assimilation should be included in a single frame, and not dispersed over several pages.
COMMENT: (A,E)

2.3.1-5 Consistent Orientation (Tier 2 - Consistency)
A consistent orientation for display framing should be used.
COMMENT: Users can either 1) conceive the display frame as a window moving over a fixed array of data, here called "panning", or 2) conceive data as moving behind a fixed display frame, commonly called "scrolling." (A,E)

2.3.1-6 Framing Consistently for All Data (Tier 2 - Consistency)
Framing functions should be performed consistently so that panning and/or zooming affect all displayed data in the same way.
COMMENT: For example, on a situation display, zooming should be used to expand background data such as geographic boundaries to the same scale as the expansion of overlaid "active" data. (E)

2.3.1-7 Integrated Display (Tier 2 - Task Compatibility)
Displays should include all data relevant to a user's current transaction in one frame or page.
COMMENT: This is particularly important when critical data items must be compared by a user. (A,E)

2.3.1-8 Display Print (Tier 2 - Minimizing User Actions)
The user should be able to print a display by simple request, (e.g., PRINT-SCREEN) without having to take a series of other actions.
COMMENT: (C)

2.3.1-9 Information Displayed as Available (Tier 2 - General)
Information that the user must manipulate should be displayed as it becomes available.
COMMENT: (A)

2.3.1-10 Zooming for Display Expansion (Tier 2 - General)
The user should be provided with a zooming capability that allows the user to expand the display of any selected area.
COMMENT: (E)

2.3.1-11 Information for Navigating (Tier 2 - General)
The user interface should provide the user with information and actions that he or she needs to navigate in a structured data file or object.

COMMENT: For example, a flowchart might be provided to show the user, upon request, his or her position within such hierarchies as menus, a hierarchy of operations. The flowchart might be contained in a window separate from the application that the flowchart represents. In this example, movement from any position in the hierarchy to any other position might be accomplished by using the cursor control device to select the desired position on the flowchart. An alternative example consists of displays in a hierarchy which are identified by a convention, such as, application, operation, location in the hierarchy. An identification code for each display might then consist of abbreviations for the application and operation and numbers for the location in the hierarchy. Then, users should be able to access a display in a hierarchy by inputting a command identifying the display and directing the system to go to it. (D)

2.3.1-12 Display of Control Options (Tier 2 - General)
Screen control locations and control options should be clearly and appropriately indicated.
COMMENT: (A)

2.3.1-13 Functional Labeling for Display Framing (Tier 2 - General)
User instructions, key labels, etc., should refer to display framing in functional terms and avoid wording that implies spatial orientation.
COMMENT: Examples of framing in functional terms are: "forward" and "back", or "next" and "previous". Control of display framing functions might be implemented by keys marked with arrows, to avoid verbal labels altogether. Note that "forward" and "back" are potentially ambiguous because of the contradictory use of those words when referring to movement within books. (E)

2.3.1-14 Easy Paging (Tier 2 - General)
When requested data exceeds the capacity of a single display frame, users should be given some easy means to move back and forth over displayed material by paging or panning/scrolling.
COMMENT: Dedicated function keys can provide for paging forward and back. (A,E)

2.3.1-15 Hard copy (Tier 2 - General)
The user should have the capability to obtain a paper copy of the exact contents of the alphanumeric or digital graphic display.
COMMENT: (A,C)

2.3.1-16 Show Changing Scale (Tier 3 - Design Details)
When a display is expanded from its normal coverage, a scale indicator of the expansion factor should be provided.
COMMENT: For example, a linear indicator of current map scale might be shown in the margin, or perhaps simply a numeric indication of the display expansion factor (e.g., : x4 :). (E)

2.3.1-17 Show Overview Position of Visible Section (Tier 3 - Design Details)
When a display is panned and/or expanded from its normal coverage, some graphic indicator of the position in the overall display of the currently visible section should be provided.
COMMENT: (E)

2.3.1-18 Return to Normal Display Coverage (Tier 3 - Design Details)
If a user is allowed to pan over an extended display, or zoom for display expansion, an easy means for the user to return to normal display coverage should be provided.
COMMENT: For example, return to normal display coverage might be accomplished by a function key labeled RETURN, or perhaps RESET. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.3 Display Control
2.3.2 Display Freeze

2.3.2-1 Display Freeze (Tier 1 - Use)

The user should be able to "freeze" displayed data which are automatically updated at any point. This is necessary in order for the user to examine changed data more deliberately.

COMMENT. (A,E)

2.3.2-2 Labeling Display Freeze (Tier 2 - General)

When a display is "frozen," the display should be appropriately labelled to remind users of its "frozen" status.

COMMENT: (A,E)

2.3.2-3 Signaling Changes to Frozen Data (Tier 2 - General)

When a display being updated in real-time has been frozen, the user should be warned if some significant, but not displayed, change should be detected in the computer processing of new data.

COMMENT: (A,E)

2.3.2-4 Resuming Update After Display Freeze (Tier 3 - Design Details)

When the user elects to resume update after a display being updated in real time has been frozen, the resumed display update should be positioned at the current real-time point.

COMMENT: In some applications, a user might wish to resume display update at the point it is stopped, and so the display change would lag real-time data change. Or, a user might choose to see a speeded "replay" of interim changes to regain current display status. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.3 Display Control
2.3.3 Display Selection

2.3.3-1 User Selection of Data for Display (Tier 1 - Use)
For general data processing, the users should specify the data for displayed output.
COMMENT: (E)

2.3.3-2 Selectable Data Categories (Tier 1 - Use)
When the particular data categories required at different stages in a user's job cannot be exactly predicted, the user should be allowed to select the data categories.
COMMENT: (E)

2.3.3-3 Consistent Format for Display Labels (Tier 2 - Consistency)
The identifying label used for display selection should be positioned in a prominent location, consistent across displays.
COMMENT: (E)

2.3.3-4 Meaningful Display Labels (Tier 2 - Memory Load)
The display identification labels should be unique and concise, and sufficiently meaningful to be remembered easily.
COMMENT: (E)

2.3.3-5 Indicating Display Categories Available (Tier 2 - General)
Users should be provided with a ready reminder of what data categories are available.
COMMENT: (E)

2.3.3-6 Display Identification Labels (Tier 2 - General)
When a user selects a data display, the display should be appropriately identified.
COMMENT: (E)

2.3.3-7 Selecting or Suppressing Display Categories (Tier 3 - Design Details)
Users should be provided with means of selecting (or suppressing) displayed categories.
COMMENT: This implies category selection by menu or function keys. (E)

2.3.3-8 Nondestructive Overlay (Tier 3 - Design Details)
Data elements that are changed and temporarily overlay and obscure other display data should not erase the overlayed data.
COMMENT: For example, in a situation display moving track data may temporarily obscure stable background data. (E)

2.3.3-9 Initial Erasure to Replace Changed Data (Tier 3 - Design Details)
When the computer regenerates a display to update changed data, the old data items should be erased before adding new data items to the display.
COMMENT: The aim here is to avoid any momentary user confusion that might result from watching portions of old data being overwritten and partially overlapped by portions of new data. (E)

2.3.3-10 Signaling Completion of Display Output (Tier 3 - Design Details)
When display generation is slow, the user should be notified when the display output is complete. A nonobtrusive auditory signal such as a chime suffices for this purpose.
COMMENT: (E)

2.3.3-11 Auxiliary Coding (Tier 3 - Design Details)
Auxiliary coding, adopted for different data categories, such as shape coding of symbols, should be distinctive for any likely combination of displayed categories.

COMMENT: (E)

2.3.3-12 Printing Displays Locally (Tier 3 - Design Details)

The user should be able to locally print displayed data that are of potential long-term interest.

COMMENT: (E)

2.0 OPERATOR INPUT AND CONTROL
2.3 Display Control
2.3.4 Display Suppression

2.3.4-1 Temporary Suppression of Displayed Data (Tier 1 - Use)
The user should be able to temporarily suppress standard data displays which are used for special purposes.
COMMENT: (A,E)

2.3.4-2 Labeling Display Suppression (Tier 2 - General)
A data display that has been suppressed should be annotated with an appropriate label to remind users that data have been suppressed.
COMMENT: (E)

2.3.4-3 Signaling Changes to Suppressed Data (Tier 2 - General)
Users should be warned if some significant (but not displayed) change is detected in the computer processing of new data when data have been suppressed from a display.
COMMENT: (A,E)

2.3.4-4 Resuming Display of Suppressed Data (Tier 2 - General)
Data that has been suppressed from a display should be able to be quickly restored to its complete, originally generated form.
COMMENT: (A,E)

2.3.4-5 Dedicated Function Key (Tier 3 - Design Details)
Function keys used to restore suppressed data should have no other use.
COMMENT: For instance, if a user must press RETURN to restore suppressed data, that key only restores the data and does not also move a displayed cursor to some other position. (A,E)

2.0 OPERATOR INPUT AND CONTROL
2.3 Display Control
2.3.5 Display Update

2.3.5-1 Automatic Display Update (Tier 1 - Use)
Users should be able to request automatic update (computer regeneration) of changed data, and should be able to control the update rate.
COMMENT: (E)

2.3.5-2 Readability of Changing Data (Tier 2 - General)
Changing data values that must be read should be displayed in a fixed position and updated no more than once per second. If users need only to monitor general trends in changing data values, and do not need to take exact readings, somewhat faster update rates may be acceptable.
COMMENT: (E)

2.3.5-3 Visual Integration of Changing Graphics (Tier 2 - General)
When a user must visually integrate changing patterns on a graphic display, data should be updated at a rate appropriate to human perceptual abilities for that kind of data change.
COMMENT: Slowly developing patterns may be seen more easily with time compression, i.e., with rapid display of sequentially stored data frames. Fast changing data may require time expansion, i.e., slowed output, to aid pattern perception. In some applications it is permissible to allow a user to control the speed for update of displayed data. (E)

2.3.5-4 Refresh Rate for Free-drawn Graphics (Tier 3 - Design Details)
For free-drawn graphics, the refresh rate on the monitor should be high enough to produce the appearance of a continuous track.
COMMENT: (D)

2.0 OPERATOR INPUT AND CONTROL
2.3 Display Control
2.3.6 Hypertext

2.3.6-1 Users Having Authoring Tools (Tier 1 - Use)
Users should not have the power of authoring tools if only a browsing tool is needed.
COMMENT: (D)

2.3.6-2 Browsing Tools: Question-Answer Dialogue (Tier 2 - General)
Hypertext browsing tools should generally act in a question and answer dialogue.
COMMENT: (D)

2.3.6-3 Context-Sensitive Help (Tier 2 - General)
Hypertext tools should always have a context-sensitive help function, including an overview function that displays the entire help hierarchy.
COMMENT: (D)

2.3.6-4 Coding Linked Items (Tier 3 - Design Details)
Items of information which are linked to other items or nodes should have distinctive and unambiguous codes.
COMMENT: (D)

2.3.7-1 Scrolling Structures Appear Where Appropriate (Tier 1 - Use)
Structures for horizontal scrolling/paging appear only on displays for which horizontal movement is appropriate. Similarly, structures for vertical scrolling/paging appears only on displays for which vertical movement is applicable.
COMMENT: (D)

2.3.7-2 Common Display Structure (Tier 2 - Consistency)
Display structure used for scrolling and paging should be common to all files.
COMMENT: (D)

2.3.7-3 Paging (Tier 2 - Flexibility of Use)
Users should have the ability to page using several different techniques.
COMMENT: For example, paging by means of moving a page icon on the scroll bar or by the use of a dedicated function key for paging forward and a dedicated function key for paging back through a file. (D)

2.3.7-4 Related Data on Same Page (Tier 2 - General)
Multiple page displays should display functionally related data items together on one page.
COMMENT: (E)

2.3.7-5 Integrated Display (Tier 2 - General)
When user perception of relations among data sets are presented in a display, an integrated display should be provided rather than partitioning them display into separate frames.
COMMENT: (E)

2.3.7-6 Paging Controls (Tier 2 - General)
Users should be allowed to move easily from one page to another for displays which are partitioned into separately displayable pages
COMMENT: (E)

2.3.7-7 One Structure for Vertical, One for Horizontal Movement (Tier 2 - General)
Only one scrolling/paging structure should be used for vertical movement in a display and one for horizontal movement in a display.
COMMENT: The placement of the scrolling/paging structures clearly indicates the function for vertical or horizontal movement. For example, one scroll bar might be placed along one of the side borders of the display for vertical scrolling and another scroll bar might be placed along the top or bottom (opposite the menu bar) of the display for horizontal scrolling. (D)

2.3.7-8 Labeling Scrolling Function (Tier 2 - General)
The function of the scrolling/paging structure should be clearly indicated by either a textual or graphic label.
COMMENT: For example, a graphic label for the scroll bar might be a scroll icon. (D)

2.3.7-9 Evident Direction of Paging (Tier 2 - General)
The direction that a user must page (toward the top or bottom, left or right) should be evident to the user before he or she begins to page.
COMMENT: For example, scroll arrows on a scroll might point in the direction that corresponds to the paging direction. (D)

2.3.7-10 Paging in One or Multiple Page Increments (Tier 3 - Design Details)
Users should be able to page in one page or multiple page increments.

COMMENT: For example the user might page multiple pages directly by moving the page icon on the scroll bar at which time the display might move to the location in the file that corresponds to the page number on the page icon. (D)

2.3.7-11 Discrete Movement of File (Tier 3 - Design Details)

The movement of the file should be discrete with no display of intermediate pages between the starting page and the selected page.

COMMENT: (D)

2.3.7-12 Indicate Absolute and Relative Positions of User (Tier 3 - Design Details)

Scrolling/paging structure should indicate both the absolute and relative positions of the user in the data file.

COMMENT: For example, a page icon on the scroll bar might (1) indicate the absolute position by containing the page number in the data file and (2) indicate the relative position by means of the spatial location of the icon on the scroll bar. (D)

2.0 OPERATOR INPUT AND CONTROL

2.3 Display Control

2.3.8 Scrolling

2.3.8-1 Several Different Means of Scrolling (Tier 2 - Flexibility of Use)

Users should have access to several different means by which they may scroll.

COMMENT: e.g., a scroll bar, keyboard arrow keys, and keystroke commands. (D)

2.3.8-2 Graphic Indication of Scroll Position (Tier 3 - Design Details)

Large display outputs which are viewed by continuous panning/scrolling should be provided with a graphic indicator inset at the margin of the display frame to indicate current location.

COMMENT: (E)

2.3.8-3 Scroll by Line or Display Unit (Tier 3 - Design Details)

The scroll motion rate should allow the user to scroll by line or by display unit.

COMMENT: Either technique provides a smooth flow of text. (D)

2.3.8-4 Parameters Refer to Data not Window (Tier 3 - Design Details)

The parameters of roll/scroll functions should refer to the data being guidelined, not to the window.

COMMENT: For example, "roll up 5 lines" means that the top five lines of data would disappear and five new lines would appear at the bottom; the window through which the data is viewed remains fixed. When a windowing orientation is maintained consistently, the wording of scroll functions refers to the display page (or window) and not to the displayed data. In that case, the command "Up 10" would mean that ten lines of data will disappear from the bottom of the display and ten earlier lines will appear at the top. (B)

2.0 OPERATOR INPUT AND CONTROL
2.3 Display Control
2.3.9 Searching

2.3.9-1 Multiple Methods of Searching (Tier 2 - Flexibility of Use)
Users have multiple methods by which they can engage in searching for lines or alphanumeric strings.
COMMENT: (D)

2.3.9-2 String Search (Tier 3 - Design Details)
Users should be allowed to specify a string of text and to request the computer to advance (or back up) the cursor automatically to the next (or last previous) occurrence of that string.
COMMENT: (E)

2.3.9-3 Search for Line Numbers (Tier 3 - Design Details)
Users should have the ability to search for and move to a specific line number in a file.
COMMENT: (D)

2.4.1-1 Saving to a Data File (Tier 1 - Use)
The user should be able to save the data entered into a data file by a single action that will permit the user to continue interacting with that file.
COMMENT: For example, selecting a menu item. This action replaces the previous data stored in the data file with the newly saved data. (D)

2.4.1-2 Exit With Save (Tier 2 - Minimizing User Actions)
After finishing the interaction with any type of file, the user should be able to save the data and stop interacting with the file by a single action.
COMMENT: (D)

2.4.1-3 Exiting a Data File (Tier 2 - Minimizing User Actions)
After finishing the interaction with any type of file, the user should be able to stop interacting with the file by a single action (e.g., selecting a menu item) without saving the changes to the file.
COMMENT: Commands for exiting are different from those for saving and exiting with a save. (D)

2.4.1-4 Distinct Commands for Exit With and Without Save (Tier 2 - General)
The command used to "exit with save" should differ from the commands for "save" and for "exit without save."
COMMENT: (D)

2.4.1-5 Protection Against Exiting a File Without Saving (Tier 2 - General)
The user should be protected against exiting a data file without the opportunity to save the file contents.
COMMENT: (D)

2.4.1-6 Verify Exit With Delete New Inputs (Tier 2 - General)
The system should require the user to verify that he or she wants to exit and delete new inputs.
COMMENT: (D)

2.4.1-7 Accidentally Replacing a Data File (Tier 2 - General)
Data from a file that has been modified and stored with the "save" or "exit with save" actions should be retrievable with a single action.
COMMENT: (D)

2.4.1-8 Automatic Saving of a Data File (Tier 2 - General)
The system should save a data file automatically at frequent intervals while being edited.
COMMENT: Users should be aware of automatic file saving operations. (D)

2.4.1-9 Automatic Backup (Tier 3 - Design Details)
Users should have the option of invoking an automatic backup function that retains previous versions of data. The specific number of previous versions saved should be selectable by the user.
COMMENT: (D)

2.4.1-10 Access of Modified Data After Exit Without Save (Tier 3 - Design Details)
Data from a file that has been modified by new input should be retrievable with a single action even after exiting with deletion of new input.
COMMENT: The modified data file is accessible for a period of time after the "exit" actions. (D)

2.4.2-1 Automatic Placement of Cut Data in Buffer (Tier 1 - Use)
When selected data is cut or copied from a text file, tabular file, and/or graphics file and placed in a temporary editing buffer, the data should be placed in the buffer automatically, with the only specific action required by the user being the cut or copy action.
COMMENT: If a temporary editing buffer is used, data pasted into a text file, tabular file, and/or graphics file is pasted from that buffer. (D)

2.4.2-2 Contents of Temporary Buffer (Tier 2 - General)
The contents of the temporary editing buffer should remain intact after the application from which the contents were taken is closed.
COMMENT: (D)

2.4.2-3 Default Conditions of Buffer (Tier 3 - Design Details)
The default condition should be that additions to the temporary editing buffer are not cumulative; new data placed in the buffer replaces old data.
COMMENT: (D)

2.4.2-4 Access to Contents of Temporary Buffer (Tier 3 - Design Details)
The user should be able to access the contents of the temporary editing buffer in a window with a single action.
COMMENT: Access to the contents of the temporary editing buffer permits the user to read the contents, but not operate on them. (D)

2.4.3-1 Accessing Information Across Applications (Tier 1 - Use)
The capability to accept and maintain information, independent of application, should be provided for holding relevant information across displays or applications.
COMMENT: An example of this capability is the scrapbook or excerpt file. (D)

2.4.3-2 Excerpt File (Tier 1 - Use)
Users should have the capability to create multiple Excerpt Files.
COMMENT: (D)

2.4.3-3 Integrating Data (Tier 2 - General)
The user should have the capability to integrate new data with data already in the file.
COMMENT: Integrating data might include (1) pasting the new data following data already in the file, (2) pasting the new data before data already in the file, and (3) interleaving new data in data already in the file. Each of these capabilities is available through a single user action. (D)

2.4.3-4 (Tier 2 - General) Copying Excerpt File
The user should be able to cut or copy data from the Excerpt File and paste it to any other file.
COMMENT: (D)

2.4.3-5 (Tier 2 - General) Saving Excerpt File
The user should be able to save the Excerpt File.
COMMENT: (D)

2.0 OPERATOR INPUT AND CONTROL
2.4 Information Manipulation
2.4.4 Retrieval Buffer

2.4.4-1 Retrieval Buffer (Tier 2 - Meaningfulness)
The user should be able to view the contents of the retrieval buffer, but not to operate on the contents.
COMMENT: (D)

2.4.4-2 Print Queue (Tier 2 - General)
The user should be able to view a list of the contents of the print queue, but not to operate on the contents, with one exception: The user is able to delete jobs from the print queue selectively.
COMMENT: D)

2.0 OPERATOR INPUT AND CONTROL
2.5 System Response Time

2.5-1 Response time consistent with requirements (Tier 2 - General)
System response times sh ou'd be consistent with operational requirements.
COMMENT: Required user response times should be compatible with required system response time. Required user response times should be within the limits imposed by total user tasking expected in the operational environment. (C)

2.5-2 Processing delay (Tier 2 - General)
Where system overload or other system conditions will result in a processing delay, the system should acknowledge the data entry and provide an indication of the delay to the user.
COMMENT: If possible, the system should advise the user of the time remaining for the process or of the fraction of the process completed. (A)

2.5-3 Indicating Completion of Processing (Tier 2 General)
When processing in response to a control entry is lengthy, the user should be given a positive indication of subsequent completion time, and appropriate related information.
COMMENT: Appropriate related information includes a message stating the need for further user action is required. (A,E)

2.5-4 Response time induced keyboard lockout (Tier 2 - General)
If computer processing time requires delay of concurrent user inputs and no keyboard buffer is available, keyboard lockout should occur until the computer can accept the next transaction. An alert should be displayed to indicate to the user that lockout has occurred.
COMMENT: (C)

2.5-5 Keyboard restoration (Tier 2 - General)
When the computer is ready to continue following response time-induced keyboard lockout, a signal to so indicate should be presented.
COMMENT: For example, cursor changes back to normal shape. (C)

2.5-6 Maximum Response Delay Time (Tier 3 - Design Details)
T. delay between the controller input and the resulting response on the screen should be less than 0.1 second.
COMMENT: (D)

2.5-7 Appropriate Computer Response Time For User Control Entries (Tier 3 - Design Details)
Computer response to a "simple" control entry should be within 0.5 - 1.0 seconds. Computer response to a less "simple" control entry should be no longer than 2.0 seconds.
COMMENT: An example of a "simple" control request is NEXT PAGE. (E)

2.5-8 Fast Acknowledgement of Pointing (Tier 3 - Design Details)
In pointing actions, the computer should acknowledge entry of a designated position within 0.2 seconds.
COMMENT: For example, almost any consistently provided display change will suffice to acknowledge pointing actions, such as brightening or flashing a selected character. In some applications, an explicit message indicating that a selection has been made, could be appropriate. (E)

2.5-9 Response Time to Menu Selections (Tier 3 - Design Details)
The response to menu selections, function keys, and most entries during graphic interaction should be immediate.
COMMENT: (A,E)

2.5-10 Response Time to Lightpen Menu Selections (Tier 3 - Design Details)
The maximum delay for computer response to menu selection by ligh pen should be 1.0 seconds.
COMMENT: (A,E)

2.5-11 Quick Response to Simple Display Request (Tier 3 - Design Details)
System responses to simple requests for data displays should take no more than 0.5 to 1.0 second.
COMMENT: An example of a "simple" request is for a request for the next page of a multipage display, or when a display begins to move in response to a scrolling command. When display output is paced in segments (blocks, paragraphs, etc.), response time refers to output of the first segment. (E)

2.5-12 Response to Non-Simple Display Request (Tier 3 - Design Details)
System responses to "non-simple" requests for data displays should take no more than 2 to 10 seconds.
COMMENT: Non-simple requests involve more complicated operations, such as accessing different files, transforming data, etc. (E)

2.5-13 Error Message Display Time (Tier 3 - Design Details)
Error messages should be displayed within 2-4 seconds.
COMMENT: (E)

2.5-14 Variability of Response Time (Tier 3 - Design Details)
Response time deviations should not exceed more than half the mean response time.
COMMENT: For example, if the mean response time is 4 seconds, the variation is limited to a range of 2 to 6 seconds. (E)

2.5-15 Maximum System Response Times (Tier 3 - Design Details)
Maximum system response times for real-time systems should not exceed the values presented in the associated figure.
COMMENT: (C)

Action	Response Time Definition	Maximum Response Time (Secs)
Key Response	Key depression until positive response; for example, "click"	0.1
Key Print	Key depression until appearance of character	0.2
Page Turn	End of request until first few lines are visible	1.0
Page Scan	End of request until text begins to scroll XY	0.5
Entry	From selection of field until visual verification	0.2
Function	From selection of command until response	2.0
Pointing	From input of point to display point	0.2
Sketching	From input of point to display of line	0.2
Local Update	Change to image using local data base; for example, new menu list from display buffer	0.5
Host Update	Change where data is at host in readily accessible form; for example, a scale change of existing image	2.0
File Update	Image update requires an access to a host file	10.0
Inquiry (Simple)	From command until display of a commonly used message	2.0
Inquiry (Complex)	Response message requires seldom used calculations in graphic form	10.0
Error Feedback	From entry of input until error message appears	2.0

3.0 ALARMS

3-1 Alarm settings (Tier 1 - Use)

When alarm signals are established on the basis of user-defined logic, users should be able to obtain status information concerning current alarm settings, in terms of dimensions (variables) covered and values (categories) established as critical.

COMMENT: Alarm status information is particularly necessary in monitoring situations where responsibility may be shifted from one user to another as in changes of shift. (C)

3-2 Alarm Acknowledgment (Tier 1 - Use)

Simple means of acknowledging and turning off non-critical alarms should be provided.

COMMENT: (E)

3-3 Special Acknowledgment of Critical Alarms (Tier 2 - General)

If operators are required to acknowledge a special or critical warning in some special way, acknowledgment should not slow operator response to the condition.

COMMENT: (E)

3-4 Alarm Settings (Tier 2 - General)

Operators should be able to obtain status information concerning current alarm settings, in terms of dimensions (variables) and setpoints.

COMMENT: Alarm status information will be particularly helpful in monitoring situations where responsibility may be shifted from one operator to another ("change of shift"). (E)

3-5 Alarm Reset (Tier 2 - General)

Operators should be provided with simple means to turn off non-critical audible alarms, without erasing associated messages.

COMMENT: (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.1 Prompts

4.1.1-1 Prompting LOG-ON (Tier 1 - Use)
LOG-ON process should provide prompts for all operator entries.
COMMENT: (E)

4.1.1-2 Prompting Control Entries (Tier 1 - Use)
Operators should be provided information needed to guide control entries during transactions.
COMMENT: For example, by incorporating prompts in a display and/or by providing prompts in response to requests for HELP. Where six or fewer control options exist, they should be listed. Where more input options exist, an example of the type of entry that is required should be presented. (E)

4.1.1-3 Prompting Entries (Tier 1 - Use)
Advisory messages or prompts should be provided to guide data and/or control parameter entry.
COMMENT: If a default value has been defined for null entry, that value should be included in the prompting information. (E)

4.1.1-4 Prompting Address Entry (Tier 1 - Use)
When a operator specifies the address for a message, prompting should be provided.
COMMENT: Prompting might consist of a series of questions to be answered, an address form to be completed by the operator, or reminders of command entries required. (E)

4.1.1-5 Standard Display Location for Prompting (Tier 2 - Consistency)
Prompts for data/command entry should be in a standard location.
COMMENT: Prompts may be provided in a window overlay. (E)

4.1.1-6 Consistent Format for Prompts (Tier 2 - Consistency)
Consistent phrasing and punctuation should be used in prompts.
COMMENT: (E)

4.1.1-7 Standard Symbol for Prompting Entry (Tier 2 - Consistency)
Standard symbols should be used for input prompting. The symbol should be reserved for that use.
COMMENT: (E)

4.1.1-8 Familiar Wording (Tier 2 - Meaningfulness)
Labels, prompts and operator guidance messages, should use familiar terminology.
COMMENT: For example, "Data requires special access code; call Data Base Admin, X 9999 for access." is preferable to "IMS/VS DBMS private data; see OP-DBSA-0/99-99." (E)

4.1.1-9 Prompting Command Correction (Tier 2 - General)
When a command entry is not recognized or inappropriate, operators should be prompted to correct, rather than re-entry the command.
COMMENT: A faulty command should be able to be retained in the command entry area of the display, with the cursor automatically positioned at the incorrect item, with an advisory message describing the problem. (E)

4.1.1-10 Prompting Field Length (Tier 2 - General)
Cues should be provided in field delineation to indicate when fixed or maximum length is needed for data entry.
COMMENT: Underscoring gives a direct visual cue as to the number of characters to be entered, and the operator does not have to count them. For example, "Enter ID: _ _ _ _ _ _ _ _ _" is preferable to "Enter ID (9 characters)." (E)

4.1.1-11 Operator-Requested Prompts (Tier 2 - General)

Operators should be able to request computer generated prompts to determine required parameters or available options for a command.
COMMENT: Using a HELP function key, or perhaps simply keying a question mark in the command entry area, are satisfactory methods to request prompting. (E)

4.1.1-12 Concise Wording of Prompts (Tier 2 - General)
Prompts should be concisely worded.
COMMENT: (E)

4.1.1-13 Prompting Data Entry (Tier 2 - General)
Prompting should be provided for required formats and acceptable values for data entries.
COMMENT: (E)

4.1.1-14 Data Format Cueing in Labels (Tier 3 - Design Details)
Additional cueing of data format should be included in a field labelwhen that seems helpful.
COMMENT: For example, "DATE (MM/DD/YY) : __ __/__ __/__ __" (E)

4.1.1-15 Graphic Display of Control Prompting (Tier 3 - Design Details)
Graphic means may be provided for displaying to operators prompting aids and other guidance pertaining to current control actions.
COMMENT: For example, a guidance display providing a graphic representation of keypad layout with notes explaining the various key functions can help an operator to learn the control options available via function keys. (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.2 Cautions and Warnings

4.1.2-1 Distinctive and Consistent Warnings (Tier 2 - General)
Warnings (or warning messages) should be distinctive.
COMMENT: For example, warning messages might be marked with a blinking symbol and/or displayed in red, and be accompanied by a distinct auditory signal, caution and error messages might be marked with a different special symbol and/or displayed in yellow. (E)

4.1.2-2 Redundant Display (Tier 2 - General)
Caution and warning information should be presented through visual and auditory means.
COMMENT: The visual display of emergency information should be redundant, using pictures, schematics, color, and text and should be accompanied by an auditory alerting tone. (D)

4.1.2-3 Warning Operators of Potential Data Loss (Tier 2 - General)
Provisions to prompt against data loss should be provided.
COMMENT: For example, during log-off, the system should check pending transactions to determine if data loss seems probable. If so, the computer should prompt for confirmation before the log-off command is executed. (E)

4.1.2-4 Time-consuming processes (Tier 2 - General)
Warning should be provided when a command will be time consuming to process.
COMMENT: (C)

4.1.2-5 Warning of Threats to Security (Tier 2 - General)
Computer logic should generate messages or alarm signals that warn operators of threats to data security or attempted intrusion by unauthorized personnel.
COMMENT: (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.3 System Messages

4.1.3-1 Signaling Completion of Display Output (Tier 1 - Use)
When display generation is slow, notification should be provided when display output is complete.
COMMENT: For example, a non-obtrusive signal such as a chime. (E)

4.1.3-2 Feedback for Function Key Activation (Tier 2 - Feedback)
Function key activation should be accompanied with some form of acknowledgment.
COMMENT: For example, an advisory message may be displayed. (E)

4.1.3-3 Clearly Worded Messages (Tier 2 - General)
The content of messages and actions required by the operator should be explicit.
COMMENT: (A)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.4 Operator Guidance - General

4.1.4-1 Standard Procedures (Tier 2 - Consistency)
Standard procedures should be used for accomplishing similar operations.
COMMENT: For example, consistent use of command words (such as SAVE) across operations. (E)

4.1.4-2 Consistent Format for Operator Guidance (Tier 2 - Consistency)
Guidance format should be consistent across displays.
COMMENT: For example, display titles might be consistently centered at the top of the display, with display identification codes at the upper left corner. (E)

4.1.4-3 Wording Consistent with Control Entry (Tier 2 - Consistency)
Wording for operator guidance that is consistent with the words should be used for control entries.
COMMENT: For example (Good) To delete a paragraph, press DELETE and then PARAGRAPH. (Bad) To erase a paragraph, press DELETE and then PARAGRAPH. (E)

4.1.4-4 Wording Consistent with Operator Guidance (Tier 2 - Consistency)
The wording and required format of control functions should be reflected consistently in the wording of guidance, including labels, messages, and instructional material.
COMMENT: Examples (Good) To delete a paragraph, press DELETE and then PARAGRAPH. (Bad) If a paragraph must be erased, press DELETE and then PARAGRAPH. (E)

4.1.4-5 Consistent Grammatical Structure (Tier 2 - Consistency)
Grammatical construction of operator guidance should be consistent.
COMMENT: (E)

4.1.4-6 Highlighting Critical Operator Guidance (Tier 2 - Consistency)
A consistent method should be used to highlight display of critical guidance information.
COMMENT: Warnings and warning messages may require output of auxiliary auditory signals as well as display highlighting. (E)

4.1.4-7 Familiar Wording (Tier 2 - Meaningfulness)
Operator guidance should use familiar terminology.
COMMENT: For example: (Good) Data requires special access code; call Data Base Admin, X 9999. (Bad) IMS/VS DBMS private data; see DBSA, 0/99-99 (E)

4.1.4-8 Familiar Coding Conventions (Tier 2 - Meaningfulness)
Codes and abbreviations for data entry/display should have conventional usage.
COMMENT: (E)

4.1.4-9 Only Necessary Information Displayed (Tier 2 - Task Compatibility)
Only needed data should be displayed.
COMMENT: Only relevant data to a task or operation should be displayed. (E)

4.1.4-10 Task-Oriented Wording (Tier 2 - Task Compatibility)
Labels and identifiers should be task oriented.
COMMENT: For example, a save operation should be called "Save", and not "Function 1" or "Update Data". (E)

4.1.4-11 Speaking Directly to Operators (Tier 2 - General)
Wording for operator guidance should be directed at the operator.
COMMENT: For example (Good) Press ENTER to continue. (Bad) The operator should press ENTER to continue. (E)

4.1.4-12 Affirmative Statements (Tier 2 - General)
Affirmative wording should be used for operator guidance messages.
COMMENT: Tell the operator what to do rather than what to avoid. For example, (Good) Clear the screen before entering data. (Bad) Do not enter data before clearing the screen. (E)

4.1.4-13 Active Voice (Tier 2 - General)
Active voice should be used in guidance messages.
COMMENT: For example, (Good) Pressing CLEAR clears screen. (Bad) The screen is cleared by using CLEAR. (E)

4.1.4-14 Anthropomorphism (Tier 2 - General)
Presenting the system as a person should be avoided.
COMMENT: For example, "I AM LOADING YOUR FILE NOW. I'LL TELL YOU WHEN I'M DONE.". (A)

4.1.4-15 Temporal Sequence (Tier 2 - General)
Guidance should describe sequence of steps in order of performance.
COMMENT: For example, (Good) Enter LOG-ON sequence before running programs. (Bad) Before running programs, enter LOG-ON sequence. (E)

4.1.4-16 Easy Ways to Get Guidance (Tier 2 - General)
Operators should be able to switch easily between information handling and guidance material.
COMMENT: Guidance might be displayed as a temporary "window" overlay on the working display, which a operator could request or suppress at will. (E)

4.1.4-17 Speech Output (Tier 3 - Design Details)
Computer-generated speech output for guidance messages should be used only when attention may not be directed toward a visual display.
COMMENT: Computer-generated speech may be useful when attention is focused away from a visual display. (E)

4.1.4-18 Limited Number of Spoken Messages (Tier 3 - Design Details)
Computer-generated speech should be limited to a few messages.
COMMENT: Computer-generated speech is not useful if many messages might be given at one time, or for conveying a lengthy list of menu options. (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.5 Status Information

4.1.5-1 Indicating Status (Tier 1 - Use)
Indication of system status should be presented at all times.
COMMENT: Status display can be explicit (e.g., by message), or can be implicit (e.g., by a displayed clock whose regular time change offers assurance that the computer link is still operating). Alternatively, system status information may be provided at operator request. (E)

4.1.5-2 Operator Status (Tier 1 - Use)
Displays or messages detailing the operator's status should be provided.
COMMENT: For example, files in use and ongoing processing. (D)

4.1.5-3 Operational Mode (Tier 1 - Use)
When results of operator action are contingent upon operational modes, the current mode should be displayed.
COMMENT: (E)

4.1.5-4 System Load (Tier 1 - Use)
When task performance is affected by operational load, operators should be able to obtain status information indicating current system performance, expressed in terms of computer response time.
COMMENT: It may be necessary to define a "standard" function for which computer response time is predicted on a normalized basis. (E)

4.1.5-5 Other Operators (Tier 1 - Use)
When task performance requires data exchange and/or interaction with other operators, operators should be able to obtain status information concerning others currently using the system.
COMMENT: (D,E)

4.1.5-6 Keyboard Lock (Tier 1 - Use)
When the keyboard is locked or the terminal is disabled, the status should be displayed.
COMMENT: For example, control lockout may be signaled by absence of the cursor from the display, or by a change in the shape of the cursor. An auditory signal should be presented. (E)

4.1.5-7 Consistent Status Presentation (Tier 2 - Consistency)
Status information should be presented in a specific message window or in a consistent screen location.
COMMENT: (D)

4.1.5-8 LOG-ON Feedback. (Tier 2 - Feedback)
Feedback in log-on procedures should be provided.
COMMENT: (E)

4.1.5-9 Processing Delay (Tier 2 - Feedback)
When system functioning requires the operator to stand by, periodic feedback should present the reason for the delay.
COMMENT: When a process or sequence is completed by the system, positive indication should be presented to the operator concerning the outcome of the process and requirements for subsequent operator actions. Successive periodic feedback messages should differ in wording from presentation to presentation, or be otherwise indicated. (A,B)

4.1.5-10 Status Message Alert (Tier 2 - General)
Status messages should be accompanied with a consistent auditory signal to alert when a message has been displayed.

COMMENT: (D)

4.1.5-11 Indicating Operational Mode (Tier 2 - General)
When an action establishes a change in operational mode that affects operator actions, current mode should be indicated.
COMMENT: For example, selection of a DELETE mode should produce a warning signal on the display. (E)

4.1.5-12 LOG-ON Failure (Tier 2 - General)
Where LOGON is incorrect, a message should explain (1) that the LOGON procedure was unsuccessful and (2) why the procedure failed.
COMMENT: For example, "Incorrect LOGON sequence, expired password." (D)

4.1.5-13 LOG-ON Delay (Tier 2 - General)
Where LOG-ON is denied because of system unavailability, an advisory message should be displayed.
COMMENT: For example, "System is down for maintenance until 9: 30 AM." Avoid "as soon as possible" messages. (E)

4.1.5-14 Wording of Status Messages (Tier 3 - Design Details)
Status messages should be free from jargon.
COMMENT: The use of standard acronyms and abbreviations is acceptable. (D)

4.1.5-15 Context (Tier 3 - Design Details)
When the results of an entry depend upon context or mode, context indication should be provided.
COMMENT: For example, when the effects of entries are contingent upon operational modes, indicate the current mode. (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.6 Routine Feedback

4.1.6-1 Feedback During Data Entry (Tier 2 - Feedback)
Display feedback should be provided for all operator actions during data entry.
COMMENT: For reasons of data protection, it may not be desirable to display passwords and other secure entries. (E)

4.1.6-2 Feedback for Completion of Data Entry (Tier 2 - Feedback)
The computer should acknowledge completion of a data entry transaction with success or failure confirmation.
COMMENT: In a sequence of routine, repetitive data entry transactions, successful completion of one entry might result simply in regeneration of the initial (empty) data entry display, in order to speed the next entry in the sequence. Successful data entry should not be signaled merely by automatic erasure of entered data from the display, except possibly in the case of repetitive data entries. For single data entry transactions, it is preferred to leave entered data on the display until the operator takes an explicit action to clear the display. (E)

4.1.6-3 Feedback when Changing Data (Tier 2 - Feedback)
If an operator requests change (or deletion) of a data item that is not currently being displayed, the operator should be able to display the old data before confirming the change.
COMMENT: Displayed feedback will help prevent inadvertent data change, and is particularly useful in protecting delete actions. (E)

4.1.6-4 Indicating Item Selection (Tier 2 - Feedback)
Display items selected for operation (such as icons or text) should be highlighted.
COMMENT: This provides a routine natural feedback that item selection has been accomplished, and provides indication as to what selection has been made. (E)

4.1.6-5 Feedback for Control Entries (Tier 2 - Feedback)
The computer should acknowledge every control entry immediately.
COMMENT: (E)

4.1.6-6 Indicating Option Selection (Tier 2 - Feedback)
When previously selected control options are still operative, those options should be displayed.
COMMENT: (E)

4.1.6-7 Status Indication During Processing (Tier 2 - Feedback)
Indication of transaction status should be presented whenever the complete response to a operator entry is delayed.
COMMENT: Delays in computer response longer than a few seconds can be disturbing, especially for a transaction that is usually processed immediately. In such a case, intermediate feedback should be provided. When system functioning requires the operator to stand-by, WORKING, BUSY, or WAIT messages should be displayed until interaction is possible. Where the delay is likely to exceed 15 seconds, the operator should be informed. For delays exceeding 60 seconds, a count-down display should show delay time remaining. (E)

4.1.6-8 Indicating Completion of Processing (Tier 2 - Feedback)
When processing in response to a control entry is lengthy, positive indication of processing completion should be provided.
COMMENT: For long delays, interim feedback on processing status (before completion) should be provided. Interim messages, however, should not interfere with operator activities. (E)

4.1.6-9 Feedback for Operator Interrupt (Tier 2 - Feedback)
Following operator interrupt of data processing, an advisory message should be displayed.
COMMENT: (E)

4.1.6-16 Feedback for Print Requests (Tier 2 - Feedback)
An advisory message should be presented confirming that a print request is being processed.
COMMENT: (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.7 Error Feedback

4.1.7-1 Informative Error Messages (Tier 1 - Use)
When the computer detects an entry error, an error message should be displayed stating the error and possible subsequent operations.
COMMENT: For example, (Good) "Code format not recognized; enter two letters, then three digits." (Bad) "Invalid input." Operators should not have to search through reference information to translate error messages. (E)

4.1.7-2 Invalid Action (Tier 1 - Use)
Where an entry is invalid or inoperative at the time of selection, no action should result except a display of an advisory message indicating appropriate functions, options, or commands.
COMMENT: For example, attempting to print a document from within an edit mode. (A)

4.1.7-3 Task-Oriented Error Messages (Tier 2 - Task Compatibility)
Wording for error messages should be appropriate to the task.
COMMENT: For example, (Good) "Trend Point number not recognized check the number." (Bad) "Entry error - Status Flag 4." (E)

4.1.7-4 Brief Error Messages (Tier 2 - General)
Error messages should be brief and informative.
COMMENT: For example, use "Entry must be a number." rather than "Alphabetic characters are not acceptable in this data field or transaction." (E)

4.1.7-5 Neutral Wording for Error Messages (Tier 2 - General)
Error messages should use neutral wording.
COMMENT: Error messages should not imply blame to the operator, personaliz he computer, or attempt to make a message humorous. For example, use (Good) Entry must be a number. (Bad) Illegal entry. (Bad) I need some digits. (Bad) Don't be dumber, use a number. (E)

4.1.7-6 Non-Disruptive Error Messages (Tier 2 - General)
The computer should display an error message only after completion of an entry.
COMMENT: For example, an error message should not be generated as wrong data are keyed, but only after an explicit ENTER action has been taken. (E)

4.1.7-7 Advisory Error Messages (Tier 2 - General)
Where data or control entry is made from a small set of alternatives, error messages should indicate the correct alternatives.
COMMENT: (E)

4.1.7-8 Displaying Erroneous Entries (Tier 2 - General)
When an entry error has been detected, the erroneous entry should remain displayed.
COMMENT: The error itself will provide information as to the nature of the error. (E)

4.1.7-9 Cursor Placement Following Error (Tier 2 - General)
The location of a detected error should be marked.
COMMENT: For example by positioning the cursor at that point on the display, i.e., at that data field or command word. (E)

4.1.7-10 Indicating Repeated Errors (Tier 2 - General)
If a operator repeats an error, a noticeable change should exist in the displayed error message.
COMMENT: For example, a display of the same verbal message but with changing annotation. (E)

4.1.7-11 Removing Error Messages (Tier 2 - General)
Displayed error messages should be removed after the error has been corrected.
COMMENT: (E)

4.1.7-12 Errors in Stacked Commands (Tier 2 - General)
If only a portion of a merged command can be executed, guidance should be provided to permit correction, completion, or cancellation of the merged command.
COMMENT: If an error is detected in a group of entries, the system should process correct commands until the error is displayed. (A,B)

4.1.7-13 Multilevel Error Messages (Tier 2 - General)
Following the output of a simple error message, operators should be able to request a more detailed explanation of the error.
COMMENT: A more complete discussion of each error should be made available on-line. (E)

4.1.7-14 Cautionary Messages (Tier 2 - General)
When a data or command entry error is suspected but cannot be determined (in terms of system error logic), a cautionary message asking confirm should be displayed.
COMMENT: For example,: "Cooldown rate of 200 °F per hour degrees is outside the normal range; confirm or change entry." (E)

4.1.7-15 Multiple Error Messages (Tier 3 - Design Details)
Notification should be made for each error when multiple errors are detected.
COMMENT: For example, "DATE should be numeric [+ 2 other errors]". The computer should place the cursor in the data field referred to by the displayed error message, with other error fields highlighted. There should also be means to request sequential display of the other error messages. (E)

4.1.7-16 Error Message Placement (Tier 3 - Design Details)
Error messages should be presented at the point of the error or in a consistent area of the display.
COMMENT: (D)

4.1.7-17 Documenting Error Messages (Tier 3 - Design Details)
As a supplement to on-line guidance, system documentation should include a listing and explanation of all error messages.
COMMENT: (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.8 Job Aids

4.1.8-1 On-Line System Guidance (Tier 1 - Use)
Reference material describing system capabilities and procedures should be available on-line.
COMMENT: (E)

4.1.8-2 Guidance Information Always Available (Tier 1 - Use)
Specific guidance should be available for display at any point in a transaction sequence.
COMMENT: (E)

4.1.8-3 Index of Data (Tier 1 - Use)
An on-line data index (procedures, etc) should be provided.
COMMENT: The data index should indicate file names, objects, properties, and other aspects of file structure that might be used to access data. (E)

4.1.8-4 Index of Commands (Tier 1 - Use)
For command entry, an on-line command index should be provided.
COMMENT: (E)

4.1.8-5 Dictionary of Abbreviations (Tier 1 - Use)
A dictionary of abbreviations should be provided.
COMMENT: (E)

4.1.8-6 Logical Menu Structure (Tier 2 - Sequencing and Grouping)
Menu options should be in logical groups.
COMMENT: (E)

4.1.8-7 Transaction-Specific Option Display (Tier 2 - Task Compatibility)
Control options that are appropriate to the current transaction should be indicated on the display.
COMMENT: An exception, control options that are generally available at every step in a transaction sequence should be treated as implicit options that need not be included in a display of specific current options. (E)

4.1.8-8 Guidance for OPERATOR GUIDANCE (Tier 2 - Feedback)
At every point in a transaction sequence, guidance should be provided as to how to continue.
COMMENT: For example, use (Good) "Procedures are current through March 1991. Press STEP key to continue." rather than (Bad) "Data are current through March 1991." (E)

4.1.8-9 General List of Control Options (Tier 2 - General)
A general list (menu) of control options should be provided that is always available to serve as a consistent starting point to begin transactions.
COMMENT: (E)

4.1.8-10 Record of Past Transactions (Tier 2 - General)
The operator shuould be able to request a displayed record of past operations.
COMMENT: Near term tasks related to ongoing operations should be available. (E)

4.1.8-11 Access to Job Aids (Tier 3 - Design Details)
Explicit actions should be required to access or suppress job performance aids.
COMMENT: (D)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.9 Operator Performance Monitoring

4.1.9-1 Transaction Records (Tier 3 - Design Details)
The computer should maintain records of operator transactions.
COMMENT: (E)

4.1.9-2 Data Access Records (Tier 3 - Design Details)
The computer should maintain records of data access.
COMMENT: For example, which data files, categories, or items have been called out for display. (E)

4.1.9-3 Error Records (Tier 3 - Design Details)
Errors should be recorded.
COMMENT: (E)

4.1.9-4 HELP Records (Tier 3 - Design Details)
Requests for HELP should be recorded.
COMMENT: (E)

4.1.9-5 Notifying Operators (Tier 3 - Design Details)
Operators should be informed of records kept of individual performance.
COMMENT: (E)

4.0 OPERATOR AIDS
4.1 Routine System Messages and Guidance
4.1.10 Help

4.1.10-1 HELP (Tier 1 - Use)
Operators should be able to obtain on-line guidance by requesting HELP.
COMMENT: (E)

4.1.10-2 Standard Action to Request HELP (Tier 2 - Consistency)
A simple, standard action should be available to request HELP.
COMMENT: Operators should have multiple methods of requesting help. For example, a operator might (1) select Help in a pull-down menu, (2) type a "Help" command, and/or (3) press a Help Function Key. (E)

4.1.10-3 Task-Oriented HELP (Tier 2 - Task Compatibility)
HELP request should be tailored to task context.
COMMENT: For example, if an error in command entry has just been made, HELP should display information concerning that command, its function, its proper structure and wording, required and optional parameters, etc. (E)

4.1.10-4 Access to HELP (Tier 2 - General)
Operators should be able to access Help at any point.
COMMENT: A operator should be able to request HELP at any point in a transaction sequence. The procedure should always be the same, whether the operator wants an explanation of a particular data entry, a displayed data item, or a command option. (D)

4.1.10-5 Browsing HELP (Tier 2 - General)
Operators should be able to browse on-line HELP.
COMMENT: (E)

4.1.10-6 Return from HELP (Tier 2 - General)
The operator should be able to easily return to the task after accessing HELP.
COMMENT: (A)

4.1.10-7 Automatic HELP (Tier 3 - Design Details)
When appropriate, HELP should be automatically provided.
COMMENT: A condition for automatic help might be frequent errors in a specific interaction with the system. However, operators should be able to limit automatically-presented help displays with a single action. (D)

4.1.10-8 Clarifying HELP Requests (Tier 3 - Design Details)
When a request for HELP is ambiguous in context, the computer should initiate a dialogue to specify what data, message or command requires explanation.
COMMENT: For example, the computer might ask a operator to point at a displayed item about which HELP is requested. (E)

4.1.10-9 HELP Context (Tier 3 - Design Details)
When a help request depends upon context established by previous entries, context should be indicated.
COMMENT: Operators should be able to request a displayed record of recent transactions. (A)

4.1.10-10 Multilevel HELP (Tier 3 - Design Details)
When a HELP display provides summary information, more detailed explanations should be available.
COMMENT: (E)

4.1.10-11 HELP Guidance (Tier 3 - Design Details)
Advisory messages or prompts should be available to guide operators in accessing help messages.

COMMENT: (A)

4.1.10-12 HELP Index (Tier 3 - Design Details)
On-line HELP index should be provided.
COMMENT: (A)

4.1.10-13 Synonyms for Standard Terminology (Tier 3 - Design Details)
When a operator requests HELP on a topic, the computer should accept synonyms and abbreviations.
COMMENT: (E)

4.1.10-14 HELP Display Format (Tier 3 - Design Details)
HELP should be displayed in text and/or annotated graphics.
COMMENT: For example, displaying procedural data in a flowchart format. (D)

4.1.10-15 HELP Security (Tier 3 - Design Details)
Design of the Help function should be consistent with system security restrictions.
COMMENT: (D)

4.0 OPERATOR AIDS
4.2 Decision Aids
4.2.1 Expert Systems
4.2.1.1 Dialog

4.2.1.1-1 Information Exchange (Tier - Task Compatibility)
Operator-expert system information exchange should be based on task requirements.
COMMENT: For example, the range of data types which will be input (text, numeric, graphic), the extent and frequency of data type entry, how data are acquired the range of data types which will be output by the expert system (text, numeric, graphic), the frequency of each data type output, and pacing of operator queries. (A)

4.2.1.1-2 Dialog Initiation Flexibility (Tier 1 - Use)
The system should support a flexible dialog permitting initiation of an action without canceling an ongoing transaction.
COMMENT: (A)

4.2.1.1-3 Minimize the Systems Inquire of Operators (Tier 2 - Minimizing User Actions)
Querying the operator for routine information should be minimized.
COMMENT: (A)

4.2.1.1-4 Dialog Sequencing Flexibility (Tier 2 - Flexibility of Use)
The operator-expert system dialog should be flexible in terms of the type and sequencing of operator input it will accept.
COMMENT: (A)

4.2.1.1-5 Dialog Modes for Operators (Tier 2 - General)
When interacting with the expert system, command language dialog should be avoided.
COMMENT: (A)

4.2.1.1-6 Rapid Transaction Retrieval (Tier 3 - Design Details)
The system should permit rapid retrieval of previous exchanges between the operator and the expert system for the current transaction.
COMMENT: (A)

4.2.1.1-7 Minimize Operator Request Requirements (Tier 3 - Design Details)
The operator should not have to complete all elements (e.g., fields) of an expert system requested form to complete a phase of a transaction.
COMMENT: (A)

4.0 OPERATOR AIDS
4.2 Decision Aids
4.2.1 Expert Systems
4.2.1.2 Planning and Consultation

4.2.1.2-1 Strategy Planning Provision (Tier 2 - General)
The expert system should provide the capability to plan a strategy for addressing a problem.
COMMENT: The capability provided by the expert system should include: planning aids (such as time lines, worksheets); an evaluation function which assesses the adequacy of the operator's plan and recommends revisions where necessary; the ability to form, state and test hypotheses in a manner consistent with the operator's plan; and, the capacity to store and recall plans. (A)

4.2.1.2-2 Strategy Support and Selection (Tier 2 - General)
The expert system should be able to support a complete range of problem solving strategies.
COMMENT: Including: reliability (i.e., failure rate); conditional probability; syndrome/symptom analysis; signal tracing; half-split; and, bracketing. The expert system should be capable of accepting direction from the operator in terms of which strategy to employ. (A)

4.2.1.2-3 Forward and Backward Chaining Support (Tier 2 - General)
The control strategy should support forward and backward chaining.
COMMENT: (A)

4.2.1.2-4 Action Simulation Mode Support (Tier 2 - General)
The system should support speculative analysis by providing an "Action-Simulation mode" that allows investigation of effects of an action without implementing the action.
COMMENT: Speculative analyses are "what if" scenarios. (A)

4.2.1.2-5 Interactive Explanation Capability (Tier 2 - General)
The expert system should provide interactive explanations using the facts and rules contained in its knowledge base.
COMMENT: Types of questions an expert systems should be capable of handling include: What would happen if...? Are there significant side effects to...? How do x and y interact? What causes x? What are the results (effects) of x? Given x, how should I respond? (A)

4.2.1.2-6 Action Simulation Mode Command and Identification (Tier 3 - Design Details)
Entering reconnoiter mode should require an explicit command and result in a distinguishable change in system output.
COMMENT: For example, a blinking Action Simulation mode symbol. (A)

4.0 OPERATOR AIDS
4.2 Decision Aids
4.2.1 Expert Systems
4.2.1.3 Expert System Display

4.2.1.3-1 Consistency of Coding Techniques (Tier 2 - Consistency)
Coding techniques should be consistently applied across the expert system.
COMMENT: (A)

4.2.1.3-2 Critical Information Alert (Tier 3 - Design Details)
If critical information becomes available during an explanation session, the system should indicate so, via prompts or warning mechanisms, and display the information to the operator.
COMMENT: (A)

4.2.1.3-3 Graphic Representation of System Configuration and Parameters (Tier 3 - Design Details)
Graphics, such as a system schematic, should be available to depict relationships between system configuration and measurable parameters.
COMMENT: (A)

4.2.1.3-4 Graphic Representation of Rules (Tier 3 - Design Details)
The expert system should be able to graphically represent its rules network and reasoning process.
COMMENT: This capability should be available to the operator as an adjunct to the explanation subsystem. (A,B)

4.2.1.3-5 Status Display Using Coding Techniques (Tier 3 - Design Details)
Graphics should portray system and process status through the use of color, shading, or similar coding techniques.
COMMENT: (A)

4.2.1.3-6 Freeze Capability for Dynamic Information (Tier 3 - Design Details)
Display of dynamic information should "freeze" during explanation sessions.
COMMENT: (A)

4.2.1.3-7 Status Change Highlights (Tier 3 - Design Details)
At the completion of the explanation session, the system should update and highlight changes in displayed values and request acknowledgement by the operator.
COMMENT: (A)

4.2.1.3-8 Off-line Printing Capability (Tier 3 - Design Details)
The expert system should have an off-line printer to permit requests for hardcopy of data including: screen displays (text or graphics), summaries of consultations, lists of rules/facts invoked during a consultation, and summaries of hypotheses tested and data employed during a consultation.
COMMENT: (A)

4.0 OPERATOR AIDS
4.2 Decision Aids
4.2.1 Expert Systems
4.2.1.4 Certainty Factors

4.2.1.4-1 Certainty Factors Representation Capability (Tier 2 - General)
The rule set for an expert system should represent certainty factors to the operator.
COMMENT: Certainty factors may be contained in the data, in one or more rules, or both. (A)

4.2.1.4-2 Use of Decimal Coding of Certainty (Tier 2 - General)
Certainty factors should be represented as a decimal number from -1 to +1; with -1 indicating absolute certainty that a fact is not true, and +1 indicating absolute certainty that a fact is true.
COMMENT: (A)

4.2.1.4-3 Cumulative Certainty Representation (Tier 3 - Design Details)
Certainty factors should reflect the cumulative certainty for all elements of the conclusion being drawn.
COMMENT: (A)

4.2.1.4-4 Underlying Certainty Judgement Rationale (Tier 3 - Design Details)
In addition to numerical values of certainty, the system should provide indication of rationale underlying the uncertainty, such as conditions when the rule is invalid.
COMMENT: (A)

4.0 OPERATOR AIDS
4.2 Decision Aids
4.2.1 Expert Systems
4.2.1.5 Explanation Facilities

4.2.1.5-1 Explanation Capability (Tier 1 - Use)
The expert system should be capable of explaining its behavior, problem solutions, and knowledge.
COMMENT: (A)

4.2.1.5-2 Consistent Nomenclature (Tier 2 - Consistency)
The explanation facility should employ the same nomenclature, abbreviations and acronyms for system elements as those employed by the operator.
COMMENT: (A)

4.2.1.5-3 Respond to Operator Requests (Tier 2 - General)
The expert system should respond to operator requests to clarify questions and assertions.
COMMENT: (A)

4.2.1.5-4 Explanation Display (Tier 2 - General)
The system should display rule-based and descriptive explanations, as requested by the operator.
COMMENT: (A)

4.2.1.5-5 Strategy Explanation (Tier 2 - General)
At any point during a transaction, the expert system should explain which problem solving strategy is being employed, why a particular strategy was selected, and the current status.
COMMENT: (A)

4.2.1.5-6 Operator Control of Explanation Detail (Tier 2 - General)
The level of detail of information presented as part of an explanation or justification should be under the control of the operator.
COMMENT: (A)

4.2.1.5-7 Display of Current Rule (Tier 2 - General)
At any point during a consultation, the expert system should display the rule currently being invoked.
COMMENT: (A)

4.2.1.5-8 Representing Results (Tier 2 - General)
At the request of the operator, the expert system should represent forward causality, in the form of predictions; and backward causality, in the form of speculative reconstruction of events.
COMMENT: (A)

4.2.1.5-9 Rule Recording (Tier 3 - Design Details)
The expert system should automatically record all rules invoked during a consultation.
COMMENT: (A)

4.2.1.5-10 Post Hoc Rule-Event Recall (Tier 3 - Design Details)
Following a consultation, the explanation facility should recall each invoked rule and associate it with a specific event (i.e., question or conclusion) to explain the rationale for the event.
COMMENT: (A)

4.2.1.5-11 Knowledge Base Search to Operator Query (Tier 3 - Design Details)
The explanation facility should search the knowledge base to locate rules or items of knowledge in response to specific inquiries from the operator.

COMMENT: (A)

4.2.1.5-12 Inadequate Knowledge Alert (Tier 3 - Design Details)
The explanation facility should alert when a problem is beyond its current capabilities, and instruct as to what additional knowledge or rules are required to complete the transaction.
COMMENT: (A)

4.2.1.5-13 Strategy Selection Explanation (Tier 3 - Design Details)
At any point during a transaction, the expert system should explain which problem solving strategy is being employed, why a particular strategy was selected, and the current status.
COMMENT: (A)

4.2.1.5-14 Consistency with Operator Strategies (Tier 3 - Design Details)
The presentation of information to explain the knowledge of the system should be consistent in content and format with the cognitive strategies and mental models employed by the operator.
COMMENT: Particularly when the operator and the expert system are independently working the same problem. (A)

4.2.1.5-15 Strategy and Process Understanding (Tier 3 - Design Details)
Explanation facility knowledge should include an understanding of the strategies and processes by which rules and facts are applied.
COMMENT: (A)

4.2.1.5-16 Explicit Rule Representation (Tier 3 - Design Details)
Rules should be represented explicitly in the knowledge base and encoded such that it is accessible to the explanation facility and can be translated for human understanding.
COMMENT: (A)

4.2.1.5-17 Rule Exceptions (Tier 3 - Design Details)
Rule exceptions should be explicitly contained in the knowledge base and available to the operator as part of the explanation facility.
COMMENT: (A)

4.2.1.5-18 Access to Hypothesis Ordering Rationale (Tier 3 - Design Details)
The explanation facility should have access to the rationale by which hypotheses in a rule's premise were ordered.
COMMENT: For example, the rank ordering of decision rule priority. (A)

4.2.1.5-19 Explanation Detail Default (Tier 3 - Design Details)
Control of the explanation facility should be designed so the operator may specify the level of detail as a default option at the beginning of a transaction.
COMMENT: (A)

4.2.1.5-20 Explanation by Means-Ends Analysis Systems (Tier 3 - Design Details)
Systems employing means-ends analysis as an element of control strategy should provide descriptions of the current state and goal state; differences between the current state and goal state; all candidate operators, including the type/amount of difference they eliminate, and strategies for transforming the current state or revising the goal state.
COMMENT: (A)

4.2.1.5-21 Provide Goodness-of-Fit Estimate (Tier 3 - Design Details)
When representing reasoning processes, the expert system should be capable of describing how observed data support each hypothesis under consideration and how hypotheses under consideration account for the observed data.
COMMENT: (A)

5.0 INTER-PERSONNEL COMMUNICATION

5.1 General

5.1-1 Interactive Communication (Tier 1 - Use)

Users should be able to communicate interactively with other users who are currently using the same system.

COMMENT: (E)

5.1-2 Consistent Procedures (Tier 2 - Consistency)

Procedures for preparing, sending and receiving messages should be consistent from one transaction to another, and consistent with procedures for other information handling tasks.

COMMENT: Procedures should be the same for handling different kinds of messages and for messages sent to different destinations, although procedures for handling high-priority messages might incorporate special actions to ensure special attention. Users should be able to use the same procedures to enter, edit and display messages as they use to enter, edit and display other kinds of data. Data transmission that does not involve formal messages might by-pass standard procedures as in the direct linking of terminals, or might require special procedures as in the transfer of data files. (E)

5.1-3 Minimal User Actions (Tier 2 - Minimizing User Actions)

The data transmission procedures should be designed to minimize required user actions.

COMMENT: Examples -- in some applications, software logic might prepare and transmit messages automatically, derived from data already stored in the computer; software logic might provide automatic reformatting of stored data for transmission, where format change is required; interface software might provide automatic insertion into messages of standard header information, distribution lists, etc. (E)

5.1-4 Flexible Control of Data Transmission (Tier 2 - Flexibility of Use)

Flexible control of data transmission should be provided, so that users can decide what data should be transmitted, when, and where.

COMMENT: Flexible control of message handling will help ensure that routine data transmissions will not interfere with a user's other activities. Exceptions are monitoring and operation control applications, in which data transmission must often be event-driven. (E)

5.1-5 Flexible Message Filing (Tier 2 - Flexibility of Use)

Users should be provided with flexible capabilities for filing copies of draft messages during preparation, transmitted messages, and received messages, and organizing those message files.

COMMENT: For most information handling systems, it is probably desirable to design the user interface so that users do not have to concern themselves with the detailed structure of data files. For message handling, however, users will often need to decide themselves whether and where to store transmitted data, i.e., how messages should be organized in their filing. Appropriate computer aids should be provided for message storage and retrieval, to permit naming of message files, grouping of files into larger "folders", and indexing the resulting file structure. (E)

5.1-6 Functional Integration (Tier 2 - General)

Data transmission functions should be integrated with other information handling functions within a system.

COMMENT: A user should not have to log off from a general data processing system and log on to some other special system in order to send or receive a message. If data transmission facilities are in fact implemented as a separate system, that separation should be concealed in user interface design, so that a user can move from general information handling to message handling without interruption. A user should be able to communicate with other users without exiting an application in which he or she is working. A user should be able to transmit data using the same computer system (and procedures) used for general entry, editing, display, and other processing of data. (E)

5.1-7 Control by Explicit User Action (Tier 2 - General)

Both sending and receiving messages should be accomplished by explicit user action.

COMMENT: Automatic message generation and receipt will be helpful in many applications, but in such cases the user should be able to monitor transmissions, and should be able to participate by establishing, reviewing and/or changing the computer logic that controls automatic data transmission. (E)

5.1-8 Functional Wording (Tier 2 - General)
Functional wording should be employed for the terms used in data transmission so that those terms will match users' work-oriented terminology.
COMMENT: Functional wording should be employed for preparing and addressing messages, for initiating and controlling message transmission and other forms of data transfer, and for receiving messages. In general, a user should not have to learn the technical details of communication protocols, codes for computer "handshaking", data format conversion, etc., but should be able to rely on the computer to handle those aspects of data transmission automatically. For example, a user should be able to address messages to other people or agencies by name, without concern for computer addresses, communication network structure and routing. (E)

5.1-9 Automatic Queuing (Tier 2 - General)
The computer should provide automatic queuing of outgoing messages pending confirmation of transmission, and of incoming messages pending their review and disposition.
COMMENT: For example, interface software might provide automatic insertion into messages of standard header information, distribution lists, etc., or provide automatic record keeping, message logging, status displays, etc. (E)

5.1-10 Interrupt (Tier 3 - Design Details)
Users should be able to interrupt message preparation, review, or disposition, and then resume any of those tasks from the point of interruption.
COMMENT: (E)

5.1-11 Message Highlighting (Tier 3 - Design Details)
Software capabilities should be provided to annotate transmitted data with appropriate highlighting to emphasize alarm/alert conditions, priority indicators, or other significant second-order information that could affect message handling.
COMMENT: Second-order information, i.e., data about data, will often aid the handling and interpretation of messages. Such annotation might be provided automatically by software logic (e.g., a computer-generated date-time stamp to indicate currency), or might be added by the sender of a message to emphasize some significant feature (e.g., attention arrows), or by the receiver of a message as an aid in filing and retrieval. (E)

5.1-12 Printing Messages (Tier 3 - Design Details)
Within the constraints of data security, users should be able to generate printed copies of transmitted data, including messages sent and received.
COMMENT: User requirements for printed data are often unpredictable, and printing restrictions may handicap task performance. Rather than restrict printing, appropriate procedures for restricting further distribution of printed messages should be employed. (E)

5.2-1 Stored Message Forms (Tier 1 - Use)
When message formats should conform to a defined standard or are predictable in other ways, prestored forms should be provided to aid users in message preparation.
COMMENT: It may also be desirable to enable users to modify stored forms for their own purposes, and to define and store their own message forms. For example, a stored form might be used to create a routine report for transmission to a standard distribution list. (E)

5.2-2 Automatic Message Formatting (Tier 1 - Use)
When data must be transmitted in a particular format, as in data forms or formatted text, computer aids to generate the necessary format automatically should be provided.
COMMENT: It is not sufficient merely to provide computer checking of formats generated by the user. Computers should help users to avoid errors, and not just to identify errors. When transmitting data, a user should not have to convert those data from whatever format was used originally for data entry. (E)

5.2-3 User-Designed Message Formats (Tier 1 - Use)
When required message formats will vary unpredictably, users should be able to c[illegible] and transmit messages with a format of their own design.
COMMENT: Establishing new formats, particularly if automatic data validation mus[illegible] [illegible]fied fields, may require special skills. Therefore this capability might be provided to a system [illegible] to all system users. (E)

5.2-4 Unformatted Text (Tier 1 - Use)
Users should be able to compo[illegible] transmit messages as unformatted text.
COMMENT: Allowing users to create arbitrary text messages (sometimes called "chatter") will let users deal flexibly with a variety of communication needs not anticipated by system designers. (E)

5.2-5 Message Composition Compatible with Data Entry (Tier 2 - Consistency)
Procedures for composing messages should be compatible with general data entry procedures, especially those for text editing.
COMMENT: A user should not have to learn procedures for entering message data that are different from more general data entry, particularly if those procedures might involve conflicting habits. In systems where special editing capabilities are available for special tasks, as in some programming systems, users should be able to choose whether a special computer editor will be used for message preparation. (E)

5.2-6 Flexible Data Specification (Tier 2 - Flexibility of Use)
Users should be provided with flexible means for specifying the data to be transmitted.
COMMENT: When preparing a message, a user may wish to specify data to be included in the message by selecting a particular file, either all or a designated part, or by defining a data category. (E)

5.2-7 Variable Message Length (Tier 2 - General)
Users should be able to prepare messages of any length.
COMMENT: In particular, data transmission facilities should not limit the length of a message to a single display screen or to some fixed number of lines. There will usually be some implicit limit on message length imposed by storage capacity or the amount of time it would take to transmit a very long message. However, a user might sometimes choose to increase storage or accept transmission delays in order to send a long message required by a particular task. (E)

5.2-8 Data Forms (Tier 2 - General)
In preparing data forms for transmission, users should be able to enter, review, and change data on an organized display with field labels rather than being required to deal with an unlabeled string of items.
COMMENT: User composition and review [illegible] unlabeled data strings, especially those requiring delimiters to mark

items, will be prone to error. If such data strings are needed for economy of transmission, they should be generated by the computer automatically from data entered in a form-filling dialogue. (E)

5.2-9 Tables and Graphics (Tier 2 - General)
In preparing tabular or graphic data for transmission, users should be able to enter, review, and change data in customary formats.
COMMENT: Regardless of what the computer-imposed format will be for actual transmission purposes. For example, tabular data in messages should be prepared (and later received) in row-column format, even though the table entries might actually be transmitted as a coded string of data items. (E)

5.2-10 Incorporate Existing Files (Tier 3 - Design Details)
Users should be able to incorporate an existing data file in a message, or to combine several files into a single message for transmission.
COMMENT: It should not be necessary for a user to re-enter for transmission any data already entered for other purposes. It should be possible to combine stored data with new data when preparing messages for transmission. (E)

5.2-11 Incorporate Other Messages (Tier 3 - Design Details)
Users should be able to incorporate other messages in a message being prepared for transmission.
COMMENT: For example, a user might wish to forward with comments a message received from someone else. (E)

5.2-12 Editing Address Fields (Tier 3 - Design Details)
Users should be able to edit the address fields in the header of a message being prepared for transmission.
COMMENT: (A)

5.2-13 Saving Draft Messages (Tier 3 - Design Details)
Users should be able to save draft messages during their preparation, or upon their completion.
COMMENT: A user should not be forced to recreate a message if its preparation is interrupted for some reason. Users should be able to specify how to save draft messages (i.e., in what file), just as they may decide how to save copies of transmitted and received messages. (E)

5.2-14 Message Storage (Tier 3 - Design Details)
Users should be able to save or delete messages that they have created prior to or after sending.
COMMENT: (D)

5.0 INTER-PERSONNEL COMMUNICATION

5.3 Addressing Messages

5.3-1 Destination Selection (Tier 1 - Use)

Users should be able to specify the destination(s) to which data will be transmitted.

COMMENT: Specification of message destination might be in terms of system users, as individuals or groups, or other work stations and terminals (including remote printers), or users of other systems. Standard destinations may be specified as a matter of routine procedure, with special destinations designated as needed for particular transactions. For most applications, it is important that users be able to send a message to multiple destinations with a single transmission action. For multiple recipients, it will usually be helpful to show all addresses to all recipients, so that they will know who else has received the message. In some cases, however, it may be desirable to permit transmission of "blind" copies. (E)

5.3-2 Automatic Addressing of Reply (Tier 2 - Minimizing User Actions)

The appropriate address(es) should be automatically provided for users responding to messages.

COMMENT: (E)

5.3-3 Standard Address Header (Tier 2 - General)

For addressing and identifying messages, a basic set of header fields should be provided that can be interpreted by all systems to which users will send messages.

COMMENT: In any particular system, it should be possible for users (or a system administrator) to specify additions to the standard header fields in order to convey more descriptive information about different types of messages. Possible additions to the basic address fields might include SUBJECT, KEYWORDS, and REFERENCES. The address of a recipient should occur only once in a message. For example, basic header fields might include DATE, TO, FROM, COPIES, and perhaps some message identification number. (E)

5.3-4 Prompting Address Entry (Tier 2 - General)

When a user must specify the address for a message, prompting should be provided to guide the user in that process.

COMMENT: Prompting might consist of a series of questions to be answered, or an address form to be completed by the user, or reminders of command entries that may be needed. (E)

5.3-5 Address Verification (Tier 2 - General)

Computer checks for address accuracy (i.e., recognized content and format) should be provided.

COMMENT: (A)

5.3-6 User-Assigned Nicknames for Addressing (Tier 3 - Design Details)

Users should be able to define nicknames for formal addresses, to save those nicknames in their own files, and to specify those nicknames when addressing messages.

COMMENT: There are several implications to such a nickname capability. First, a user might wish to assign nicknames to computers and other devices (e.g., printers) as well as to people. Second, if a user defines a nickname, the computer must check to ensure that the nickname is unique in that user's nickname file. Third, nicknames must take precedence over system names when a user addresses a message; i.e., the computer must check the user's nickname file before checking the system-wide address list. Fourth, nicknames should not be transmitted; i.e., the computer should automatically transform nicknames into standard system addresses when completing the address header for message transmission. (E)

5.3-7 Address Directory (Tier 3 - Design Details)

Users should be provided with a directory showing all acceptable forms of message addressing for each destination in the system, and for links to external systems.

COMMENT: In addition to the names of people, users may need to find addresses for organizational groups, functional positions, other computers, data files, work stations, and devices. The directory should include specification of system distribution lists as well as individual addresses. (E)

5.3-8 Aids for Directory Search (Tier 3 - Design Details)

Computer aids so that a user can search an address directory by specifying a complete or partial name should be provided.
COMMENT: Users will often remember a partial address, even if they cannot remember its complete form. (E)

5.3-9 Extracting Directory Addresses (Tier 3 - Design Details)
Users should be able to extract selected addresses from a directory for direct insertion into a header in order to specify the destination(s) for a message. Users may also wish to extract addresses from the directory in order to build their own distribution lists, or add to a "nickname" file.
COMMENT: Direct insertion of addresses from a directory will avoid errors which a user might make in manual transcription and entry, as well as being faster. (E)

5.3-10 System Distribution Lists (Tier 3 - Design Details)
Formal distribution lists recognized by the system should be provided so that users can specify multiple addresses with a single distribution list name. Recognized system distribution lists need not be expanded to the names of individual addressees when a message is transmitted.
COMMENT: For example, a formal distribution list might be maintained of people who are working on a particular project, or who are members of a particular organizational group. The authority to use system distribution lists may be limited in some cases. For example, not everyone might be permitted to send messages to a distribution list of all employees in a large organization. (E)

5.3-11 Informal Distribution Lists (Tier 3 - Design Details)
Individuals or groups should be allowed to create their own informal distribution lists for local use.
COMMENT: As a procedural matter, informal distribution lists shared by a group might be created and maintained by some designated custodian, who could control access to such lists. Whereas any individual user's personal distribution lists might be changed freely. Such informal group and individual distribution lists should be expanded by the computer to show individual addressees prior to message transmission. (E)

5.3-12 Access to Distribution List Information (Tier 3 - Design Details)
Users should be provided with information about distribution lists on which they are included, and about those distribution lists which they are authorized to use.
COMMENT: Users should be able to discover the names of all people on distribution lists they are authorized to use. (E)

5.3-13 Serial Distribution (Tier 3 - Design Details)
Where coordinated review of messages by several recipients is required, the sender should be allowed to specify a serial distribution so that a message will be passed from one recipient to the next.
COMMENT: (A)

5.0 INTER-PERSONNEL COMMUNICATION

5.4 Initiating Transmission

5.4-1 User-Initiated Transmission (Tier 1 - Use)

Users should be able to initiate data transmission directly, by entering a single, explicit SEND command.

COMMENT: In applications where message review is critical users might be required to take some extra
CONFIRM action to release data for transmission. In some routine reporting situations it might help to initiate
message transmission automatically. More often, however, users will wish to initiate transmission themselves.
User control of initiation could permit a user to review and edit prepared messages before sending them, and possibly
catch some mistakes before they are propagated. (E)

5.4-2 User Review Before Transmission (Tier 2 - General)

When computer aids are provided for preparing, addressing, and initiating message transmission, users should be able to review and change messages prior to transmission.

COMMENT: (E)

5.4-3 Assignment of Priority (Tier 2 - General)

When messages will have different degrees of urgency, the sender of a message should be allowed to designate its relative priority, or else have the computer assign priority automatically.

COMMENT: The computer might impose limits on the priority that any particular user can assign to messages. (E)

5.4-4 Computer-Initiated Transmission (Tier 2 - General)

When standard messages must be transmitted, as when a computer is monitoring external events and reporting data change, computer aids should be provided to initiate transmission automatically.

COMMENT: Automatic transmission of routine messages will reduce user workload and help ensure timely
reporting. However, users should be able to monitor automatic message initiation, and may sometimes wish to
modify initiation logic. Appropriate review/change procedures should be provided, perhaps under control of a system
administrator. For example, many operations-monitoring tasks might benefit from automatic generation of
messages to report routine events. (E)

5.4-5 Automatic Queuing for Transmission (Tier 2 - General)

Automatic queuing of outgoing messages should be provided, in order to reduce the need for user involvement in the routine processing of data transmission.

COMMENT: Specific requirements will vary with the application, but some queuing should be provided. For example, the computer might queue outgoing messages when communication channels to some addressees are temporarily unavailable, and then initiate transmission automatically when a link can be established. (E)

5.4-6 Cancel Transmission (Tier 2 - General)

Senders should be allowed to cancel a request for transmission of a message that has not yet been sent.

COMMENT: (E)

5.4-7 Optional Message Display (Tier 3 - Design Details)

For sending messages, users should be able to choose whether to transmit a displayed version or to transmit directly from computer-stored data files.

COMMENT: Message transmission from displays will permit a user to review and edit messages before sending
them. But users might sometimes wish to transmit a prepared message directly, without having first to display that
message for review. (E)

5.4-8 Information About Communication Status (Tier 3 - Design Details)

Users should be allowed access to status information concerning the identity of other system users currently on-line, and the availability of communication with external systems.

COMMENT: Such information may influence a user's choice of destinations and choice of communication methods, as well as the decision when to initiate transmission. For example, a user might choose to link directly with another user who is currently on-line, but might compose a message for deferred transmission to an inactive user. (E)

5.4-9 Sender Identification (Tier 3 - Design Details)

When a message is sent, the computer should append to it fields showing the sender's address, and the date and time of message creation and/or transmission.

COMMENT: Recipients will generally need to know the origin of any received message. For some messages, a simple identification of the sender may be sufficient. In special situations, however, it may be necessary to provide special procedures for authenticating a sender's identity. For some applications, recipients must know when a message was created, in order to assess the currency of its contents. For other applications, users may need to know when a message was transmitted; its time of creation might not be important. Like other formatting recommendations, this guideline would not apply when data transmission may be accomplished without formal messages, i.e., transmission by direct linking (where no formal headers are prepared) or by file transfer (where header information might be sent as a separate message rather than incorporated in the transmitted data file). (E)

5.4-10 Deferring Message Transmission (Tier 3 - Design Details)

Users should be able to defer the transmission of prepared messages, to be released by later action.

COMMENT: A user might wish to defer data transmission until a batch of related messeges has been prepared, or perhaps until some specified date- time for release. For example, prepared messages might be left in some "outbox" file for subsequent transmission when a user has finished an entire batch. (E)

5.4-11 Return Receipt (Tier 3 - Design Details)

Message transmission with "return receipt requested" should be provided if users will require that capability. Any "registered mail" of this kind should be labeled as such for all recipients of this mail.

COMMENT: The logic of what constitutes message "receipt" might vary from one application to another. Where sender and receiver share a common system, receipt might be defined as occurring when the recipient actually requests display of an incoming message. Where sender and receiver work with different (and perhaps dissimilar) message systems, receipt might be defined more tenuously. For example, a message might be considered "received" when the recipient is merely notified of its arrival, or opens an "in-box" permitting potential access to that message. (E)

5.4-12 Printing Messages (Tier 3 - Design Details)

Users should be able to print copies of transmitted or untransmitted messages in order to make hard-copy records.

COMMENT: User requirements for printed data are often unpredictable to system designers, and so a general printing capability should be provided. In some applications, however, security constraints might make printed records inadvisable. (E)

5.0 INTER-PERSONNEL COMMUNICATION

5.5 Controlling Transmission

5.5-1 Automatic Feedback (Tier 2 - General)

Automatic feedback for data transmission confirming that messages have been sent or indicating transmission failures should be provided as necessary to permit effective user participation in message handling.

COMMENT: Users might require notification only of exceptional circumstances, as in the event of transmission failure after repeated attempts. For the electronic equivalent of registered mail, it might be helpful to provide the sender confirmation that a message has been successfully transmitted, or possibly even to notify the sender when a recipient has actually read (displayed) the message. Specific information requirements will vary with the application, but some feedback should be provided. (E)

5.5-2 Queuing Messages Received (Tier 2 - General)

Default logic should be provided so that, unless otherwise specified by a user, the computer will route incoming messages automatically to a queue ("in-box"), pending subsequent review and disposition by the user.

COMMENT: Some computer buffering of received messages will be required for a user who is not logged on, and also to deal with near simultaneous receipt of multiple transmissions. The recommendation here is that the buffer queue for incoming transmissions be enlarged as necessary to permit indefinite retention of messages. Any queue will have limits, of course, and the user should be warned before those limits are exceeded. (E)

5.5-3 Saving Undelivered Messages (Tier 2 - General)

If message transmission is not successful, automatic storage of undelivered messages should be provided.

COMMENT: Transmission failure should not cause loss or destruction of messages, and should not disrupt the sender's work in any other way. (E)

5.5-4 Notification of Transmission Failure (Tier 2 - General)

If message transmission is not successful, the sender should be notified, if possible with an explanation of the problem.

COMMENT: It may help a user to know whether transmission has failed because of faulty addressing, or communication link failure, or some other reason, in order to take appropriate corrective action. (E)

5.5-5 User Specification of Feedback (Tier 3 - Design Details)

Users should be able to specify what feedback should be provided for routine message transmission, and also to request specific feedback for particular messages.

COMMENT: Users may wish to specify minimal feedback (or perhaps none at all) for routine message transmissions. On the other hand, users may wish to request more specific feedback for transmission of critical messages, as an electronic equivalent of registered mail. (E)

5.5-6 Single Copy Transmission (Tier 3 - Design Details)

Only one copy of any message should be transmitted to any individual addressee.

COMMENT: The problem of duplicative message transmission might arise if the same address should appear in both the TO and COPY fields of a message header, or appear once explicitly and again in some added distribution list(s). Thus one way to avoid message duplication is to ensure only a single appearance of each address in a message. If that is not practicable, then checking logic should be provided to transmit a single message to duplicated addresses. If for any reason a user did want to send multiple copies of a message to a single recipient, that should be specified explicitly in message transmission, rather than being accomplished by duplicate addressing. Receiving multiple copies of the same message can be confusing to a user, and will impose an unnecessary burden on the review and disposition of received messages. (E)

5.5-7 Queuing Failed Transmissions (Tier 3 - Design Details)

In the event of transmission failure, automatic queuing to preserve outgoing messages should be provided.

COMMENT: Automatic queuing and retransmission of outgoing messages will reduce the need for user attention. If transmission fails in repeated attempts, however, then user intervention may be required, and some notification of that problem should be given to the user. If transmission fails because of faulty addressing, the user should be notified immediately. (E)

5.5-8 Message Recall (Tier 3 - Design Details)

Users should be able to recall any message whose transmission has been initiated, if it has not yet been received by its addressee(s).

COMMENT: If a message to several addressees has been seen by some recipients but not by others, then it would be subject only to partial recall; countermanding might be a better solution. Users should be able to change their minds, in situations where a message may have been sent by mistake. The difficulty of message recall will vary with the circumstances. If a message is still in the "out-box" (i.e., it has not yet actually been sent), then its recall can be accomplished simply by canceling the transmission request. If a message has been transmitted but not yet actually received (i.e., it still resides unread in a recipient's "in-box"), then perhaps it can still be retrieved. If a message is recalled before its intended recipient has seen it, that recipient need not be notified. If the recipient has seen it, then the sender should be notified that the message cannot be recalled. In that case, the message might be canceled or countermanded procedurally, by sending some follow-up message. (E)

5.5-9 Automatic Record Keeping (Tier 3 - Design Details)

When a log of data transmissions is required, that log should be automatically maintained, based on user specification of message types and record formats.

COMMENT: The objective here is to minimize routine "housekeeping" chores for the user. Once a user has specified the appropriate logging format (i.e., what elements of each message should be recorded), computer aids should generate the log automatically, either for all messages, or for specified categories of messages, or for particular messages identified by the user. (E)

5.0 INTER-PERSONNEL COMMUNICATION

5.6 Receiving Messages

5.6-1 Message Review Compatible with Data Display (Tier 2 - Consistency)

Computer aids and procedures for reviewing messages should be consistent with other system capabilities for general data display.

COMMENT: Users should not have to learn procedures for reviewing messages that are different from general data display, particularly if those procedures might involve conflicting habits. Users should be able to page or scroll through a summary list of messages, or a particular displayed message, just as they might manipulate any other data display. Users should be able to select items from a displayed summary list of messages, just as they might select items from a displayed menu of control options. (E)

5.6-2 Message Notification at LOG-ON (Tier 2 - General)

When users log on to a system, they should be notified of any data transmissions received since their last use of the system.

COMMENT: If automatic notification of received messages is not feasible, users should be able to check for message arrival by requesting information from their general data processing system, without having to access some special message handling system for that purpose. At the least, a user should be able to find out how many new messages have arrived. Depending on the application, a user might wish to know that some message has been received, or how many messages, or what kinds of messages. (E)

5.6-3 Specifying Sources (Tier 2 - General)

For receiving messages, Users should be able to specify from what sources data are needed, and/or will be accepted.

COMMENT: Source specification might be in terms of data files, or other users, or external sources. Standard sources might be specified as a matter of routine procedure, with special sources designated as needed for particular transactions. Computer-mediated message handling offers the potential for screening out the electronic equivalent of "junk mail" or "crank calls". A user might choose to be selective in specifying the people or organizations from which messages will be received, or in specifying data categories of interest. (E)

5.6-4 Nondisruptive Notification of Arriving Messages (Tier 2 - General)

For messages arriving while a user is logged on to a system, notification of message arrival should not interfere with that user's other information handling tasks. Review and disposition of received messages, like other transactions, should generally require explicit actions by a user.

COMMENT: An incoming message should not preempt a user's working display. Instead, the computer might indicate message arrival by an advisory notice in a portion of the display reserved for that purpose. When an incoming message implies an urgent need for user attention, the user should be notified immediately. (E)

5.6-5 Indicating Priority of Received Messages (Tier 2 - General)

In applications where incoming messages will have different degrees of urgency, i.e., different implications for action, recipients should be notified of message priority and/or other pertinent information.

COMMENT: Notification of urgent messages might be routed to a special area of a user's working display for immediate reference, whereas notification of routine messages might be deferred, or perhaps routed to a printer for review at the user's convenience. If incoming messages are queued so that their arrival will not interrupt current user tasks, then users should be advised when an interruption is in fact necessary. (E)

5.6-6 User Selection of Messages (Tier 2 - General)

The user should be allowed to select any message from an ordered queue with a single action.

COMMENT: (D)

5.6-7 Authenticating Message Sources (Tier 3 - Design Details)

When a user must confirm the identity of a message source, computer aids should be provided for that purpose.

COMMENT: (E)

5.6-8 Specifying Device Destination (Tier 3 - Design Details)
For receiving messages, users should be able to choose the method of receipt, i.e., what device (files, display, printer) will be the local destination. If a specified receiving device is not operable, such as a printer that is not turned on, the computer should call that to the user's attention.
COMMENT: When messages are received via display, queuing of incoming messages should be provided so that they will not interfere with use of that display for other information handling tasks. Device destination might be specified differently for different types of messages, or for messages received from different sources. Transmitted data might be received directly into computer files. Incoming messages might be routed to an electronic display for quick review, and/or to a printer for hard-copy reference. (E)

5.6-9 Filters for Message Notification (Tier 3 - Design Details)
Users should be able to specify "filters" based on message source, type, or content, that will control what notification is provided for incoming messages.
COMMENT: For example, a user might wish the arrival of all messages from a particular source to produce a special notification of some sort. (E)

5.6-10 Filters for Ordering Message Review (Tier 3 - Design Details)
Users should be able to specify "filters" based on message source, type, or content, that can control the order in which received messages will be read.
COMMENT: The aim here is to facilitate flexible user control over the review of incoming messages. In particular, a user should not be constrained to read incoming messages in the order in which they are received. (E)

5.6-11 Filters for Message Filing (Tier 3 - Design Details)
Users should be able to specify "filters" based on message source, type, or content, that will control how messages should be filed.
COMMENT: For example, a user might want to file in a single "folder" all messages about a particular topic. (E)

5.6-12 Warning of Incompatible Format (Tier 3 - Design Details)
If a message (or other data transmission) arrives in a format incompatible with system decoding and/or device capabilities, the intended recipient should be advised to take some appropriate action that will not destroy the message itself or any other data.
COMMENT: In some instances a recipient might be able to resolve a format problem by changing the device destination specified for a particular message. Failure of message delivery should not disrupt any other work of the intended recipient. For example, the arrival of some message with an unrecognized format, or the attempted delivery of a graphic message at a text-only terminal, should not cause any system failure. Such an undeliverable message might be saved in a system file for subsequent disposition. Or that message (or some notification) might be returned to its sender. For example, if the user of an alphanumeric terminal should receive a message that includes nondisplayable graphic symbols, then the computer might notify the user and offer partial display of the readable portions of the message. (E)

5.6-13 Indicate Message Size (Tier 3 - Design Details)
Some indication of message size should be included in summary listings and at the beginning of each message.
COMMENT: For example, message size might be calculated as number of lines, and indicated in its header. (E)

5.6-14 Information about Queued Messages (Tier 3 - Design Details)
Users should be able to review summary information about the type, source, and priority of queued incoming messages.
COMMENT: In some applications, a user might need notification only of urgent messages, and rely on periodic review to deal with routine messages. Summary information about queued incoming messages should help guide message review. (E)

5.6-15 Specifying Format for Message Listings (Tier 3 - Design Details)
Users should be provided some means to specify the order in which header fields are displayed in

messages and in message summary listings.

COMMENT: Users should be able to assign names to various stored header format specifications of this kind, so that a particular desired header format might be invoked by name. At the minimum, the queue should list the message title, sender, date, and time of receipt. The default order for the queue should be according to the date and time of receipt. For different purposes, a user might wish to display messages with the topic on the first line, or with the sender's name on the first line. (D,E)

5.6-16 User Review of Messages in Queue (Tier 3 - Design Details)

Convenient means should be provided for user review of received messages in their incoming queue, without necessarily requiring any further disposition action, i.e., without removal from the queue.

COMMENT: Rapid review of queued messages will permit a user to exercise judgment as to which require immediate attention, and/or which can be dealt with quickly. Other messages may be left in the queue for disposition later. A user with limited facilities for data storage might not be able to accept for immediate filing all of the messages received during a prolonged absence from the system. In such circumstances it seems clear that the user should be able to review received messages before deciding which to store in personal files. In some operational applications, user review of critical messages might be accompanied by a requirement for further actions to ensure timely response. (E)

5.6-17 Labeling Received Messages (Tier 3 - Design Details)

Users should be able to assign their own names and other descriptors to received messages. In the absence of labeling by a recipient, the computer might assign by default whatever descriptors have been provided by the message sender.

COMMENT: A user might wish to file received messages for future reference. User-assigned labels could help identify a stored message and distinguish it from other filed messages. (E)

5.6-18 Annotating Received Messages (Tier 3 - Design Details)

Users should be able to append notes to a received message, and ensure that such annotation will be displayed so that it will be distinct from the message itself.

COMMENT: In most applications, users should not be allowed to make changes in received messages. Any such changes would simply provide too much chance for resulting confusion. But users should be able to append, file, and display in some distinctively separate form, their own comments about received messages. If changes are desired in a message itself, then its recipient might make a copy of that message (with appropriate change of its header information) and then edit that copy. (E)

5.6-19 Discarding Messages (Tier 3 - Design Details)

Users should be able to discard unwanted messages without filing them, or even without reading them.

COMMENT: Discarding messages, like other user actions, should be reversible. That is to say, a discarded message should be filed temporarily in some "wastebasket" from which it could later be retrieved if the user has not yet left the system. (E)

6.0 INFORMATION PROTECTION

6.1 General

6.1-1 Automated Security Measures (Tier 1 - Use)

When required, automated measures to protect data security should be provided, relying on computer capabilities rather than on more fallible human procedures.

COMMENT: For protection against unauthorized users, who may be intruders in a system, the need for automated security measures is clear. For legitimate users, the need for data protection is to minimize data loss resulting from potentially destructive equipment failures and user errors. Even careful, conscientious users will sometimes make mistakes, and user interface logic should be designed to help mitigate the consequences of those mistakes. (E)

6.1-2 Warning of Threats to Security (Tier 1 - Use)

Messages and/or alarm signals in order to warn users (and system administrators) of potential threats to data security (i.e., of attempted intrusion by unauthorized users) should be provided.

COMMENT: For protecting data from unauthorized use, it may not be enough merely to resist intrusion. It may also be helpful if the computer can detect and report any intrusion attempts. In the face of persistent intrusion attempts, it may be desirable to institute countermeasures of some sort, such as changing user passwords or establishing other more stringent user authentication procedures. (E)

COMMENT: Covert entry of passwords will prevent casual eavesdropping by onlookers. This represents an exception to the general recommendation that all entries should be displayed. Audio feedback, rather than visual, may be considered for entering secure passwords during log-on. (C,E)

6.2-9 Single Authorization for Data Entry/Change (Tier 3 - Design Details)

User authorization for data entry/change should be established at initial LOG-ON.

COMMENT: (E)

6.0 INFORMATION PROTECTION

6.1 General

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6.0 INFORMATION PROTECTION
6.2 User Identification

6.2-1 Auxiliary Tests to Authenticate User Identity (Tier 2 - Memory Load)
When system security requires more stringent user identification than is provided by password entry, auxiliary tests should be devised that authenticates user identity without imposing impractical demands on users' memory.
COMMENT: (E)

6.2-2 Easy LOG-ON (Tier 2 - General)
The LOG-ON process and procedures for user identification should be as simple as possible consistent with protecting data from unauthorized use.
COMMENT: Authentication of user identity is generally not enhanced by requiring a user to enter routine data such as terminal, telephone, office or project numbers. In most organizations, those data can readily be obtained by other people. If verification of those data is needed, the user should be asked to review and confirm currently stored values in a supplementary procedure following LOG-ON. (E)

6.2-3 Prompting LOG-ON (Tier 2 - General)
The LOG-ON process should provide prompts for all user entries, including passwords and/or whatever other data are required to confirm user identity and to authorize appropriate data access/change privileges.
COMMENT: (E)

6.2-4 User Choice of Passwords (Tier 2 - General)
When passwords are required, users should be allowed to choose their own passwords.
COMMENT: Where data protection is critical, user selected passwords should be tested against a list of common passwords ("me", car types, names spelled backwards "ydnA", birth dates, etc.). A password chosen by a user will generally be easier for that individual to remember. User choice is especially helpful when passwords must be periodically changed, with changing demands on memory. (E)

6.2-5 Limiting Unsuccessful LOG-ON Attempts (Tier 2 - General)
A maximum limit on the number and rate of unsuccessful LOG-ON attempts should be imposed.
COMMENT: These limits should provide a margin for user error while protecting the system from persistent attempts at illegitimate access. A record of continuing failure by any particular user to complete successful LOG-ON procedures, including password entry and other tests of claimed user identity, may indicate persistent intrusion attempts. Repeated LOG-ON failures might thus be grounds for denying access to that user. Access might be denied temporarily for some computer-imposed time interval, or indefinitely pending review by a system administrator. Legitimate users will sometimes have difficulty completing a successful LOG-ON, perhaps due to inattention, or a faulty terminal, or faulty communications. Occasional LOG-ON failures of that kind should be tolerable to the system, with the user simply invited to try again. (E)

6.2-6 Continuous Recognition of User Identity (Tier 2 - General)
Once a user's identity has been authenticated, whatever data access/change privileges are authorized for that user should continue throughout a work session.
COMMENT: If an identified user is required to take separate actions to authenticate data handling transactions, such as accessing particularly sensitive files or issuing particular commands, the efficiency of system operations may be degraded. Where continuous verification of user identity seems required for data protection, some automatic means of identification might be employed for that purpose. (E)

6.2-7 Changing Passwords (Tier 3 - Design Details)
Users should be able to change their passwords.
COMMENT: A user may sometimes suspect that a password has been disclosed, and thus wish to change it. (E)

6.2-8 Private Entry of Passwords (Tier 3 - Design Details)
When a password must be entered by a user, password entry should not be displayed.

COMMENT: Covert entry of passwords will prevent casual eavesdropping by onlookers. This represents an exception to the general recommendation that all entries should be displayed. Audio feedback, rather than visual, may be considered for entering secure passwords during log-on. (C,E)

6.2-9 Single Authorization for Data Entry/Change (Tier 3 - Design Details)

User authorization for data entry/change should be established at initial LOG-ON.

COMMENT: (E)

6.0 INFORMATION PROTECTION
6.3 Data Access

6.3-1 Encryption (Tier 1 - Use)
When sensitive data may be exposed to unauthorized access, a capability for encrypting those data should be provided.
COMMENT: Potential exposure may be assumed during any external data transmission, with encryption imposed routinely by the computer. For protection of data within a shared system, a user might choose to encrypt private files to prevent their reading by other people. In such a case, the user must specify a private encryption "key", which will then serve as the basis for automatic encryption by the computer. (E)

6.3-2 Protecting Displayed Data (Tier 2 - General)
When protection of displayed data is essential, computer control over the display should be maintained.
COMMENT: It is not enough simply to instruct users not to make changes in displayed data. Users may attempt unwanted changes by mistake, or for curiosity, or perhaps even to subvert the system. (E)

6.3-3 Displayed Security Classification (Tier 2 - General)
When displayed data are classified for security purposes, a prominent indication of security classification should be included in each display. In applications where either real or simulated data can be displayed, a clear indication of simulated data should be included as part of the classification label.
COMMENT: Where a display includes partitioned "windows" of data from different sources, it may be necessary to label security classification separately for each window. Under those conditions, some form of auxiliary coding (e.g., color coding) might help users distinguish a window which contains data at a high security level. This practice will serve to remind users of the need to protect classified data, both in access to the display itself and in any further dissemination of displayed data. (E)

6.3-4 Display Suppression for Security (Tier 2 - General)
When confidential information is displayed at a work station that might be viewed by casual onlookers, the user should be provided with some rapid means of temporarily suppressing a current display if its privacy is threatened, and then resuming work later.
COMMENT: A suppressed display should not be entirely blank, but should contain an appropriate message indicating its current status, e.g., "Display is temporarily suppressed; enter password to resume work." Such a capability is sometimes called a "security pause". For quick display suppression a function key might be provided. To retrieve a suppressed display and resume work, a user might be required to make a code entry such as a password, in the interests of data protection. (E)

6.3-5 Protecting Printed Data (Tier 2 - General)
As required for security, procedures to control access to printed data should be established, rather than simply prohibiting the printing of sensitive data.
COMMENT: User requirements for printed data are often unpredictable, and printing restrictions may handicap task performance. Rather than restrict printing, establish appropriate procedures for restricting further distribution of data printouts. (E)

6.3-6 Ensuring Reversible Encryption (Tier 2 - General)
Data encryption should be reversible, i.e., that encrypted data are protected from any change that might prevent successful reversal of their encryption.
COMMENT: (E)

6.3-7 Indicating "Read-Only" Displays (Tier 3 - Design Details)
When users are not authorized to change displayed data, "read-only" status should be indicated on the display.
COMMENT: In applications where the use of read-only displays is common, then some simple cue in the display header may suffice to indicate that status. In applications where users can usually make additions and/or corrections

to displayed data, then any exception to that practice may confuse a user and so should be noted more prominently on the display. (E)

6.3-8 Protecting Display Formats (Tier 3 - Design Details)

Display formatting features, such as field labels and delimiters, should be protected from accidental change by users.

COMMENT: In many data entry tasks users will be allowed to change data fields but should be prevented from making any structural changes to the display. In applications where a user may have to create or modify display formats, special control actions should be provided for that purpose. (E)

6.3-9 Automatic Records of Data Access (Tier 3 - Design Details)

When records of data access are necessary, the records should be maintained automatically.

COMMENT: Transaction records and logs should be stamped with user identifiers, time, and date. Provisions should be made to control requests for records and logs of data transactions with classified material. Users should be informed concerning the nature and purpose of automated recording of individual actions. Even cooperative, well-intentioned users can forget to keep manual logs of data access, and will resent the time and effort required to keep such logs. Subversive users, of course, cannot be expected to provide accurate records. (A,E)

6.0 INFORMATION PROTECTION

6.4 Data Transmission

6.4-1 Encrypting Messages (Tier 1 - Use)

When it is necessary to transmit sensitive data over insecure communication channels, automatic encryption to protect such data should be provided.

COMMENT: Do not rely on users to remember to request message encryption. A user might be asked to supply an encryption key, but the computer should handle any actual encryption process. (E)

6.4-2 Automatic Protection of Transmitted Data (Tier 1 - Use)

Measures adopted to protect data during transmission should be applied automatically, without the need for user action.

COMMENT: The computer should check transmitted data to determine whether an error has occurred; correct errors automatically, if necessary by requesting retransmission; and call to the user's attention any case in which a detected error cannot be automatically corrected. Measures adopted to protect data during transmission include encryption, parity checks, buffering until acknowledgment of receipt, etc. (E)

6.4-3 User Review of Data Before Transmission (Tier 2 - General)

When human judgment may be required to determine whether data are appropriate for transmission, users (or a system administrator) should be provided some means to review outgoing messages and confirm their release before transmission.

COMMENT: Sometimes message release may require coordination among several reviewers in the interests of data protection. (E)

6.4-4 Saving Transmitted Data Until Receipt is Confirmed (Tier 3 - Design Details)

A copy of any transmitted message should be saved automatically until correct receipt has been confirmed.

COMMENT: The primary objective is to prevent irretrievable data loss during transmission. For many system applications, however, the originator of a message will probably want to retain a copy in any case. Any subsequent deletion of that copy should probably be handled as a separate transaction, distinct from data transmission. (E)

7.0 WORKSTATION DESIGN

7.1 Display Devices

7.1.1 Console Video Display Units

7.1.1.1 General

7.1.1.1-1 Mechanical overlays (Tier 3 - Design Details)

Use of mechanical overlays should be avoided.

COMMENT: For example, transparent sheets placed on displays. (C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.1 Console Video Display Units
7.1.1.2 CRTs

7.1.1.2-1 Image Continuity (Tier 2 - General)
The display should maintain the illusion of a continuous image. The viewer should not have to resolve scan lines or matrix spots.
COMMENT: It does not matter if the the raster is scanned or directly addressed. (B)

7.1.1.2-2 Controls (Tier 2 - General)
Frequently used controls should be easily visible and accessible to the VDT user from the normal working position.
COMMENT: The controls should be designed so that they are not accidentally actuated. They should give a clear indication of their function and current setting. A monochrome CRT display should have a means of controlling luminance. (F)

7.1.1.2-3 Screen Size (Tier 2 - General)
The screen should be the smallest size which will allow required information to be seen clearly and easily by the viewer.
COMMENT: The screen should take into account the distance of the operator from the screen (e.g. large screen overviews). (B)

7.1.1.2-4 Choice of Phosphor (Tier 2 - General)
A medium persistence, green phosphor should be used in monochrome CRT displays.
COMMENT: (B)

7.1.1.2-5 Use of Color (Tier 2 - General)
Pure red should not be used in video displays. Pure blue on a dark background should not be used for the presentation of text, thin lines or high-resoultion information. Pure red and pure blue should not be used together on a dark background, unless chromostereopsis is desired.
COMMENT: Dominant wavelengths above 650 nm (red) in displays should be avoided because protanopes are noticeably less sensitive to these wavelengths. (F)

7.1.1.2-6 Pictorial/Graphic Situation Formats (Tier 2 - General)
Pictorial or situation data such as plan position indicator data should be presented as luminous symbols on a dark background.
COMMENT: (C)

7.1.1.2-7 Display glare (Tier 2 - General)
Reflected glare should be minmimized.
COMMENT: For example, by proper positioning of CRT relative to light source, or by use of a shield or filter on the CRT or light source. If glare reduction or contrast enhancement techniques are used, they should be such as not to violate the requirements of luminance, contrast, and resolution as stated in this document. (B,C,F)

7.1.1.2-8 Ambient illumination (Tier 2 - General)
The ambient illuminance in the CRT area necessary for other visual functions (e.g., setting controls, reading instruments, maintenance) should not degrade the visibility of signals on the CRT display.
COMMENT: (C)

7.1.1.2-9 Illuminance of surrounding area (Tier 2 - General)
There should be no light source (direct or reflected) in the immediate surrounding area of greater luminance than the CRT.
COMMENT: The luminance range of surfaces immediately adjacent to scopes should be between 10% and 100% of

screen background luminance. Surfaces adjacent to the CRT should have a dull matte finish. (C)

7.1.1.2-10 Viewing distance (Tier 3 - Design Details)
The minimum design viewing distance should be equal to or greater than 30 cm (12 inches).
COMMENT: When periods of observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 250 mm (10 in). Displays which must be placed at viewing distances greater than 400 mm (16 in) due to other considerations should be appropriately modified in aspects such as display size, symbol size, brightness ranges, line-pair spacing and resolution. (B,C)

7.1.1.2-11 Display Luminance (Tier 3 - Design Details)
Either the character or its background, whichever is of higher luminance, should achieve a luminance of at least 35 cd/m2 (10 foot-lamberts) or more.
COMMENT: The preferred display luminance is 80 to 160 cd/m2. (B)

7.1.1.2-12 Luminance Control (Tier 3 - Design Details)
A control to vary the CRT luminance from 10% of minimum ambient luminance to full CRT luminance should be provided.
COMMENT: (C)

7.1.1.2-13 Faint Signals (Tier 3 - Design Details)
When the detection of faint signals is required and when the ambient illuminance may be above 2.7 lux (0.25 ft-c), scopes should be hooded, shielded, or recessed.
COMMENT: In some instances, a suitable filter system may be employed. (C)

7.1.1.2-14 Resolution (Tier 3 - Design Details)
The display should have adequate resoultion. The modulation transfer function, which is a measure of resoultion, should have a value of at least 5. Raster modulation should be less than 20 percent.
COMMENT: The Modulation Transfer Function Area (MTFA) metric of a display should have a value of at least 5. This value may be directly developed from microphotometric measurements, or for monochrome CRT displays it may be estimated using the following formula: MTFA = 10A where, A = b0 + b1VD + B2WD + b3AB + b4VDAB + b5WDAB + b6LMAB + b7VDLMAB where, b0 = 1.[illegible]8 b1 = 0.60 b2 = -1.07 b3 = -1.62 b4 = -0.17 b5 = 0.59 b6 = 0.48 b7 = 0.06 where, VD = Viewing Distance in meters, when 0.30 m < VD , 1.02m, where WD = the full width of the Gaussian spot at the halfamplitude point in mm, when 0.15 mm < WD < 0.76 mm, where AB = log10 of the reflected luminance (in cd/m2) from the display screen, when 0 < AB < 1.7 (= 50 cd/m2), and where LM = log10 of the peak display luminance (in cd/m2), when 1.3 (= 20 cd/m2) < LM < 2.54 (= 343 cd/m2). Percent Raster Modulation and Percent Active Area: Raster modulation is a significant factor in image quality. For a CRT display having a pixel density of fewer than 30 pixels per degree perpendicular to the raster (at the design viewing distance), the luminance modulation in the direction perpendicular to adjacent raster lines should be equal to, or less than, 20 percent when all lines and all pixels are in their "on" state. For displays having a luminance control, this requirement is to be met when the pixel luminance is at one half the maximum luminance. For non-CRT matrix displays, the percent active area (fill factor) should be at least 30 percent (75 percent preferred) of the space allocated to the pixel. This requirement is for displays having a pixel density of less than 30 pixels per degree at the design viewing distance. The edge of a pixel, for purposes of this requirement, is defined as the five percent luminance contour (F)

7.1.1.2-15 Contrast (Tier 3 - Design Details)
The contrast ratio of the display should be greater than 3:1; a contrast ratio of 7:1 is preferred.

COMMENT: Either display polarity - that is, dark characters on a light background - or light characters on a dark background is acceptable provided it meets the requirements for resolution, percent raster modulation and percent active area, luminance, and contrast. Luminance modulation, M =(Lmax - Lmin)/(Lmax + Lmin) Contrast ratio, CR = Contrast Ratio = Lmax/Lmin Contrast, C = (Lmax - Lmin)/Lmin. Lmax is the higher luminanc of the background or of the character, and Lmin is the lower luminance of the two. These values include the contribution from ambient light. Small characters (characters between 10 and 17 minutes of arc) should have minimum luminance modulation which is calculated from the following formula: Luminance Modulation, M = minimum luminance modulation which is calculated from the following formula: $0.3 + 0.07\,(20 - S)$ where S is the vertical size of the character set, in minutes of arc. (F)

7.1.1.2-16 Color Coding (Tier 3 - Design Details)
When color coding is used for discriminability or conspicuousness of displayed information, all colors in the set should differ from one another by a minimum of 40 ΔE (CIE L*u*v*) distances.
COMMENT: This approach will make available at least 7 to 10 simultaneous colors. Increasing ambient illuminance decreases color purity and, consequently, color discriminability. Accordingly, color measurements should be made under the presumed ambient lighting conditions in which the display will be used. (F)

7.1.1.2-17 Color Contrast (Tier 3 - Design Details)
For adequate legibility, colored symbols should differ from their color background by a minimum of 100 ΔE (CIE Yu'v') distances.
COMMENT: (F)

7.1.1.2-18 Image Linearity (Tier 3 - Design Details)
The display should be free of geometric distortion.
COMMENT: Linearity, the horizontal displacement of a symbol position relative to the symbol positions directly above and below the symbol position, should vary by not more than five percent of the symbol box height. The vertical displacement of a symbol position, relative to the symbol positions to the right and left of the symbol position, should vary by not more than five percent of the symbol box height. Nonlinearity of any column or row should be not more than two percent of the length of the column or row. Lines and columns should be parallel and orthogonal one to the other within the limits of the linearity requirement. This may be expressed as: $0.04\ (\text{Shorter edge/Longer edge}) \geq \text{Diagonal1/Diagonal2} - 1$ The size of a specific symbol anywhere on the display should not vary by more than 10 percent, regardless of its location within the image area. This is expressed as follows: $2(h2 - h1)/(h2 + h1) \leq 0.1$ and $2(w2 - w1)/(w2 + w1) < 0.1$ where "h" is the height of the symbol and "w" is the width of the symbol. When all the character positions on the screen are filled with "Hs" or "Ms" of the same character set, h1 is the height of the smallest character, h2 is the height of the largest character, w1 is the width of the smallest character, and w2 is the width of the largest character. (F)

7.1.1.2-19 Geometric stability (Tier 3 - Design Details)
The display should be free of "jitter".
COMMENT: Variations in the geometric location of a picture element should be no more than 0.0002 mm per mm of viewing distance (0.0002 inch per inch of viewing distance) over a period of one second. This may be expressed as: $VD \times 0.0002 \geq (H2 + V2)0.5$, where VD is the viewing distance H and V are the maximum excursions of picture element centers, horizontally and vertically. (F)

7.1.1.2-20 Luminance Uniformity (Tier 3 - Design Details)
All luminances that are supposed to be the same should appear the same.
COMMENT: Luminance uniformity, the variation from the center to the edge of the active area of the display, should not vary more than 50 percent of the center luminance. Unintended luminance variations, within half a degree of arc, calculated from the design viewing distance anywhere on the display, should be less than 50 percent. For an intended uniform luminance, the variation in luminance from the center of the display to the edge or any portion thereof should not vary by more than 50 percent of the center luminance. This measurement is to be made in a dark room. (F)

7.1.1.2-21 Flicker (Tier 3 - Design Details)
The display should be "flicker free" for at least 90 percent of a sample of the user population under conditions representative of actual use.
COMMENT: (B)

7.1.1.2-22 Viewing Angle (Tier 3 - Design Details)
The display should not be tilted more than 40 degrees relative to the viewer's line of sight.
COMMENT: The angle formed by the intersection of the line of sight and the line normal to the surface of the display at the point where the line of sight intersects the image surface of the display is no more than 40 degrees.

(F)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.1 Console Video Display Units
7.1.1.3 Liquid Crystal

7.1.1.3-1 Liquid Crystal Luminance (Tier 3 - Design Details)

The diplay should be of adequate luminance.

COMMENT: Either the character or its background, whichever is of higher luminance, should be able to achieve a luminance of at least 35 cd/m2 (10 foot-lamberts) or more. The incident illumination on the surface of the display should be at least 35π/R lux, where R equals the reflectivity of the display in its most reflective state. (F)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.1 Console Video Display Units
7.1.1.4 Electroluminescent

7.1.1.4-1 Character Size (Tier 3 - Design Details)
The height of alphanumeric characters and geometric and pictorial symbols should not subtend less than 4.5 mrad (15 minutes) of vis angle.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.1 Console Video Display Units
7.1.1.5 LEDs

7.1.1.5-1 Intensity Control (Tier 3 - Design Details)

The dimming of LEDs should be compatible with the dimming of incandescent lamps.

COMMENT: (C)

1

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

7.0 WORKSTATION DESIGN

7.1 Display Devices

7.1.2 Large Screen Displays

7.1.2-1 Maximum Viewing Distance (Tier 2 - General)
The display should not be placed further from an observer than will provide appropriate resolution of critical detail presented on the display.
COMMENT: (C)

7.1.2-2 Interruption of View (Tier 2 - General)
Large screen displays should not be located relative to critical observers so that the view is regularly obscured by people moving about.
COMMENT: (C)

7.1.2-3 Control of Display (Tier 2 - General)
Control of large-screen group display systems should be such that critical information cannot be modified or deleted inadvertently or arbitrarily.
COMMENT: Control of changes in the group display should be under the control of designated operators who operate according to pre-established procedures, upon command of a person in charge, or both. When an individual must make changes that are of interest only to him or her, a separate, remote display should be provided. (C)

7.1.2-4 Minimum Viewing Distance (Tier 2 - General)
The display should not be closer to any observer than 1/2 the display width or height, whichever is greater.
COMMENT: (C)

7.1.2-5 Seating Area (Tier 3 - Design Details)
Off-centerline viewing should not exceed 175 mrad (10 degrees) for individual viewing from a fixed location.
COMMENT: (C)

7.1.2-6 Image Luminance (Tier 3 - Design Details)
Image luminance and light distribution should be uniform. In any case, the luminance of the screen center at maximum viewing angle should be at least half its maximum luminance.
COMMENT: (C)

7.1.2-7 Size of Projected Characters (Tier 3 - Design Details)
The height of letters and numerals should not be less than 4.5 mrad (15 minutes) of visual angle.
COMMENT: In no instance should the height of letters and numerals be less than 3 mrad (10 minutes) as measured from the longest anticipated viewing distance. (C)

7.1.2-8 Luminance Ratio (Tier 3 - Design Details)
The luminance ratio provided by the projection system should be adequate for the type of material being projected.
COMMENT: The luminance ratio is defined as image or subject luminance divided by the nonimage or background luminance. Under optimal ambient lighting conditions, the luminance ratio for optically projected displays should be 500:1. Minimum luminance ratios are as follows: a) For viewing charts, printed text and other linework via slides or opaque projectors the minimum luminance ratio is 5:1. b) For projections which are limited in shadows and detail, such as animation and photographs with limited luminance range, the minimum luminance is 25:1. c) For images which show a full range of colors (or grays in black-and-white photographs), the minimum luminance ratio is 100:1. (C)

7.1.2-9 Contrast Polarity (Tier 3 - Design Details)
Contrast should be either light on a dark background or vice-versa, except where superposition is used.

COMMENT: For subtractive superposition (at the source), data should be presented as dark markings on a transparent background. For additive superposition (at the screen), data should be presented as light markings on an opaque background. Colored markings against colored backgrounds of comparable brightness should be avoided. (C)

7.1.2-10 Alignment (Tier 3 - Design Details)
The misregistration of superimposed alphanumeric data or other symbols should be minimized.
COMMENT: (C)

7.1.2-11 Keystone Effects (Tier 3 - Design Details)
The projector/screen should be arranged so as to minimize "keystone effect," i.e., distortion of projected data proportions due to non-perpendicularity between projector and screen.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.3 Printers

7.1.3-1 Use (Tier 1 - Use)
Printers should be used when a visual record of data is necessary or desirable.
COMMENT: (C)

7.1.3-2 Legibility (Tier 2 - General)
The print output should be free from character line misregistration, character tilt or smear.
COMMENT: (C)

7.1.3-3 Printed tapes (Tier 2 - General)
The information on the tapes should be printed in such a manner that it can be read as it is received from the machine without requiring the cutting and pasting of tape sections.
COMMENT: (C)

7.1.3-4 Visibility (Tier 2 - General)
The printed matter should not be hidden, masked or obscured in a manner that impairs direct reading.
COMMENT: (C)

7.1.3-5 Annotation (Tier 2 - General)
Where applicable, printers should be mounted so that the printed matter (e.g., paper, metalized paper) may be easily annotated while still in the printer.
COMMENT: (C)

7.1.3-6 Contrast (Tier 3 - Design Details)
A minimum of 3.0 luminance contrast between the printed material and the background on which it is printed should be provided.
COMMENT: (C)

7.1.3-7 Illumination (Tier 3 - Design Details)
The printer should be provided with internal illumination if the printed matter is not legible in the planned operational ambient illumination.
COMMENT: (C)

7.1.3-8 Take-up provision (Tier 3 - Design Details)
A take-up device for printed material should be provided.
COMMENT: (C)

7.1.3-9 Indication of Supply of Materials (Tier 3 - Design Details)
A positive indication of the remaining supply of printing materials (e.g., paper, ribbon) should be provided .
COMMENT: (C)

7.1.3-10 Servicability (Tier 3 - Design Details)
Routine servicing functions should be accomplished without requiring disassembly, special equipment or tools.
COMMENT: Functions as insertion, adjustment for operation and removal of paper, replacement of ribbons, or other items determined to be operator tasks should be accomplished without special equipment. (C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.4 Plotters

7.1.4-1 Visibility (Tier 2 - General)
Critical graphics (those points, curves and grids that must be observed when the recording is being made) should not be obscured by pen assembly, arm or other hardware elements.
COMMENT: (C)

7.1.4-2 Job Aids (Tier 2 - General)
Graphic overlays should be provided where these may be critical to proper interpretation of graphic data as it is being generated.
COMMENT: Such aids should not obscure or distort the data. (C)

7.1.4-3 Annotation (Tier 2 - General)
Where applicable, plotters and recorders should be designed so that the operator can write on or mark the paper while it is still in the plotter/recorder.
COMMENT: (C)

7.1.4-4 Contrast (Tier 3 - Design Details)
A minimum of 1.0 luminance contrast between the plotted function and the background on which it is drawn should be provided.
COMMENT: (C)

7.1.4-5 Take-up device (Tier 3 - Design Details)
A take-up device for extruded plotting materials should be provided where necessary or desirable.
COMMENT: (C)

7.1.4-6 Smudging/smearing (Tier 3 - Design Details)
The plot should be resistant to smudging or smearing under operational use.
COMMENT: (C)

7.1.4-7 Control, replenishment and service (Tier 3 - Design Details)
Plotters should conform to the guidance given printers with respect to control, replenishment, and service.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.5 Audio and Voice Displays
7.1.5.1 Speech

7.1.5.1-1 Speech Output (Tier 1 - Use)
Computer-generated speech output for user guidance messages should be used in environments with low ambient noise, when a user's attention may not be directed toward a visual display or when providing a visual display is impractical.
COMMENT: (E)

7.1.5.1-2 Type of Voice (Tier 2 - General)
A distinctive and mature voice should be used in recording verbal warning signals.
COMMENT: Spoken messages should be produced in the form of the "average talker", in an American English accent without regional dialects. (A)

7.1.5.1-3 Delivery Style (Tier 2 - General)
Verbal warning signals should be presented in a formal, impersonal manner.
COMMENT: (C)

7.1.5.1-4 Limited Number of Spoken Messages (Tier 2 - General)
Computer-generated speech should be limited to provide only a few messages.
COMMENT: As negative examples, computer-generated speech would not be useful if many messages might be given at one time, or for conveying a lengthy list of menu options. When messages are spoken, the user must remember each message. If many different messages are given one after another, then a user would probably not remember them all, and might only remember one or two. (E)

7.1.5.1-5 Simple Spoken Messages (Tier 2 - General)
When using computer-generated speech to provide messages, those messages should be short and simple.
COMMENT: If a user does not understand a written message, s/he can reread it. That is not the case with spoken messages. Though a REPEAT function might be provided, a better solution is to restrict use of speech outputs for short and simple messages. If a user who may not be watching a display must be given long or complex messages, it is probably better to provide a simple auditory signal such as a chime, and then display the messages visually for the user to read. In general, users will understand complex messages better when they see them displayed than when they hear them. (E)

7.1.5.1-6 Word Selection (Tier 2 - General)
Words presented in a voice signal should be concise, intelligible, and appropriate for the information presented.
COMMENT: Where possible, words that rhyme or may confuse message interpretation should not be part of the spoken lexicon, or should not be presented within the same message. Use of slang should be avoided. Words with more than one syllable should be used. Alphanumeric data should be presented using phonetic alphabets, e.g., "Whiskey Zebra three two seven" should be used in preference to "WZ327" where the "Z" and "3" are too phonetically similar. (A)

7.1.5.1-7 Distinctive Spoken Warnings (Tier 2 - General)
If computer-generated speech is used to provide warnings as well as other forms of user guidance, spoken warnings should be easily distinguishable from routine messages.
COMMENT: For example, speech output used to identify dangerous conditions might use some distinctive voice (perhaps female rather than male, or vice versa) and/or preface each warning message with some other distinctive auditory signal. In some applications, computer-generated speech might be useful for providing a few short and simple warnings. However, if speech output is also used for other purposes, then the warning messages must be distinctive. (E)

7.1.5.1-8 Coding Synthesized Voice Warnings (Tier 2 - General)
If computer-generated speech output is used for auditory display, a special alerting signal should be provided to introduce voice alarms and warning messages in order to distinguish them from routine advisory messages.
COMMENT: (E)

7.1.5.1-9 Voice Coding (Tier 2 - General)
For auditory displays with voice output, different voices to distinguish different categories of data should be used.
COMMENT: At least two voices, male and female, can be readily distinguished, and perhaps more depending upon fidelity of auditory output, and listening conditions. (E)

7.1.5.1-10 Intensity of Voice Presentation (Tier 3 - Design Details)
Voice signal intensity should be appropriate for the expected ambient noise environment. Verbal alarms for critical functions should be at least 20 db above the speech interference level at the operating position of the intended receiver.
COMMENT: Signal to noise ratios should be at least 5:1. Audio signal power should be approximately 300 milliwatts at the listeners ear. Speech signals should fall within the range of 200 to 6100 Hz. (A,C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.5 Audio and Voice Displays
7.1.5.2 Non-speech audio displays

7.1.5.2-1 Warning Signals (Tier 1 - Use)
Audio signals should be provided, as necessary, to warn personnel of impending danger, to alert an operator to a critical change in system or equipment status, and to remind the operator of a critical action or actions that must be taken.
COMMENT: An alerting/warning system or signal should provide the operator with a greater probability of detecting the triggering condition than his normal observation would provide in the absence of the alerting/warning system or signal. (C)

7.1.5.2-2 Use with Several Visual Displays (Tier 1 - Use)
One audio signal may be used in conjunction with several visual displays, provided that immediate discrimination is not critical to personnel safety or system performance.
COMMENT: (C)

7.1.5.2-3 Relation to Visual Displays (Tier 1 - Use)
When used in conjunction with visual displays, audio warning devices should be supplementary or supportive.
COMMENT: The audio signal should be used to alert and direct operator attention to the appropriate visual display. (C)

7.1.5.2-4 Confusible Signals (Tier 1 - Use)
Audio warning signals that might be confused with other sounds in the operating environment should not be used.
COMMENT: Examples of such signals include trains of impulses that resemble electrical interference, signals similar to noise generated by air conditioning or other equipment. The frequency of a warning tone should be different from that of the electric power employed in the system, to preclude the possibility that a minor equipment failure may generate a spurious signal. (C)

7.1.5.2-5 Audio Coding (Tier 1 - Use)
If absolute discrimination is required, the number of audio codes should be limited to four.
COMMENT: (C)

7.1.5.2-6 Nature of Signals (Tier 2 - General)
Audio warning signals should normally consist of two elements: an alerting signal and an identifying or action signal.
COMMENT: When reaction time is critical and a two element signal is necessary, an alerting signal of 0.5 second duration should be provided. All essential information should be transmitted in the first 2.0 seconds of the identifying or action signals. If reaction time is critical and a single element signal is permissible, all essential information should be transmitted in the first 0.5 second. (C)

7.1.5.2-7 Action segment. (Tier 2 - General)
The identifying or action segment of an audio warning signal should specify the precise emergency or condition requiring action.
COMMENT: (C)

7.1.5.2-8 Critical signals. (Tier 2 - General)
The first 0.5 second of an audio signal requiring fast reaction should be discriminable from the first 0.5 second of any other signal that may occur.
COMMENT: Familiar signals with established names or associations should be selected for use as critical signals. (C)

7.1.5.2-9 Masking. (Tier 2 - General)
Audio warning signals should not interfere with any other critical functions or warning signals, or mask any other critical audio signals.
COMMENT: Where a warning signal delivered to a headset might mask another essential audio signal, separate channels may be provided to direct the warning signal to one ear and the other essential audio signal to the other ear. In such a situation and when required by operating conditions, this dichotic presentation may further provide for alternation of the two signals from ear to ear. (C)

7.1.5.2-10 Failure (Tier 2 - General)
The audio display device and circuit should be designed to preclude warning signal failure in the event of system or equipment failure and vice versa.
COMMENT: (C)

7.1.5.2-11 Caution signals (Tier 2 - General)
Caution signals should be readily distinguishable from warning signals and used to indicate conditions requiring awareness, but not necessarily immediate action.
COMMENT: (C)

7.1.5.2-12 Intensity of Audio Signal (Tier 3 - Design Details)
Audio signal intensity should provides a signal-to-noise ratio of at least 20 dB in at least one octave band between 200 and 5,000 Hz at the operating position of the intended receiver.
COMMENT: Determination of signal audibility should allow for the use of protective garments or hearing protection devices where applicable. (C)

7.1.5.2-13 Frequency of Audio Signal (Tier 3 - Design Details)
Signal frequencies of between 200 and 5000 Hz, and if possible between 500 and 3000 Hz should be used.
COMMENT: When signals must travel over 300 m (985 ft), sounds with frequencies below 1,000 Hz should be used. Frequencies below 500 Hz should be used when signals must bend around obstacles or pass through partitions. (C)

7.1.5.2-14 Circuit Test (Tier 3 - Design Details)
All audio displays should be equipped with circuit test devices or other means of operability test.
COMMENT: (C)

7.1.5.2-15 Message categories. (Tier 3 - Design Details)
Critical warning signal should repeat with not more than a 3-second pause between messages until the condition is corrected or overridden by the CR staff. A message priority system should be established and more critical messages override the presentation of any message occurring below it on the priority list.
COMMENT: If two or more incidents or malfunctions occur simultaneously, the message having the higher priority should be given first. The remaining messages should follow in order of priority. In the event of a complete subsystem failure, the system should integrate previous messages via electronic gating and report the system rather than the component failure. (C)

7.1.5.2-16 Auditory Signals for Alerting Operators (Tier 3 - Design Details)
During text entry/editing, an auditory signal should be provided as necessary to draw attention to the display.
COMMENT: For non critical operations, operators should be able to disable the auditory signal. (E)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.5 Audio and Voice Displays
7.1.5.3 Control of audio displays

7.1.5.3-1 Volume control. (Tier 2 - General)
The volume (loudness) of an audio warning signal should be designed to be controlled by the operator, the sensing mechanism, or both, depending on the operational situation and personnel safety factors. Control movements must be restricted to prevent reducing the volume to an inaudible level.
COMMENT: Volume controls may be ganged to mode switches to provide maximum output during periods in which intense noise may occur and to provide reduced volume at other times. Ganging should not be used if there is a possibility that intense noise may occur in an emergency situation in which the volume would be decreased below an audible level. Audio caution signals should be provided with manual reset and volume controls. (C)

7.1.5.3-2 Duration limitations (Tier 2 - General)
In an emergency situation, signals that persist or increase progressively in level should not be used if manual shut-off may interfere with the corrective action required.
COMMENT: (C)

7.1.5.3-3 Automatic or manual shut-off. (Tier 2 - General)
When an audio signal is designed to persist as long as it contributes useful information, a shut-off switch controllable by the operator, the sensing mechanism, or both, should be provided, depending on the operational situation and personnel safety factors.
COMMENT: (C)

7.1.5.3-4 Automatic reset. (Tier 2 - General)
Whenever audio warning signal are designed to be terminated automatically, by manual control, or both, an automatic reset function should be provided.
COMMENT: The automatic reset function should be controlled by the sensing mechanism which recycles the signal system to a specified condition as a function of time or the state of the signalling system so that the warning device can sound again if the condition repeats. (C)

7.1.5.3-5 Duration. (Tier 3 - Design Details)
Audio warning signal duration should be at least 0.5 second, and may continue until the appropriate response is made. Completion of a corrective action by the operator or by other means should automatically terminate the signal.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.1 Display Devices
7.1.5 Audio and Voice Displays
7.1.5.4 Speech communication equipment

7.1.5.4-1 Headsets (Tier 1 - Use)
If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets should be provided.
COMMENT: Unless operational requirements dictate otherwise, binaural headsets should be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities should be capable of reducing the ambient noise level to less than 85 dB(A). Provisions should be incorporated to furnish the same protection to those who wear glasses. (C)

7.1.5.4-2 Noise shields (Tier 1 - Use)
When the talker is in an intense noise field, the microphone should be put in a noise shield.
COMMENT: Noise shields should be designed to meet the following requirements: a. A volume of at least 250 cu cm (15.25 cu in) to permit a pressure gradient microphone to function normally. b. A good seal against the face with the pressure of the hand or the tension of straps. c. A hole or combination of holes covering a total area of 65 sq mm (0.1 sq in) in the shield to prevent pressure buildup. d. Prevention of a standing wave pattern by shape, or by use of sound absorbing material. e. No impediment to voice effort, mouth or jaw movement or breathing. (C)

7.1.5.4-3 Noise Canceling Microphones (Tier 1 - Use)
In very loud, low frequency noise environments (100 dB overall), noise canceling microphones should be used.
COMMENT: The noise canceling microphones must be capable of effecting an improvement of not less than 10 dB peak-speech to root-mean-square-noise ratio as compared with non-noise-canceling microphones of equivalent transmission characteristics. (C)

7.1.5.4-4 Squelch control (Tier 1 - Use)
When communication channels are to be continuously monitored, each channel should be provided with a signal- activated switching device (squelch control) to suppress channel noise during no-signal periods.
COMMENT: A manually operated, on-off switch, to deactivate the squelch when receiving weak signals, should be provided. (C)

7.1.5.4-5 Foot-operated controls (Tier 1 - Use)
When normal working conditions, operator should be permitted to remain seated at the working position and have access to "talk-listen" or "send-receive" control switches required for normal operation.
COMMENT: If console operation requires the use of both hands, foot-operated controls should be provided. Hand-operated controls for the same functions should be provided for emergency use and for use when the operator may need to move from one position to another. (C)

7.1.5.4-6 Hands-free operation (Tier 2 - General)
Operator microphones, headphones, and telephone headsets should be designed to permit hands-free operation under normal working conditions.
COMMENT: (C)

7.1.5.4-7 Comfort (Tier 2 - General)
Communication equipment to be worn by an operator should be designed to preclude operator discomfort.
COMMENT: Metal parts of the headset should not come in contact with the user's skin. (C)

7.1.5.4-8 Accessibility of handsets (Tier 2 - General)

Where communication requirements necessitate the use of several telephone handsets, accessibility of their standby locations should be determined by operational priority.
COMMENT: The most frequently or urgently needed handset should be the most accessible, etc. Color-coding may also be employed where operating personnel will have visual contact with headsets under the working conditions. (C)

7.1.5.4-9 Frequency (Tier 2 - General)
Microphones and associated system-input devices should be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz).
COMMENT: Where system engineering necessitates speech-transmission dynamic range bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range is 250 to 4,000 Hz. (C)

7.1.5.4-10 Frequency (Tier 3 - Design Details)
Microphones and associated system-input devices should be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz).
COMMENT: Where system engineering necessitates speech-transmission dynamic range bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range is 250 to 4,000 Hz. (C)

7.1.5.4-11 Dynamic Range (Tier 3 - Design Details)
The dynamic range of a microphone used with a selected amplifier should be great enough to admit variations in signal input of at least 50 dB.
COMMENT: (C)

7.1.5.4-12 Frequency range (Tier 3 - Design Details)
Loudspeakers for use in multi-speaker installations and multiple channels fed into headphones should respond uniformly (plus or minus 5 dB) over the range 100 to 4,800 Hz.
COMMENT: Headphones and loudspeakers are subject to the same frequency response restrictions as microphones and transmission equipment. (C)

7.1.5.4-13 Volume controls (Tier 3 - Design Details)
Accessible volume or gain controls should be provided for each communication receiving channel (e.g., loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 100 dB overall when using two earphones.
COMMENT: The minimum setting of the volume control should be limited to an audible level, i.e., it should not be possible to inadvertently disable the system with the volume control. While separation of power (on-off) and volume control adjustment functions into separate controls is preferred, should conditions justify their combination, a noticeable detent position should be provided between the OFF position and the lower end of the continuous range of volume adjustment. When combined power and volume controls are used, the OFF position should be labeled. (C)

7.1.5.4-14 Loudspeakers for multi-channel monitoring. (Tier 3 - Design Details)
When several channels are to be monitored simultaneously by means of loudspeakers, the speakers should be mounted at least 10 degrees apart in the horizontal plane frontal quadrant, ranging radially from 45 degrees left to 45 degrees right of the operator's normal forward facing position.
COMMENT: When additional channel differentiation is required, apparent lateral separation should be enhanced by applying low-pass filtering (frequency cutoff, Fc = 1,800 Hz) to signals fed to loudspeakers on one side of the central operator position. If there are three channels involved, one channel should be left unfiltered, a high pass filter with 1,000 Hz cutoff should be provided in the second channel, and a low-pass filter with 2,500 Hz cutoff should be provided in the third channel. A visual signal should be provided to show which channel is in use. (C)

7.1.5.4-15 Peak-clipping of speech signals. (Tier 3 - Design Details)
Where speech signals are to be transmitted over channels showing less than 15 dB peak speech to root-mean-square-noise ratios, peak clipping of 12 to 20 dB may be employed at system input and may be preceded by frequency pre-emphasis.
COMMENT: (C)

7.1.5.4-16 Pre-emphasis. (Tier 3 - Design Details)
If necessary, speech system input devices should employ frequency pre-emphasis.
COMMENT: The frequency pre-emphasis should have a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 to and no greater than 9 dB per octave over the frequency range 1,500 to 4,800 Hz, when no clipping is used. (C)

7.1.5.4-17 Use of de-emphasis (Tier 3 - Design Details)
When transmission equipment employs pre-emphasis and peak clipping is not used, reception equipment should employ frequency de-emphasis of characteristics complementary to those of pre emphasis only if it improves intelligibility.
COMMENT: Frequency de-emphasis should be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4,800 Hz. (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.1 Keyboards
7.2.1.1 General

7.2.1.1-1 Numeric Keypads (Tier 1 - Use)
Keyboards should be equipped with a numeric keypad when the primary task includes entry of numeric data.
COMMENT: (C)

7.2.1.1-2 Overlays (Tier 1 - Use)
Mechanical overlays, such as coverings over the keyboard, should be not used.
COMMENT: (C)

7.2.1.1-3 Minimization of Shift Keying (Tier 2 - Minimizing User Actions)
The use of key shifting functions should be minimized during data entry transactions.
COMMENT: (C)

7.2.1.1-4 Keying Feedback (Tier 2 - Feedback)
The actuation of a key should be accompanied by tactile or auditory feedback or both.
COMMENT: If there is only one, tactile feedback is preferred. Should supplementary auditory feedback be used, the sound should occur at the same point in the displacement for all keys. Supplementary auditory feedback should be adjustable in volume and should be capable of being turned off. (F)

7.2.1.1-5 Standard Layout (Tier 2 - General)
An ANSI standard (QWERTY) layout should be used for the typing keyboard.
COMMENT: Common usage and the ability to transfer from one machine to another has led to the general acceptance of the QWERTY keyboard. (F)

7.2.1.1-6 Keyboard Placement (Tier 2 - General)
The operator should be able to reposition the keyboard on the worksurface.
COMMENT: (F)

7.2.1.1-7 Keyboard Stability (Tier 2 - General)
The keyboard should be stable during normal keying operations (i.e., it does not slip or rock).
COMMENT: (B)

7.2.1.1-8 Slope Adjustment (Tier 2 - General)
The slope of the keyboard should be adjustable by the operator.
COMMENT: (B)

7.2.1.1-9 Keytop Symbols (Tier 2 - General)
Key symbols should be etched (to resist wear) and colored with high contrast lettering.
COMMENT: (B)

7.2.1.1-10 Repeat Capability (Tier 2 - General)
A repeat capability for alphanumeric and symbol character keys should be provided.
COMMENT: The repeat should have a user selectable delay with a default of 0.5 second. In addition, the character should be repeated at a user selectable rate with a default of 0.1 second. The physical release of the key should terminate the repeat. (D)

7.2.1.1-11 Repeat Capability for Cursor Keys (Tier 2 - General)
A repeat capability for cursor keys should be provided.
COMMENT: Repeat should operate in the same manner for cursor keys as for alphanumeric keys. (D)

7.2.1.1-12 Cursor Control (Tier 2 - General)
Horizontal and vertical cursor control keys should be provided for text processing applications.
COMMENT: Ideally, keys for cursor control should allow (1) horizontal and vertical movement, (2) movement along the diagonals, and (3) two or more rates of movement that are user selectable. Cursor keys should be dedicated to cursor movement, that is, should not be used for any function but cursor control. If, however, the cursor keys are not dedicated, that is, have collateral functions, their functional status shall be clearly indicated. (D,F)

7.2.1.1-13 Cursor Key Layout (Tier 2 - General)
Cursor control keys should be arranged so that their orientation is compatible with the cursor motion they produce.
COMMENT: Cursor keys should be arranged in a "box," a "cross," or inverted-T format. (D,F)

7.2.1.1-14 Keystroke Commands (Tier 2 - General)
A specially designated key (e.g., a Control key) should be one of the keys used for keystroke commands.
COMMENT: (D)

7.2.1.1-15 Simultaneous Keystrokes (Tier 2 - General)
Keystroke commands should require the user to press both keys simultaneously, not in close temporal sequence.
COMMENT: Requiring the user to press two keys simultaneously reduces the likelihood of inadvertent input of a command due to a missed keystroke that hits the specially designated key, followed immediately by another keystroke. (D)

7.2.1.1-16 Alternate Key Definitions (Tier 2 - General)
When the keyboard is redefined, a display of the alternate characters and their locations should be available to the operator.
COMMENT: (D)

7.2.1.1-17 Inadvertent Operation (Tier 2 - General)
Keys with major or fatal effects should be located so that inadvertent operation is unlikely.
COMMENT: (B)

7.2.1.1-18 Keytop Font (Tier 2 - General)
Keys should be labeled with a non-stylized font.
COMMENT: (B)

7.2.1.1-19 Multiple-key Rollover (Tier 3 - Design Details)
N-key (multiple key)rollover capability should be provided for the reduction of keying errors.
COMMENT: (B)

7.2.1.1-20 Functional grouping (Tier 3 - Design Details)
Color-coding should be used to highlight functional key groups.
COMMENT: Color of alphanumeric keys should be neutral (e.g., beige, grey) rather than black or white or one of the spectral colors (red, yellow, green, or blue). (B)

7.2.1.1-21 Key Force (Tier 3 - Design Details)
The maximum force required to depress keys should be between .25 and 1.5 N; a key force of between 0.5 and 0.6 N is preferred.
COMMENT: The force required for key displacement should be 0.3 to 0.75 N for repetitive keying tasks. (B,F)

7.2.1.1-22 Key Displacement (Tier 3 - Design Details)
Keys should have a maximum vertical displacement between 1.5 mm and 6.0 mm (0.06 and 0.24 inch); the preferred displacement is between 2.0 and 4.0 mm (0.08 and 0.16 inch).
COMMENT: Displacement variability between keys should be minimized. (B,F)

7.2.1.1-23 Keyboard Surfaces (Tier 3 - Design Details)
A matte finish should be used for keyboard surfaces.
COMMENT: The spectacular reflectance, gloss, of key caps and visible surfaces should be 45 percent or less when measured with a 60-degree gloss instrument or equivalent device. (B,F)

7.2.1.1-24 Keytop Size (Tier 3 - Design Details)
The minimum horizontal strike surface of the keytop should be at least 12 mm (0.47 inch) in width.
COMMENT: The keytop may be of any shape (square, round, rectangular, etc.) provided spacing requirements are not violated. (F)

7.2.1.1-25 Key Spacing (Tier 3 - Design Details)
Center line distances between adjacent keys should be between 18 and 19 mm (0.71 and 0.75 inch) horizontally and between 18 and 21 mm (0.71 and 0.82 inch) vertically.
COMMENT: (F)

7.2.1.1-26 Push-Button Height (Tier 3 - Design Details)
Push-button height for decimal entry key pads should be betwen 1/4 and 3/8 inch.
COMMENT: (C)

7.2.1.1-27 Key Height (Tier 3 - Design Details)
Key height for alphanumeric keyboards should be between 3/8 and 1/2 inch.
COMMENT: (C)

7.2.1.1-28 Keyboard Slope (Tier 3 - Design Details)
Keyboards should have a slope of 15 to 25 degrees from the horizontal; 12 to 18 degrees is preferred.
COMMENT: (B)

7.2.1.1-29 Keyboard Thickness (Tier 3 - Design Details)
The thickness of the keyboard, i.e., base to the home row of keys, should be less than 50 mm (acceptable); 30 mm or less is preferred.
COMMENT: (B)

7.2.1.1-30 Key Nomenclature (Tier 3 - Design Details)
Nomenclature for the primary symbols on the keys should be a minimum of 2.6 mm (0.1 inch) in height and has a minimum luminance modulation of 0.5 (contrast ratio of 3:1).
COMMENT: Key nomenclature may be darker or lighter than the background. (F)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.1 Keyboards
7.2.1.2 Special Function Keys

7.2.1.2-1 Availability (Tier 1 - Use)
Fixed function keys should be selected to control functions that are continuously available.
COMMENT: Lockout of fixed function keys should be minimized. At any step in a transaction sequence, however, function keys which are not used for current inputs should be temporarily disabled under computer control. Mechanical overlays should not be used for this purpose. (C)

7.2.1.2-2 Grouping (Tier 2 - Sequencing and Grouping)
Fixed function keys should be logically grouped and should be placed in distinctive locations on the keyboard.
COMMENT: (C)

7.2.1.2-3 Standardization (Tier 2 - Consistency)
Fixed function keys should be common throughout the system.
COMMENT: (C)

7.2.1.2-4 Functional Consistency (Tier 2 - Consistency)
A key assigned a given function should not be reassigned to a different function for a given user.
COMMENT: (C)

7.2.1.2-5 Feedback (Tier 2 - Feedback)
When fixed function key activation does not result in an immediately observable natural response, the user should be given an indication of system acknowledgement.
COMMENT: (C)

7.2.1.2-6 Actuation (Tier 2 - General)
Except when used to toggle between two opposing states, a fixed function key should require only a single actuation to accomplish its function.
COMMENT: (C)

7.2.1.2-7 Function labels (Tier 2 - General)
Key assignments should be displayed at all times, preferably through direct marking.
COMMENT: Where abbreviations are necessary, standardized abbreviations should be used. (C)

7.2.1.2-8 Repeat (Tier 2 - General)
Function keys (except for the delete key) should not repeat.
COMMENT: (D)

7.2.1.2-9 Inactive Function Keys (Tier 2 - General)
Unneeded function keys, either fixed or programmable, should be disabled so that no other action occurs upon their depression except an advisory message.
COMMENT: (D)

7.2.1.2-10 Inactive Keys (Tier 3 - Design Details)
Non-active fixed function keys should be replaced by a blank key on the keyboard.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.1 Keyboards
7.2.1.3 Variable Function Keys

7.2.1.3-1 Status display (Tier 2 - General)
When the effect of a function key varies, the status of the key should be displayed.
COMMENT: (C)

7.2.1.3-2 Relabeling (Tier 2 - General)
Variable function keys should be easily relabeled.
COMMENT: Labels for variable function keys, located along the perimeter of a display, may be generated on the display face. (C)

7.2.1.3-3 Easy return to base-level functions. (Tier 2 - General)
Where the functions assigned to a set of function keys change as a result of user selection, the user should be given an easy means to return to the initial, base-level functions.
COMMENT: (C)

7.2.1.3-4 Reprogrammable or inactive default functions (Tier 2 - General)
When keys with labeled default functions are reprogrammed or turned off, a visual warning should alert the user that the standard function is not currently accessible via that key.
COMMENT: (C)

7.2.1.3-5 Shifted Characters (Tier 2 - General)
Shift keys should be not required to operate variable function keys.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.2 Direct Manipulation Controls
7.2.2.1 General

7.2.2.1-1 Feedback (Tier 2 - Feedback)
Visual or auditory feedback should be provided to indicate that a controller input has been registered.
COMMENT: This is especially important when the control surface does not depress or move (such as with a force joystick or touchscreen), thereby providing little tactual feedback to the user. (D)

7.2.2.1-2 Controller X-Y Movement Requirements (Tier 2 - General)
The controller should be able to produce any combination of x and y output values.
COMMENT: (D)

7.2.2.1-3 Single Monitor/Single Controller Cursor Travel Limits (Tier 2 - General)
In a single monitor/single controller environment, movement of the controller should be able to drive the follower only to the edge of the screen, not off the screen.
COMMENT: (D)

7.2.2.1-4 Control/Display Ratios (Tier 2 - General)
Control/display ratios should take into account both screen size and maneuvering surface size.
COMMENT: At a minimum, movement of the controller across the entire maneuvering surface should move the cursor from one side of the screen to the other. (D)

7.2.2.1-5 Selectable Screen Region Size (Tier 2 - General)
Selectable screen items or regions should be separated from each other by a sufficient distance to minimize inadvertent activation of adjacent items or regions.
COMMENT: (D)

7.2.2.1-6 Selectable Tracking Speed (Tier 3 - Design Details)
The controller tracking speed (control display ratio) should be user selectable from a predefined list of alternatives, but should have a moderate default speed.
COMMENT: Selectable is, for example, slow 2:1, unenhanced, 1:1, moderate enhancement, 1:2, and high enhancement 1:3) The control/display ratios should take into account both screen size and maximum maneuvering displacement. (D)

7.2.2.1-7 Selectable Inter-Click Interval (Tier 3 - Design Details)
If multiple clicks are required on a selection button, the user should be able to select the inter-click interval from a predefined list of alternatives.
COMMENT: There should be a moderate default setting. (D)

7.2.2.1-8 Cursor-Controller Movement Correlation (Tier 3 - Design Details)
The pointing cursor manipulated by an x-y controller should smoothly track the movement of the controller in the same direction, within +/-10 degrees without backlash, crosscoupling, or the need for multiple corrective movements.
COMMENT: (D)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.2 Direct Manipulation Controls
7.2.2.4 Joysticks

7.2.2.4-1 Appropriate Use of Displacement (Isotonic) Joysticks (Tier 1 - Use)
When positioning accuracy is more critical than positioning speed, displacement joysticks should be selected over isometric joysticks. Displacement joysticks may also be used for various display functions such as data pickoff from a display and generation of free-drawn graphics.
COMMENT: Displacement joysticks which are used for rate control should be spring-loaded for return to center when the hand is remove. Displacement joysticks usually require less force than isometric joysticks and are less fatiguing for long operating periods. In addition to the general use, hand-operated displacement joysticks may be used as vehicle controllers and aiming sensors. Hand operated displacement joysticks may be used as mounting platforms for secondary controls, such as thumb and finger operated switches. Operation of secondary controls has less induced error on the displacement hand grip than does isometric handgrips. In addition to the general uses, finger-operated displacement joysticks are useful for free-drawn graphics. Thumb/fingertip joysticks may also be used but specific uses are TBD. (C)

7.2.2.4-2 Appropriate Use of Force Joysticks (Tier 1 - Use)
Isometric joystick controls may be used when the task requires precise or continuous control in two or more related dimensions.
COMMENT: Isometric joysticks are particularly appropriate for applications: (1) which require precise return to center after each use; (2) in which operator feedback is primarily visual rather than tactile feedback from the control itself; and (3) where there is minimal delay and tight coupling between control and input and system reaction. Isometric sticks should ordinarily not be used in applications where it would be necessary for the operator to maintain a constant force on the control inputs have been exceeded. When positioning speed is more critical than positioning accuracy, isometric joysticks should be selected over displacement joysticks. Hand-operated force joysticks may be used as mounting platforms for secondary controls, such as thumb and finger operated switches. Operation of secondary controls has greater induced error on the isometric hand grip than on displacement handgrip joysticks. Finger and thumb/fingertip joysticks may also be used but specific uses are TBD. (C)

7.2.2.4-3 Finger-Operated Displacement Joysticks Mounting (Tier 2 - General)
Joysticks should be mounted to provide forearm or wrist support. Modular devices should be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.
COMMENT: (C)

7.2.2.4-4 Finger-Operated Force Joystick Mounting (Tier 2 - General)
Joysticks should be mounted to provide forearm or wrist support. Modular devices should be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.
COMMENT: (C)

7.2.2.4-5 Thumbtip/Fingertip-Operated Displacement Joysticks Dimensions (Tier 2 - General)
Joysticks should be mounted to provide wrist or hand support. Modular devices should be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.
COMMENT: (C)

7.2.2.4-6 Hand-Operated Displacement Joysticks Dynamic Characteristics (Tier 3 - Design Details)
The output of the displacement joystick should be proportional to and in the same direction as the displacement of the joystick from the center. Movement should not exceed 45 degrees from the center position.

COMMENT: Movement should be smooth in all directions, and positioning of a follower should be attainable without noticeable backlash, cross-coupling or need for multiple corrective movements. Control ratios, friction and inertial should meet the dual requirements of rapid gross positioning and precise fine position. When used for generation of free-drawn graphics, the refresher rate for the follower on the display should be sufficiently high to give the appearance of a continuous track. (C,D)

7.2.2.4-7 Hand-Operated Force Joysticks Dynamic Characteristics (Tier 3 - Design Details)

The output of the force joystick should be proportional to and in the same direction as the user's perceived applied force. Maximum force for full output should not exceed 26.7lb (118 N).
COMMENT: (C,D)

7.2.2.4-8 Hand-Operated Displacement Joysticks Dimensions, Resistance, and Clearance (Tier 3 - Design Details)

The hand grip length shoud between 4.3in - 7.1in (110 - 180mm). The grip diameter should not exceed 2in (50mm). Clearances of 4 in (100mm) to the side and 2in (50mm) to the rear should be provided to allow for hand movement.
COMMENT: Joysticks should be mounted to provide forearm support. Modular devices should be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base. (C)

7.2.2.4-9 Hand-Operated Force Joysticks Dimensions; Resistance; and Clearance (Tier 3 - Design Details)

The hand grip length should be between 4.3in - 7.1in (110 - 180mm).
COMMENT: The grip diameter should not exceed 2in (50mm). Clearances of 4in (100mm) to the side and 2in (50mm) to the rear should be provided to allow for hand movement. Joysticks should be mounted to provide forearm support. Modular devices should be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base. (C)

7.2.2.4-10 Finger-Operated Displacement Joysticks Dynamic Characteristics (Tier 3 - Design Details)

The output of the displacement joystick should be proportional to and in the same direction as the displacement of the joystick from the center. Movement should not exceed 45 degrees from the center position.
COMMENT: The resistance should be sufficient to maintain the handle position when the hand is removed. Movement should be smooth in all directions, and positioning of a follower should be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements. Control ratios, friction and inertial should meet the dual requirements of rapid gross positioning and precise fine positioning. When used for generation of free-drawn graphics, the refresher rate for the follower on the display should be sufficiently high to give the appearance of a continuous track. (C,D)

7.2.2.4-11 Finger-Operated Force Joystick Dynamic Characteristics (Tier 3 - Design Details)

The output of the force joystick should be proportional to and in the same direction as the user's perceived applied force.
COMMENT: (D)

7.2.2.4-12 Thumbtip/Fingertip-Operated Displacement Joysticks Dynamic Characteristics (Tier 3 - Design Details)

. Thumbtip/fingertip operated joysticks may be mounted on a handgrip, which serves as a steady rest to damp vibrations and increase precision. If so mounted, the hand grip should not simultaneously function as a joystick controller.
COMMENT: (C,D)

7.2.2.4-13 Thumb/Fingertip-Operated Force Joystick Dynamic Characteristics (Tier 3 - Design Details)

The output of the force joystick should be proportional to and in the same direction as the user's

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.2 Direct Manipulation Controls
7.2.2.2 Trackballs

7.2.2.2-1 Appropriate Use of Trackball (Tier 1 - Use)

A trackball controller suspended on low-friction bearings may be used for various control functions such as data pickoff on a display.

COMMENT: Because the ball can be rotated without limit in any direction it is well suited for applications where there may be accumulative travel in a given direction. Trackballs should be used only as position controls (i.e., a given movement of a ball makes a proportional movement of the follower on the display). (C)

7.2.2.2-2 Trackball Dynamic Characteristics (Tier 2 - General)

The trackball should be capable of rotation in any direction so as to generate any combination of x and y output values. When moved in either the x or y directions alone there should be no apparent cross-coupling (follower movement in the orthogonal direction).

COMMENT: While manipulating the control, neither backlash nor cross-coupling should be apparent to the operator. Control ratios and dynamic features should meet the dual requirement of rapid gross positioning and smooth, precise fine positioning. (C)

7.2.2.2-3 Positive Centering Interface Requirements (Tier 2 - General)

Trackball interfacing system should provide the capability for an automatic return to point of origin.

COMMENT: Such as a pointing "home" position. The operator should not have to use the tackball to constantly position the pointing device at this home position. (C)

7.2.2.2-4 Limb Support (Tier 2 - General)

When trackball controls are used to make precise or continuous adjustments, wrist support or arm support or both should be provided.

COMMENT: (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.2 Direct Manipulation Controls
7.2.2.3 Mice

7.2.2.3-1 Appropriate Use of Mice (Tier 1 - Use)
A mouse controller may be used on any flat surface to generate x and y coordinate values which control the position of the follower on the associated display.
COMMENT: (C)

7.2.2.3-2 Use of Mouse by Either Hand (Tier 2 - General)
The controller should be operable with either the left or right hand.
COMMENT: (C)

7.2.2.3-3 Mouse Dynamic Characteristics (Tier 3 - Design Details)
The design of the controller and placement of the maneuvering surface should be such as to allow the operator to consistently orient the controller to within ±10 deg of the correct orientation without visual reference to the controller.
COMMENT: For example, when the operator grasps the controller in what seems to be the correct orientation and moves it rectilinearly along what is assumed to be straight up the y axis, then the direction of movement of the follower on the display should be between 350 and 10 deg (6110 and 175 mrad). The controller should be easily movable in any direction without a change of hand grasp. (C)

7.2.2.3-4 Mouse Dimensions and Shape (Tier 3 - Design Details)
The mouse should have no sharp edges but should be shaped roughly as a rectangular solid
COMMENT: (C)

perceived applied force.
COMMENT: (D)

7.2.2.4-14 Thumb/Fingertip-Operated Force Joystick Dimensions; Resistance; and Clearance (Tier 3 - Design Details)

Joysticks should be mounted to provide wrist or hand support. Modular devices should be mounted to allow actuation of the joystick without slippage, movement, or tilting of the mounting base.

COMMENT: Thumbtip/fingertip operated joysticks may be mounted on a handgrip, which serves as a steady rest to damp vibrations or increase precision. If so mounted the hand grip should not simultaneously function as a joystick controller. (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.3 Direct Pointing Controllers
7.2.3.1 General

7.2.3.1-1 Controller Placement and Movement (Tier 2 - General)
Movement of the controller on the control surface should result in the smooth movement of the follower in the same direction at the same rate as that of the controller.
COMMENT: Placing the controller at a point on the control surface should result in the follower appearing at the corresponding point on the screen, both when the control surface is the screen (or screen overlay) and when the control surface is remote; the follower should remain motionless until the controller is moved. (D)

7.2.3.1-2 Direct Pointing Controller Placement Location (Tier 2 - General)
Placing a direct pointing controller at the top of the control surface should result in the follower appearing at the top of the screen. This relationship should hold true even if the screen is in the vertical plane and the grid is in the horizontal.
COMMENT: (D)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.3 Direct Pointing Controllers
7.2.3.2 Touch Screen

7.2.3.2-1 Appropriate Use of Touch-screen Controllers (Tier 1 - Use)
Touch screens should be used for main item selection, scrolling, data retrieval, and data entry.
COMMENT: Touch screen control may be used to provide an overlaying control function to a data display device such as displays, dot matrix/segmented displays, electroluminescent displays, programmable indicators, or other display devices where direct visual reference access and optimum direct control access are desired. Touch screens are not recommended if task requires holding arm up to the screen for long periods of time. (B,C,D)

7.2.3.2-2 Actuation Feedback (Tier 2 - Feedback)
A positive indication of touch screen actuation should be provided to acknowledge that the command has been accepted and the system response to the control action.
COMMENT: (B,C)

7.2.3.2-3 Cursor Characteristics (Tier 2 - General)
When using a touch screen, the cursor should be visible on screen, offset from the point where the user's finger touches the screen and should be draggable as the user moves his/her finger.
COMMENT: In addition, a manual action independent from cursor control should be required for selecting an object or action. (D)

7.2.3.2-4 Serial Command Response (Tier 2 - General)
The system should accept only one command at a time.
COMMENT: (B)

7.2.3.2-5 Feedback for Multiple Workstations (Tier 2 - General)
Discriminable audible beeps (used to supply feedback) should be used when more than one touch screen is employed at more than one workstation.
COMMENT: (B)

7.2.3.2-6 Neutral Tint of Touch Overlays (Tier 2 - General)
To avoid alteration of color codes, touch screens should be toned with a neutral tint.
COMMENT: (B)

7.2.3.2-7 Dimensions and Separation of Touch Zones (Tier 3 - Design Details)
To allow for finger size and parallax inaccuracy, the dimensions and separation of response areas of touch screen should be a maximum height and width of 1.5in (38mm) and a minimum height and width of 5/8in (15mm) with a maximum separation distance of 1/4in (6mm) and minimum of 1/8in (3mm).
COMMENT: (C,D)

7.2.3.2-8 Resistance (Tier 3 - Design Details)
Force required to operate force-actuated touch screens should be a maximum of 5.3oz (1.5N) and minimum of 0.9oz (250mN).
COMMENT: (C)

7.2.3.2-9 Luminance Transmission (Tier 3 - Design Details)
Touch screen displays should have sufficient luminance transmission to allow the display with touch screen installed to be clearly readable in the intended environment.
COMMENT: (B,C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.3 Direct Pointing Controllers
7.2.3.3 Light Pen

7.2.3.3-1 Appropriate Use of a Light Pen (Tier 1 - Use)
A light pen may be used when non-critical, imprecise input functions are required.
COMMENT: Such direct-pointing controls should be used when item selection is the primary type of data entry, cursor placement, text selection, and command construction. Tasks involving light pens should not require frequent, alternating use of the light pen and the keyboard or require long, continuous intervals of light pen use. (C)

7.2.3.3-2 Feedback (Tier 2 - Feedback)
Two forms of feedback should be provided to the user when using a lightpen: (1) Feedback concerning the position of the lightpen, (2) Feedback that the lightpen has actuated and the input has been received by the system.
COMMENT: Feedback in the form of displayed cursor (such as circle or crosshair)is preferable, or highlighting which also informs the user that the system is recognizing the presence of the lightpen. The feedback should be large enough to be seen under the point of the lightpen. (C)

7.2.3.3-3 Dynamic Characteristics (Tier 2 - General)
When used as a two-axis controller, movement of the light pen in any direction on the surface should result in smooth movement of the follower in the same direction.
COMMENT: Discrete placement of the light pen at any point on the surface should cause the follower to appear at the corresponding coordinates and to remain steady so long as the light pen is not moved. Refresh rate for the follower should be sufficiently high to ensure the appearance of continuous track whenever the light pen is used for generation of free-drawn graphics. (C)

7.2.3.3-4 Dimensions and mounting (Tier 3 - Design Details)
The light pen should be 4.7-7.1in (120-180mm) long with a diameter of 0.3-0.8in (7-20mm). A convenient clip should be provided at the lower right side of the display to hold the pen when not in use.
COMMENT: (C)

7.2.3.3-5 Light Pen Actuation (Tier 3 - Design Details)
Light pens should be equipped with a discrete actuating/deactuation mechanism. For most applications, a push-tip switch, requiring 2-5oz (0.5N - 1.4N) of force to actuate, is preferred.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.3 Direct Pointing Controllers
7.2.3.4 Graphic Tablet - Grid and Stylus Devices

7.2.3.4-1 Appropriate Use of a Graphics Tablet (Tier 1 - Use)
Grid and stylus devices may be used for data pickoff from a display, entry of points on a display, generation of free-drawn graphics and similar control applications. Devices of this type should be used only for zero order control functions.
COMMENT: For example, displacement of the stylus from the reference position causes a proportional displacement of the follower. The grid may be on a transparent medium allowing stylus placement directly over corresponding points on the display or it may be displaced from the display in a convenient position for stylus manipulation. In either case a follower (bug, Mark, hook, etc.) should be presented on the display at the coordinate values selected by the stylus. (C)

7.2.3.4-2 Dynamic Characteristics (Tier 2 - General)
Movement of the stylus in any direction on the grid surface should result in smooth movement of the follower in the same direction.
COMMENT: Discrete placement of the stylus at any point on the grid should cause the follower to appear at the corresponding coordinates and to remain steady so long as the stylus is not moved. Refresh rate for the follower should be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used for generation of free-drawn graphics. (C)

7.2.3.4-3 Dimensions and Mounting (Tier 3 - Design Details)
Transparent grids which are used as display overlays should conform to the size of the display. Grids which are displaced from the display should approximate the display size and should be mounted below the display in an orientation to preserve directional relationships to the maximum extent .
COMMFNT: For example, a vertical plane passing through the north/south axis on the grid should pass through or be parallel tot he north/south axis on the display. (C)

7.0 WORKSTATION DESIGN
7.2 Control and Input Devices
7.2.3 Direct Pointing Controllers
7.2.3.3 Light Pen

7.2.3.3-1 Appropriate Use of a Light Pen (Tier 1 - Use)
A light pen may be used when non-critical imprecise input functions are required.
COMMENT: Such direct-pointing controls should be used when item selection is the primary type of data entry, cursor placement, text selection, and command construction. Tasks involving light pens should not require frequent, alternating use of the light pen and the keyboard or require long, continuous intervals of light pen use. (C)

7.2.3.3-2 Feedback (Tier 2 - Feedback)
Two forms of feedback should be provided to the user when using a lightpen: (1) Feedback concerning the position of the lightpen, (2) Feedback that the lightpen has actuated and the input has been received by the system.
COMMENT: Feedback in the form of displayed cursor (such as circle or crosshair)is preferable, or highlighting which also informs the user that the system is recognizing the presence of the lightpen. The feedback should be large enough to be seen under the point of the lightpen. (C)

7.2.3.3-3 Dynamic Characteristics (Tier 2 - General)
When used as a two-axis controller, movement of the light pen in any direction on the surface should result in smooth movement of the follower in the same direction.
COMMENT: Discrete placement of the light pen at any point on the surface should cause the follower to appear at the corresponding coordinates and to remain steady so long as the light pen is not moved. Refresh rate for the follower should be sufficiently high to ensure the appearance of continuous track whenever the light pen is used for generation of free-drawn graphics. (C)

7.2.3.3-4 Dimensions and mounting (Tier 3 - Design Details)
The light pen should be 4.7-7.1in (120-180mm) long with a diameter of 0.3-0.8in (7-20mm). A convenient clip should be provided at the lower right side of the display to hold the pen when not in use.
COMMENT: (C)

7.2.3.3-5 Light Pen Actuation (Tier 3 - Design Details)
Light pens should be equipped with a discrete actuating/deactuation mechanism. For most applications, a push-tip switch, requiring 2-5oz (0.5N - 1.4N) of force to actuate, is preferred.
COMMENT: (C)

7.0 WORKSTATION DESIGN
7.4 Control Room Configuration
7.4.1 Environment
7.4.1.1 Glare

7.4.1.1-1 Nonreflecting Screen Positioning (Tier 2 - General)
The screen should be positioned so that sources of light and/or bright objects do not reflect into the expected viewing position.
COMMENT: (B)

7.4.1.1-2 Nonglare VDU Screen Surface (Tier 2 - General)
The surface of the VDU screen should be modified to reduce specular glare.
COMMENT: (B)

ENCLOSURE 2

HFE PROGRAM REVIEW MODEL AND ACCEPTANCE CRITERIA FOR EVOLUTIONARY REACTORS

(7/10/92)

CONTENTS

1 MODEL DEVELOPMENT

1.1 Objectives

One issue to emerge from the review process of evolutionary reactor control room designs was that complete detailed HSI design information would not be available for review prior to design certification and that certification would be based partially on the approval of a design and implementation process plan. The process must contain: (1) descriptions of all required HFE program elements for the design, development and implementation of the evolutionary reactor human-system interfaces, (2) identification of predetermined NRC conformance review points, and (3) design acceptance criteria (DAC) and Inspection, Test, Analysis and Acceptance Criteria (ITAAC) for the conformance reviews.

To review the designers process, it is necessary to: (1) assess whether all the appropriate HFE elements are included, (2) identify what materials are to be reviewed for each element, and (3) evaluate the proposed DAC/ITAAC to verify each of the elements. Since a process review has not been conducted previously by the NRC as part of reactor licensing and is not addressed in the presently available guidance, i.e., NUREG-0800, a firm technical basis for such a review is not available. To conduct the review, it is important to identify which aspects of the process are required to assure that safety goals are achieved and to identify the review criteria by which each element can be assessed. Review criteria independent of that provided by the designer is required to assure that the design plan reflects currently acceptable human factors engineering practices and that it is a thorough, complete, and workable plan. Thus, a technical basis for review of the process was developed and is described in this section. The specific objectives of this effort are:

1. To develop an HFE program review model to serve as a technical basis for the review of the process proposed for certification. The model requirements are that it be: (1) based upon currently accepted practices, (2) well-defined, and (3) validated through experience with the development of complex, high-reliability systems.

2. To identify the HFE elements in a system development, design, and evaluation process that are necessary and sufficient requisites to successful integration of the human component in complex systems.

3. To identify which aspects of each HFE element are key to a safety review and are required to monitor the process.

4. To specify the specific acceptance criteria by which HFE elements can be evaluated.

1.2 Scope

The scope of the HFE Program Review Model was restricted by two factors. First, those elements of a complete HFE program that are already adequately addressed by existing NRC requirements for license applicants were excluded from the scope of the model. Included in this category were training program development and the details of procedure development. The second category of exclusion were those elements that are the responsibility of other NRC review teams. This category includes human reliability analysis which, while important to HFE program development, is the responsibility of the SSAR Chapter 19 reviewers. Therefore, the scope of the model development described below was restricted to those aspects of HFE design review remaining after the above elements are excluded.

1.3 Development Method

A technical review of current HFE guidance and practices was conducted to identify important human factors program plan elements relevant to a design process review. Sources reviewed included a wide range of nuclear industry and non-nuclear industry documents, including those currently under development as part of the Department of Defense (DoD) MANPRINT program (Booher, 1990, DoD, 1989; DoD, 1990a). From this review a generic system development, design, and evaluation process was defined. Once specified, key HFE elements were identified and criteria by which they are assessed (based upon a review of current literature and accepted practices in the field of human factors engineering) were developed.

The generic HFE Program Review Model was developed based largely on applied general systems theory (Bailey, 1982; DeGreen, 1970; Gagne, et al., 1988; VanCott et al., 1972; Woodson, 1981) and the Department of Defense (DoD) system development process which is rooted in systems theory (DoD, 1979a; DoD, 1990b; Kockler et al., 1990). Other DoD documents were utilized as well (see References section).

Applied general systems theory provides a broad approach to system design and development, based on a series of clearly defined developmental steps, each with clearly defined and goals, and with specific management processes to attain them. System engineering has been defined as "...the management function which controls the total system development effort for the purpose of achieving an optimum balance of all system elements. It is a process which transforms an operational need into a description of system parameters and integrates those parameters to optimize the overall system effectiveness (Kockler et al., 1990).

Utilization of the DoD system development as an input to the development of the Generic HFE Program Model was based on several factors. DoD policy identifies the human as a specific element of the total system (DoD, 1990a). A systems approach implies that all system components (hardware, software, personnel, support, procedures, and training) are given adequate consideration in the developmental process. A basic assumption is that the personnel element receives serious consideration from the very beginning of the design process. In addition, the military has applied HFE for the longest period of time (as compared with industrial/commercial system developers), thus the process is highly evolved and formalized and represents the most highly developed model available. Finally, since military system development and acquisition is tightly regulated by federal, DoD, and military branch laws, [illegible], requirements, and standards, the model provides the most finely [illegible], specifically defined HFE process available.

Within the DoD system, the development of a complex system begins with the mission or purpose of the system, and the capability requirements needed to satisfy mission objectives. Systems engineering is essential in the earliest planning period to develop the system concept and to define the system requirements. During the detailed design of the system, systems engineering assures:

- balanced influence of all required design specialties;
- resolution of interface problems;
- the effective conduct of trade-off analyses;
- the effective conduct of design reviews; and
- the verification of system performance.

The effective integration of HFE considerations into the design is accomplished by: (1) providing a structured top-down approach to system development which is iterative, integrative, interdisciplinary and requirements driven and (2) providing a management structure which details the HFE considerations in each step of the overall process. A structured top-down approach to NPP HFE is consistent with the approach to new control room design as described in Appendix B of NUREG-0700 (NRC, 1981) and the more recent internationally accepted standard, IEC 964 (1989) for advanced control room design. The approach is also consistent with the recognition that human factors issues and problems emerge throughout the NPP design and evaluation process and therefore, human factors issues are best addressed with a comprehensive top-down program.

The systems engineering approach was expanded to develop an HFE Program Review Model to be used for the evolutionary reactor design and implementation process review by the incorporation of NRC HFE requirements.

2 GENERAL MODEL DESCRIPTION

In this section an overview of the model is presented to generally describe the HFE elements, products reviewed for each element, and the acceptance criteria used to evaluate the element.

The model is intended as the programmatic approach to achieving a design commitment to HFE. The overall commitment and scope of the HFE effort can be stated as follows: Human-system interfaces (HSI) shall be provided for the operation, maintenance, test, and inspection of the NPP that reflect "state-of-the-art human factors principles" (10 CFR 50.34(f)(2)(iii)) as required by 10 CFR 52.47(a)(1)(ii). For the purposes of model development "state of the art" human factors principles are defined as those principles currently accepted by human factors practitioners. "Current" is defined with reference to the time at which this model was developed. "Accepted" is defined as a practice, method, or guide which is (1) documented in the human factors literature within a standard or guidance document that has undergone a peer-review process, and/or (2) justified through scientific/industry research practices.

All aspects of HSI should be developed, designed, and evaluated based upon a structured top-down system analysis using accepted HFE principles based upon current HFE practices. HSI is used here in the very broad sense and shall include all operations, maintenance, test, and inspection interfaces, procedures, and training materials.

The model developed to achieve this commitment contains eight elements:

- Element 1 - Human Factors Engineering Program Management
- Element 2 - Operating Experience Review
- Element 3 - System Functional Requirements Analysis
- Element 4 - Allocation of Function
- Element 5 - Task Analysis
- Element 6 - Human-System Interface Design
- Element 7 - Plant and Emergency Operating Procedure Development
- Element 8 - Human Factors Verification and Validation.

The elements and their interrelationships are illustrated in Figure A.1. Also illustrated are the minimal set of items submitted to the NRC for review of the COL's HFE efforts. All NRC review items are identified as falling into one of the five review stages:

- HF Management Planning Review
- Implementation Plan Review
- Analysis Results Review
- HSI Results Review
- Human Factors Verification and Validation

The materials reviewed at each stage are shown in Figure A.2.

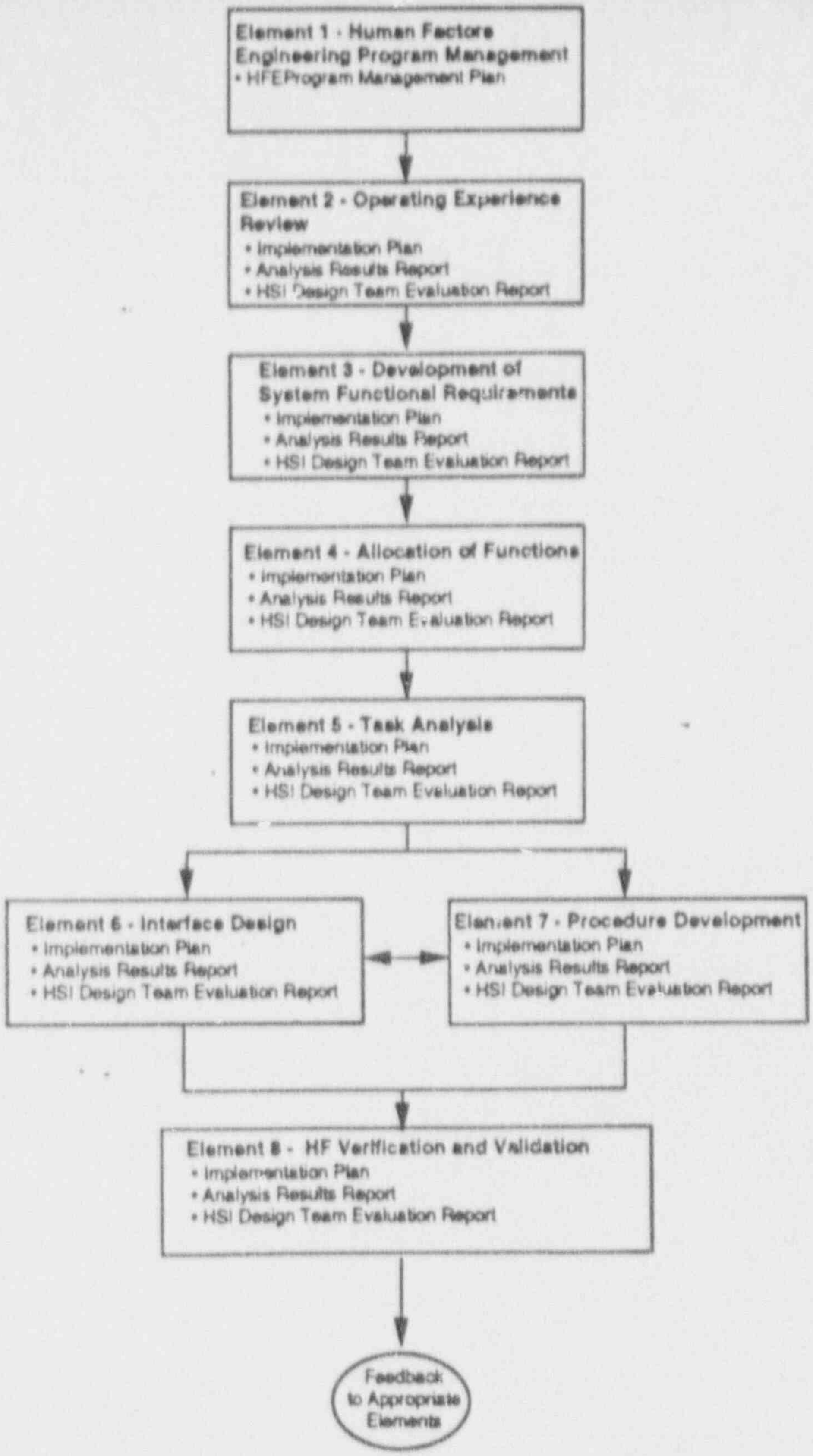

Figure A1. HFE Program Review Model Elements

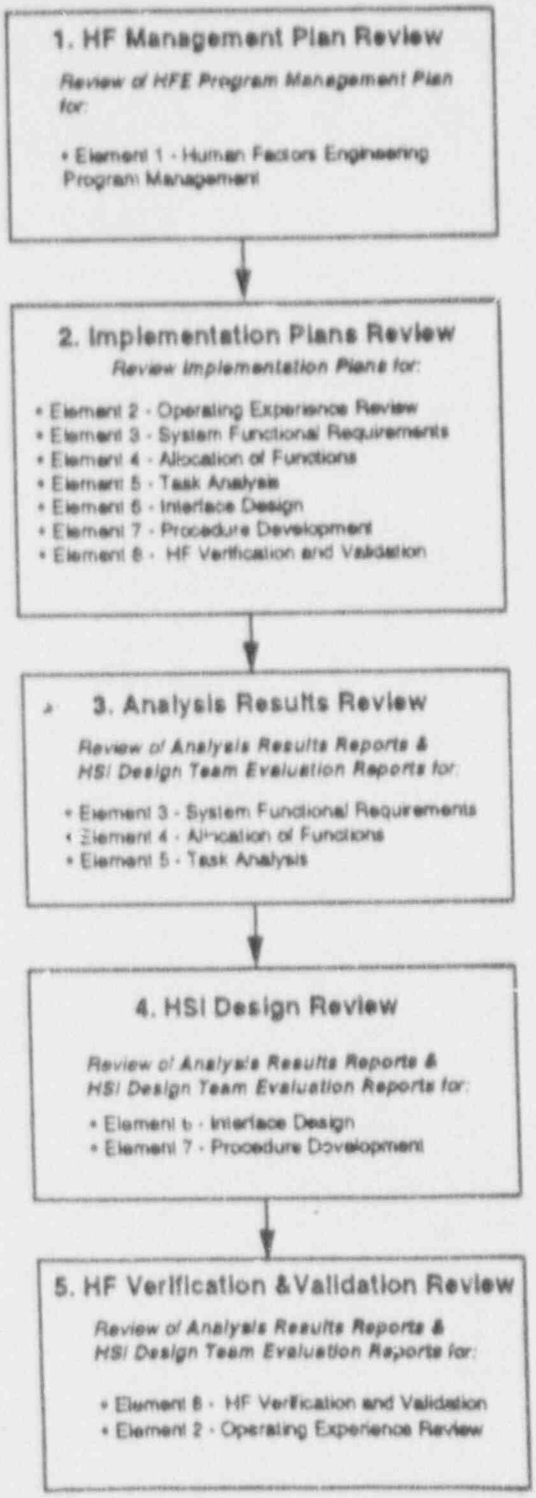

Figure A2. HFE Program Review Stages

A brief description of the purpose of each element follows:

Element 1 - Human Factors Engineering Program Management

To assure the integration of HFE into system development and the achievement of the goals of the HFE effort, an HSI Design Team and an HFE Program Plan shall be established to assure the proper development, execution, oversight, and documentation of the human factors engineering program. As part of the program plan an HFE issues tracking system (to document and track HFE related problems/concerns/issues and their solutions throughout the HFE program) will be established.

Element 2 - Operating Experience Review

The accident at Three Mile Island in 1979 and other reactor incidents have illustrated significant problems in the actual design and the design philosophy of NPP HSIs. There have been many studies as a result of these accidents/incidents. Utilities have implemented both NRC mandated changes and additional improvements on their own initiative. However, the changes were formed based on the constraints associated with backfits to existing control rooms (CRs) using early 1980s technology which limited the scope of corrective actions that might have been considered, i.e., more effective fixes could be used in the case of a designing a new CR with the modern technology typical of advanced CRs. Problems and issues encountered in similar systems of previous designs shall be identified and analyzed so that they are avoided in the development of the current system or, in the case of positive features, to ensure their retention.

Element 3 - System Functional Requirements Analysis

System requirements shall be analyzed to identify those functions which must be performed to satisfy the objectives of each functional area. System function analysis shall: (1) determine the objective, performance requirements, and constraints of the design; and (2) establish the functions which must be accomplished to meet the objectives and required performance.

Element 4 - Allocation of Functions

The allocation of functions shall take advantage of human strengths and avoids allocating functions which would be impacted by human limitations. To assure that the allocation of functions is conducted according to accepted HFE principles, a structured and well-documented methodology of allocating functions to personnel, system elements, and personnel-system combinations shall be developed.

Element 5 - Task Analysis

Task analysis shall provide the systematic study of the behavioral requirements of the tasks the personnel subsystem is required to perform in order to achieve the functions allocated to them. The task analysis shall:

- provide one of the bases for making design decisions; e.g., determining before hardware fabrication, to the extent practicable, whether system performance requirements can be met by combinations of anticipated equipment, software, and personnel,

- assure that human performance requirements do not exceed human capabilities,

- be used as basic information for developing procedures,

- be used as basic information for developing manning, skill, training, and communication requirements of the system, and

- form the basis for specifying the requirements for the displays, data processing and controls needed to carry out tasks.

Element 6 - Human-System Interface Design

Human engineering principles and criteria shall be applied along with all other design requirements to identify, select, and design the particular equipment to be operated/maintained/controlled by plant personnel.

Element 7 - Plant and Emergency Operating Procedure Development

Plant and Emergency Operating Procedures shall be developed to support and guide human interaction with plant systems and to control plant-related events and activities. Human engineering principles and criteria shall be applied along with all other design requirements to develop procedures that are technically accurate, comprehensive, explicit, easy to utilize, and validated. The types of procedures covered in the element are:

- plant and system operations (including start-up, power, and shutdown operations),
- abnormal & emergency operations,
- preoperational, start-up, and surveillance tests, and
- alarm response.

Element 8 - Human Factors Verification and Validation

The successful incorporation of human factors engineering into the final HSI design and the acceptability of the resulting HSI shall be thoroughly evaluated as an integrated system using HFE evaluation procedures, guidelines, standards, and principles.

The specification for the NRC review materials and the acceptance criteria to be used for their evaluation are identified in the next section. Generically, each element is divided into three sections: Design Commitment, Inspection/Test/Analysis, and Design Acceptance Criteria.

Design Commitment

A concise and general statement as to the HFE objective of the Element.

Inspection/Test/Analysis

A specification of the inspections, tests, analysis, or other actions (i.e., some action that is required but which is not a specific inspection, test, or analysis, such as development of a program plan) to assure the achievement of the objective. Generally these are divided into three activities: planning, "analysis," and review. The set of materials to be provided to the NRC for review of the element is specified.

Design Acceptance Criteria

Acceptance criteria are typically divided into four sections: General Criteria, Implementation Plan, Analysis Report, and HSI Design Team Review Report. The General Criteria represent the major statement of design acceptance criteria. These are the criteria the element is required to meet and which should govern the Implementation Plan, Analysis Report, and HSI Design Team Review Report development. The general criteria are derived from accepted HFE practices. These are the criteria derived from the HFE model development and HFE literature and current practices review.

The HFE Program Review Model requires that HFE elements be governed by accepted HFE practices as specified in applicable codes, standards, and guidelines. Each element requires an identification of the codes, standards, and guidelines which are to be applied. Applicable codes, standards, and guidelines for the HFE Program Review Model Elements are provided below. With respect to Element 2 - Operating Experience Review, the documents listed also provide further issue description. While these documents contain generally recognized acceptable approaches to the conduct of the HFE activity described by the element, several caveats should be identified:

· There may be inconsistencies or contradictions within and between documents. Such conflicts should be resolved on a case-by-case basis depending upon the specific application under review.

· Not each document listed under a given element necessarily address all aspects of the element. In the conduct of a review of each element a combination of the applicable section of several of the identified document may be appropriate.

· It should not be inferred that the listed documents provide complete guidance for each and every activity encompassed by the element. HFE is not at a state of maturity to be confident that all HFE activities are adequately covered in codes, standards, and guidelines.

· The listed documents represent currently accepted documents in the human factors community. Alternative approached can be found acceptable if judged by the reviewer to be based in firm rationale. Proposed alternative approaches should be evaluated on a case-by-case basis.

3 ELEMENT DESCRIPTIONS AND ACCEPTANCE CRITERIA

3.1 Element 1 - Human Factors Engineering Program Management

DESIGN COMMITMENT:

Human-system interfaces (HSI) shall be provided for the operation, maintenance, test, and inspection of the NPP that reflect "state-of-the-art human factors principles" (10 CFR 50.34(f)(2)(iii)) as required by 10 CFR 52.47(a)(1)(ii). All aspects of HSI shall be developed, designed, and evaluated based upon a structured top-down system analysis using accepted human factors engineering (HFE) principles based upon current HFE practices. HSI is used here in the broad sense and shall include all operations, maintenance, test, and inspection interfaces, procedures, and training needs. The tier 1 commitment addresses main control room and remote shutdown system functions and equipment. Local control stations should be included in the overall program.

State of the art human factors principles is defined as those principles currently accepted by human factors practitioners. "Current" is defined with reference to the time at which a program management or implementation plan is prepared. "Accepted" is defined as a practice, method, or guide which is (1) documented in the human factors literature within a standard or guidance document that has undergone a peer-review process and/or (2) can be justified through scientific/industry research/practices.

INSPECTION/TEST/ANALYSIS:

To assure the integration of HFE into system development: a HSI Design Team shall be established and a HFE Program Plan shall be established to assure the proper development, execution, oversight, and documentation of the human factors engineering program.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. The primary goal of the HFE program shall be to developing an HSI which makes possible safe, efficient, and reliable operator performance and which satisfy all regulatory requirements as stated in 10 CFR. The general objectives of this program shall be stated in "human-centered" terms which, as the E program develops, shall be objectively defined and shall serve as criteria for test and evaluation activities. Generic "human-centered" HFE design goals include:

   - The operating team can accomplish all assigned tasks within system defined time and performance criteria.

   - The system and allocation of functions will provide acceptable workload levels to assure vigilance and to assure no operator overload.

- The system will support a high degree of operating crew "situation awareness."

- Signal detection and event recognition requirements will be kept within the operators' information processing limits and will minimize the need for operators to mentally transform data in order to be usable.

- The system will minimize operator memory load.

- The operator interfaces will minimize operator error and will provide for error detection and recovery capability.

2. The program shall be developed using the following documents as guidance:

MIL-H-46855B: *Human engineering requirements for military systems, equipment and facilities*, 1979, (Department of Defense).

AR 602-1: *Human factors engineering program*, 1983, (Department of Defense).

DI-HFAC-80740: *Human engineering program plan*, 1989, (Department of Defense).

AR 602-2: *Manpower and personnel integration (MANPRINT) in the materiel acquisition process*, 1990, (Department of Defense).

DOD-HDBK-763: *Human engineering procedures guide*, 1991, (Department of Defense).

IEEE Std 1023-1988: *IEEE guide to the application of human factors engineering to systems, equipment, and facilities of nuclear power generating stations*, 1988, (IEEE).

HSI Design Team

1. An HSI Design Team shall have the responsibility, authority and placement within the organization (as defined below) to ensure that the design commitment is achieved.

2. The team shall be responsible for (1) the development of all HFE plans and procedures; (2) the oversight and review of all HFE design, development, test, and evaluation activities; (3) the initiation, recommendation, and provision of solutions through designated channels for problems identified in the implementation of the HFE activities; (4) verification of implementation of team recommendations, (5) assurance that all HFE activities comply to the HFE plans and procedures, and (7) scheduling of activities and milestones.

3. The scope of the Team's responsibility shall include:

- Control and instrumentation equipment

- all operations, maintenance, test, and inspection of interfaces and facilities both within and outside the control room,
- procedures
- training requirements development.

4. The Team shall have the authority and organizational freedom to ensure that all its areas of responsibility are accomplished and to identify problems in the implementation of the HSI design. The team shall have the authority to determine where its input is required, access work areas, design documentation. The Team shall have the authority to control further processing, delivery, installation or use of HFE/HSI products until the disposition of a non-conformance, deficiency or unsatisfactory condition has been achieved.

5. The HSI Design Team shall be placed at the level in the COL organization required to execute its responsibilities and authorities. The team shall report to a level of management such that required authority and organizational freedom are provided, including sufficient independence from cost and schedule considerations.

6. The HSI Design Team shall include the following expertise:

Technical Project Management

- Bachelor's degree,
- five years' experience in nuclear power plant design or operations, and
- three years' management experience.

Systems Engineering

- Bachelor's of Science degree, and
- four years' cumulative experience in at least three of the following areas of systems engineering; design, development, integration, operation, and test and evaluation.

Nuclear Engineering

- Bachelor's of Science degree, and
- four years' nuclear design, development, test or operations experience

Control and Instrumentation Engineering

- Bachelor's of Science degree,
- four years' experience in design of process control systems, and
- experience in at least one of the following areas of C&I engineering; development, power plant operations, and test and evaluation.

Architect Engineering

- Bachelor's of Science degree, and
- four years' experience in design of power plant control rooms.

Human Factors

- Bachelor's degree in human factors engineering, engineering psychology or related science,

- four years' cumulative experience related to the human factors aspects of human-computer interfaces. Qualifying experience shall include experience in at lease two of the following human factors related activities; design, development, and test and evaluation, and

- four years' cumulative experience related to the human factors field of ergonomics. Again, qualifying experience shall include experience in at least two of the following areas of human factors activities; design, development, and test and evaluation.

Plant Operations

- Have or have held a Senior Reactor Operator license, and
- two years' experience in relevant nuclear power plant operations.

Computer System Engineering

- Bachelor's degree in Electrical Engineering or Computer Science, or graduate degree in other engineering discipline (e.g., Mechanical Engineering or Chemical Engineering), and
- four years' experience in the design of digital computer systems and real time systems applications.

Plant Procedure Development

- Bachelor's degree, and
- four years' experience in developing nuclear power plant operating procedures.

Personnel Training

- Bachelor's degree,
- four years' experience in the development of personnel training programs for power plants, and
- experience in the application of systematic training development methods.

Systems Safety Engineering

- Bachelor's degree in Science,
- certification by the Board of Certified Safety Professionals in System Safety, and
- four years' experience in System Safety Engineering.

Reliability/Availability/Maintainability/Inspectability (RAMI) Engineering

Maintainability/Inspectability Engineering

- Bachelor's of Science degree,
- four years' cumulative experience in at least two of the following areas of power plant maintainability and inspectability engineering activity; design, development, integration and test and evaluation, and
- experience in analyzing and resolving plant system and/or equipment related maintenance problems.

Reliability/Availability Engineering

- Bachelor's degree,
- four years' cumulative experience in at least two of the following areas of power plant reliability engineering activity; design, development, integration, and test and evaluation, and
- knowledge of computer-based, human-interface systems.

7. The education and related professional experience of the HSI Design Team personnel shall satisfy the minimum personal qualification requirements specified in (6) above for each of the areas of required skills. In those skill areas where related professional experience is specified, qualifying experience of the individual HFE design team personnel shall include experience in the technologies and techniques, of the particular skill area, utilized in the HSI design and implementation activities. The required professional experience presented in those personal qualification are to be satisfied by the HSI Design Team as a collective whole. Therefore, satisfaction of the professional experience requirements associated with a particular skill area may be realized through the combination of the professional experience of two or more members of the HSI Design Team who each, individually, satisfy the other defined credentials of the particular skill area but who do not possess all of the specified professional experience. Similarly, an individual member of the HSI Design Team may possess all of the credentials sufficient to satisfy the qualification requirements for two or more of the defined skill areas.

8. Alternative personal credentials may be accepted as the basis for satisfying the minimum personal qualification requirements specified in 6 above. Acceptance of such alternative personal credentials shall be evaluated on a case-by-case basis and approved, documented and retained in auditable plant construction files by the COL Applicant. The following factors are examples of alternative credentials which are considered acceptable:

   - A Professional Engineer's license in the required skill area may be substituted for the required Bachelor's degree.

   - Successful completion of all technical portions of an e ineering, technology or related science baccalaureate program may .

substituted for the Bachelor's degree. The successful completion will be determined by a transcript or other certification by an accredited institution. For example, completion of 80 semester credit hours may be substituted for the baccalaureate requirement. The courses shall be in appropriate technical subjects relevant to the required skill areas of the HFE MMIS Design Team for which the individual will be responsible.

- Related experience may substitute for education at the rate of six semester credit hours for each year of experience up to a maximum of 60 hours credit.

- Where course work is related to job assignments, post secondary education may be substituted for experience at the rate of two years of education for one year experience. Total credit for post secondary education shall not exceed two years experience credit.

HFE Issue Tracking System

1. The tracking system shall address human factors issues that are (1) known to the industry (defined in the operating experience review, see Element 2) and (2) those identified throughout the life cycle of the ABWR system design, development and evaluation.

2. The method shall document and track human factors engineering issues and concerns, from identification until elimination or reduction to a level acceptable to the Team.

3. Each issue/concern that meets or exceeds the threshold effects established by the Team shall be entered on the log when first identified, and each action taken to eliminate or reduce the issue/concern should be thoroughly documented. The final resolution of the issue/concern, as accepted by the Team, shall be documented in detail, along with information regarding Team acceptance (e.g., person accepting, date, etc.).

4. The tracking procedures shall carefully spell out individual responsibilities when an issue/concern is identified, identify who should log it, who is responsible for tracking the resolution efforts, who is responsible for acceptance of a resolution, and who should enter closeout data.

HFE Program and Management Plan

1. An HFE Program Management plan shall be developed to describe how the human factors program shall be accomplished, i.e., the plan shall describe the HSI Design Team's organization and composition and which lays out the effort to be undertaken and provides a technical approach, schedule, and management control structure and technical interfaces to achieve the HFE program objectives. The plan is the single document which describes the designer's entire HFE program, identifies its

elements, and explains how the elements will be managed. Generally, it shall address:

- The scope of the HSI Design Team's authority within the broader scope of the organization responsible for plant construction. Included within this scope shall be the authority to suspend from delivery, installation, or operation any equipment which is determined by the Team to be deficient in regard to established human factors design practices and evaluation criteria.

- The process through which the Team will execute its responsibilities.

- The processes through which findings of the Team are resolved and how equipment design changes that may be necessary for resolution are incorporated into the actual equipment ultimately used in the plant.

- The members and qualification of the Team members.

- The process through which the Team activities will be assigned to individual team members, the responsibilities of each team member and the procedures that will govern the internal management of the Team.

- The procedures and documentation requirements of the HFE Issues Tracking System.

2. The HFE Program Management Plan shall provide the following information:

   1. Purpose and organization of the plan
   2. Literature and current practices review
   3. Overall HFE program goals and objectives
   4. The relationship between the HFE program and the overall plant design program (organization and schedule).
   5. HSI Design Team

   - Organization within the HFE program

     - Identify and describe the primary HFE organization or function within the organization of the total program, including charts to show organizational and functional relationships, reporting relationships, and lines of communication.

   - Functions and internal structure of the HFE Organization

     - Describe the responsibility, authority and accountability of the HFE organization.
     - Identify the organizational unit responsible for each HFE task.

- Describe the process through which management decisions will be made regarding HFE.
- Describe the process through which design decisions will be made regarding HFE.
- Describe all tools and techniques (e.g., review forms, documentation) to be utilized by the Team to ensure they fulfill their responsibilities.

• Staffing

  - Describe the staffing of the HSI Design Team.
  - Provide job descriptions of personnel of the HSI Design Team.
  - Indicate the assignment of key personnel and provide their qualifications with regard to the areas of expertise indicated above.

6. HFE Issue Tracking System

• Literature and current practices review
• Responsibilities

  - Responsibilities on Issue Identification
  - Responsibilities for Issue Logging
  - Responsibilities for Issue Resolution
  - Responsibilities for Issue Closeout

• Procedures

  - Issue identification
    Description
    Effects
    Criticality and Likelihood
  - Issue resolution
    Proposed Solutions
    Implemented Solution
    Residual Effects
    Resultant Criticality and Likelihood

• Documentation
• Audit of the issue identification and tracking system

7. HFE Requirements

• Identify and describe the HFE requirements imposed on the design process
• List the standards and specifications which are sources of HFE requirements

8. HFE program

Identify and describe the development of implementation plans, analyses, and evaluation/verification of:

- Operating Experience Review
- System Functional Requirements Development
- Allocation of Function
- Task Analysis
- Interface Design
- Plant and Emergency Operating Procedure Development
- HF Verification and Validation

9. HFE program milestones

- Identify HFE milestones, so that evaluations of the effectiveness of the HFE effort can be made at critical check points and show the relationship to the integrated plant sequence of events.

- Provide a program schedule of HFE tasks showing:

  - relationships between HFE elements and activities.
  - reports
  - reviews

- Identify integrated design activities applicable to the HFE program but specified in other areas.

10. HFE documentation

- Identify and briefly describe each required HFE documented item.
- Identify procedures for accessibility and retention.
- Describe the supporting documentation and its audit trail maintained for NRC audits.

11. HFE in subcontractor efforts

- Provide a copy of the HFE requirements proposed for inclusion in each subcontract.
- Describe the manner in which the designer proposes to monitor the subcontractor's compliance with HFE requirements.

3.2 Element 2 - Operating Experience Review

DESIGN COMMITMENT:

The accident at Three Mile Island in 1979 and other reactor incidents have illustrated significant problems in the actual design and the design philosophy of NPP HSIs. There have been many studies as a result of these accidents/incidents. Utilities have implemented both NRC mandated changes and additional improvements on their own initiative. However, the changes were formed based on the constraints associated with backfits to existing CRs using early 1980s technology which limited the scope of corrective actions that might have been considered, i.e., more effective fixes could be used in the case of a designing a new CR with the modern technology typical of advanced CRs. Problems and issues encountered in similar systems of previous designs shall be identified and analyzed so that they are avoided in the development of the current system or, in the case of positive features, to ensure their retention.

INSPECTION/TEST/ANALYSIS:

- An Operating Experience Review Implementation Plan shall be developed.
- An analysis of operating experience shall be conducted in accordance with the plan and the findings will be documented in an Analysis Results Report.
- The analyses shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. The following industry operating experience issues shall be reviewed:

   · See the list of issues identified in the "Operating Experience Review Issues" attachment at the end of this document

2. The issues shall be reviewed and analyzed for:
   - Human performance issues, problems and sources of human error shall be identified.
   - Design elements which support and enhance human performance shall be identified.

3. The following topics should be included in interviews as a minimum:
   - Display factors
   - Control factors
   - Information processing factors
   - Communication factors
   - Procedures

- Training factors
- Staffing and Job Design

4. The review shall include both a review of literature pertaining the human factors issues related to similar systems and operator interviews.

5. The following sources both industry wide and plant or subsystem relevant should be included in review of the identified issues:

   - Government and Industry Studies of Similar Systems
   - Licensee Event Reports
   - Outage Analysis Reports
   - Final Safety Analysis Reports and Safety Evaluation Reports
   - Human Engineering Deficiencies identified in DCRDRs
   - Modifications of the Technical Specifications for Operation
   - Internal Memoranda/Reports as Available

6. Each operating experience issue shall be documented in the HFE Tracking System.

7. The program shall be developed using the following documents as guidance and issue definition:

NUREG-0737: *Clarification of TMI action plan requirements* (Supplement 1, Item I.C.5 "Feedback of Operating Experience to Plant Staff"), 1983, (U.S. Nuclear Regulatory Commission).

NUREG-0933: *A prioritization of generic safety issues* (Main Report and Supplements 1-12), 1991, (U.S. Nuclear Regulatory Commission).

Draft NUREG-1449: *Shutdown and low-power operation at commercial nuclear power plants in the United States*, 1992, (U.S. Nuclear Regulatory Commission).

EGG-HFRU-9446: The onsite analysis of the human factors of operating events, 1991, (U.S. Nuclear Regulatory Commission - Meyer).

<u>Implementation Plan</u>

The plan shall describe the designer's approach to Operating Experience Review. The plan shall address the following:

- Documentation review and analysis
- User survey methodology (for conducting interviews) and analysis plans
- Method of documenting lessons learned
- Integration of lessons learned into the design process

<u>Analysis Results Report</u>

The report shall address the following:

- Objectives
- Description of the Methods
- Identification of any deviations from the implementation plan
- Results and Discussion
- Conclusions
- Recommendations/Implications for HSI Design

<u>HSI Design Team Evaluation Report</u>

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

3.3 Element 3 - S[illegible]m Functional Requirements Analysis

DESIGN COMMITMENT:

System requirements shall be analyzed to identify those functions which must be performed to satisfy the objectives of each functional area. System function analysis shall: (1) determine the objective, performance requirements, and constraints of the design; and (2) establish the functions which must be accomplished to meet the objectives and required performance.

INSPECTION/TEST/ANALYSIS:

- A System Functional Requirements Analysis Implementation Plan shall be developed.
- An analysis of System Functional Requirements shall be conducted in accordance with the plan and the findings will be documented in an Analysis Results Report.
- The analyses shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. System requirements shall determine system functions and the function shall determine the performance necessary to carry out the function.

2. Critical functions shall be defined (i.e., those functions required to achieve major system performance requirements; or those functions which, if failed, could degrade system or equipment performance or pose a safety hazard to plant personnel or to the general public),

3. Safety functions shall be identified and any functional interrelationship with non-safety systems shall be identified.

4. Functions shall be defined as the most general, yet differentiable means whereby the system requirements are met, discharged, or satisfied. Functions shall be arranged in a logical sequence so that any specified operational usage of the system can be traced in an end-to-end path.

5. Functions shall be described initially in graphic form. Function diagramming shall be done at several levels, starting at a "top level" where a very gross picture of major functions is described, and continuing to decompose major functions to several lower levels until a specific critical end-item requirement will emerge, e.g., a piece of equipment, software, or an operator.

6. Detailed narrative descriptions shall be developed for each of the identified functions and for the overall system configuration design itself. Each function shall be identified and described in terms of

inputs (observable parameters which will indicate system status), functional processing (control process and performance measures required to achieve the function), outputs, feedback (how to determine correct discharge of function), and interface requirements from the top down so that subfunctions are recognized as part of larger functional areas.

7. Functional operations or activities shall include:

- detecting signals
- measuring information
- comparing one measurement with another
- processing information
- acting upon decisions to produce a desired condition or result on the system or environment (e.g., system and component operation, actuation, and trips)

8. The function analysis shall be kept current over the life cycle of design development.

9. Verification

- All the functions necessary for the achievement of operational and safety goals are identified.
- All requirements of each function are identified.

10. The effort shall be performed using the following documents as guidance:

IEC 964: *Design for control rooms of nuclear power plants* , 1989, (Bureau Central de la Commission Electrotrotechnique Internationale).

MIL-H-46855B: *Human engineering requirements for military systems, equipment and facilities*, 1979, (Department of Defense).

AD/A223 168: *Systems engineering management guide*, 1990, (Department of Defense - Defense Systems Management College - Kockler, F.et al.).

Implementation Plan

The plan shall describe the designer's approach to System Functional Requirements Analysis.
The System Functional Requirements Analysis Implementation Plan shall address:

- Literature and current practices review
  - Describe the technical basis for the plan.
- List required system level functions
  - Based on System Performance Requirements.
- Graphic function descriptions

- e.g., Functional Flow Block Diagrams and Time Line Diagrams

• Detailed function narrative descriptions addressing:

  - Observable parameters which will indicate system status
  - Control process and measure/data required to achieve the function
  - How to determine proper discharge of function

• Analysis

  - Define an integration of subfunctions that are closely related so that they can be treated as a unit
  - Divide identified subfunctions into two groups
  - Common achievement is an essential condition for the accomplishment of a higher level function
  - Alternative supporting functions to a higher level function or whose accomplishment is not necessarily a requisite for higher level function
  - Identify for each integrated subfunction:

    * Logical requirements for accomplishment (Why accomplishment is required)
    * Control actions necessary for accomplishment
    * Parameters necessary for control action
    * Criteria for evaluating the result of control actions
    * Parameters necessary for the evaluation
    * Evaluation criteria
    * Criteria for choosing alternatives

  - Identify characteristic measurement and define for each measurement important factors such as Load, Accuracy, Time factors, Complexity of action logic, Types and complexities of decision making, Impacts resulting from the loss of function and associated time factors.

• Verification

  - Describe system function verification methodology.

<u>Analysis Results Report</u>

The report shall address the following:

• Objectives
• Description of the Methods
• Identification of any deviations from the implementation plan
• Results and Discussion
• Conclusions
• Recommendations/Implications for HSI Design

HSI Design Team Evaluation Report

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

3.4 Element 4 - Allocation of Function

DESIGN COMMITMENT:

The allocation of functions shall take advantage of human strengths and avoids allocating functions which would be impacted by human limitations. To assure that the allocation of function is conducted according to accepted HFE principles, a structured and well-documented methodology of allocating functions to personnel, system elements, and personnel-system combinations shall be developed.

INSPECTION/TEST/ANALYSIS:

- An Allocation of Function Implementation Plan shall be developed.
- An analysis of Allocation of Function shall be conducted in accordance with the plan and the findings will be documented in an Analysis Results Report.
- The analyses shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. All aspects of system and functions definition must be analyzed in terms of resulting human performance requirements based on the expected user population.

2. The allocation of functions to personnel, system elements, and personnel-system combinations shall be made to reflect (1) sensitivity, precision, time, and safety requirements, (2) required reliability of system performance, and (3) the number and level of skills of personnel required to operate and maintain the system.

3. The allocation criteria, rational, analyses, and procedures shall be documented.

4. As alternative allocation concepts are developed, analyses and trade-off studies shall be conducted to determine adequate configurations of personnel- and system- performed functions. Analyses shall confirm that the personnel elements can properly perform tasks allocated to them while maintaining operator situation awareness, workload, and vigilance. Proposed function assignment shall take the maximum advantage of the capabilities of human and machine without imposing unfavorable requirements on either.

5. Functions shall be re-allocated in an iterative manner, in response to developing design specifics and the outcomes of on-going analyses and trade studies.

6. Function assignm shall be evaluated.

7. The effort shall be performed using the following documents as guidance:

NUREG/CR-2623: *The allocation of functions in man-machine systems: A perspective and literature review*, 1982, (U.S. Nuclear Regulatory Commission - Price, H., et al.).

NUREG/CR-3331: *A methodology for allocation nuclear power plant control functions to human and automated control*, 1983, (U.S. Nuclear Regulatory Commission - Pulliam, R., et al.).

IEC 964: *Design for control rooms of nuclear power plants* , 1989, (Bureau Central de la Commission Electrotechnique Internationale).

AD/A223 168: *Systems engineering management guide*, 1990, (Department of Defense - Defense Systems Management College - Kockler, F.et al.).

Implementation Plan

The plan shall describe the designer's approach to Allocation of Function. The Allocation of Function Implementation Plan shall address:

- Establishment of a structured basis for function allocation
- Alternative systems analyses
  - Specification of criteria for selection
- Trade studies
  - Define objectives and requirements
  - Identify alternatives
  - Formulate selection criteria
  - Weight criteria
  - Prepare utility functions
  - Evaluate alternatives
  - Perform Sensitivity Check
  - Select Preferred Alternatives
- Evaluation of function assignment
  - The plan shall describe the tests and analyses that will be performed to evaluate the function allocation

Analysis Results Report

The report shall address the following:

- Objectives
- Description of the Methods
- Identification of any deviations from the implementation plan

- Results and Discussion
- Conclusions
- Recommendations/Implications for HSI Design

<u>HSI Design Team Evaluation Report</u>

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

3.5 Element 5 - Task Analysis

DESIGN COMMITMENT:

Task analysis shall identify the behavioral requirements of the tasks the personnel subsystem is required to perform in order to achieve the functions allocated to them. A task shall be a group of activities that have a common purpose, often occurring in temporal proximity, and which utilize the same displays and controls. The task analysis shall:

- provide one of the bases for making design decisions; e.g., determining before hardware fabrication, to the extent practicable, whether system performance requirements can be met by combinations of anticipated equipment, software, and personnel,
- assure that human performance requirements do not exceed human capabilities,
- be used as basic information for developing manning, skill, training, and communication requirements of the system, and
- form the basis for specifying the requirements for the displays, data processing and controls needed to carry out tasks.

INSPECTION/TEST/ANALYSIS:

- A Task Analysis Implementation Plan shall be developed.
- An analysis of tasks shall be conducted in accordance with the plan and the findings will be documented in an Analysis Results Report.
- The analyses shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. The scope of the task analysis shall include all operations, maintenance, test and inspection tasks. The analyses shall be directed to the full range of plant operating modes, including start-up, normal operations, abnormal operations, transient conditions, low power and shutdown conditions. The analyses shall include tasks performed in the control room as well as outside of the control room.

2. The analysis shall link the identified and described tasks in operational sequence diagrams. A review of the descriptions and operational sequence diagrams shall identify which tasks can be considered "critical" in terms of importance for function achievement, potential for human error, and impact of task failure. Human actions which are found to affect plant risk in PRA sensitivity analyses shall also be considered "critical." Where critical functions are automated, the analyses shall consider all human tasks including monitoring of an automated safety system and back-up actions if it fails.

3. Task analysis shall begin on a gross level and involve the development of detailed narrative descriptions of what personnel must do. Task analyses shall define the nature of the input, process, and output required by and of personnel. Detailed task descriptions shall address (as appropriate):

- Information Requirements
  - Information required, including cues for task initiation
  - Information available
- Decision-Making Requirements
  - Description of the decisions to be made (relative, absolute, probabilistic)
  - Evaluations to be performed
  - Decisions that are probable based on the evaluation (opportunities for cognitive errors, such as capture error, will be identified and carefully analyzed)
- Response Requirements
  - Action to be taken
  - Overlap of task requirements (serial vs. parallel task elements)
  - Frequency
  - Speed/Time line requirements
  - Tolerance/accuracy
  - Operational limits of personnel performance
  - Operational limits of machine and software
  - Body movements required by action taken
- Feedback Requirements
  - Feedback required to indicate adequacy of actions taken
- Workload
  - Cognitive
  - Physical
  - Estimation of difficulty level
- Task Support Requirements
  - Special/protective clothing
  - Job aids or reference materials required
  - Tools and equipment required
  - Computer processing support aids
- Workplace Factors
  - Workspace envelope required by action taken

- Workspace conditions
- Location and condition of the work
- Environment

- Staffing and Communication Requirements

  - number of personnel, their technical specialty, and specific skills
  - Communications required, including type
  - Personnel interaction when more than one person is involved

- Hazard Identification

  - Identification of Hazards involved

4. The task analysis shall be iterative and become progressively more detailed over the design cycle. The task analysis shall be detailed enough to identify information and control requirements to enable specification of detailed requirements for alarms, displays, data processing, and controls for human task accomplishment.

5. The task analysis results shall provide input to the personnel training programs.

6. The effort shall be performed using the following documents as guidance:

NUREG/CR-3371: *Task analysis of nuclear power plant control room crews*, 1983, (U.S. Nuclear Regulatory Commission - Burgy, D. et al.).

IEC 964: *Design for control rooms of nuclear power plants* , 1989, (Bureau Central de la Commission Electrotrotechnique Internationale).

DI-H-7055: *Critical task analysis report*, 1979, (Department of Defense).

MIL-STD-1478: *Task performance analysis*, 1991, (Department of Defense).

Implementation Plan

The plan shall describe the designer's approach to task analysis. The Task Analysis Implementation Plan shall address:

- General methods and data sources
- Gross task analysis

  - Convert Functions to Tasks
  - Develop Narrative Task Descriptions
  - General statement of task functions
  - Detailed task descriptions
  - Breakdown of tasks to individual activities
  - Develop Operational Sequence Diagrams

- Critical task analysis

- Identification of Critical Tasks
- Detailed Task Descriptions

- Information and control requirements
- Initial alarm, display, processing, and control requirements analysis

  - Develop a task-based I&C inventory

- Application of task analysis results to training development
- Evaluation of task analysis

  - The plan shall describe the methods that will be used to evaluate the results of the task analysis.

Analysis Results Report

The report shall address the following:

- Objectives
- Description of the Methods
- Identification of any deviations from the implementation plan
- Results and Discussion
- Conclusions
- Recommendations/Implications for HSI Design

HSI Design Team Evaluation Report

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

3.6 Element 6 - Human-System Interface Design

DESIGN COMMITMENT:

Human engineering principles and criteria shall be applied along with all other design requirements to identify, select, and design the particular equipment to be operated/maintained/controlled by plant personnel.

INSPECTION/TEST/ANALYSIS:

- A Human-System Interface Design Implementation Plan shall be developed.
- An analysis of Human-System Interface Design shall be conducted in accordance with the plan and the findings will be documented in an Analysis Results Report.
- The analyses shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. The design configuration shall satisfy the functional and technical design requirements and insure that the HSI will meet the appropriate HFE guidance and criteria.
2. The HFE effort shall be applied to HSI both inside and outside of the control room (local HSI).
3. HSI design shall utilize the results of the task analysis and the I&C inventory to assure the adequacy of the HSI.
4. The HSI and working environment shall be adequate for the human performance requirements it supports. The HSI shall be capable of supporting critical operations under the worst credible environmental conditions.
5. The HSI shall be free of elements which are not required for the accomplishment of any task.
6. The selection and design of HSI hardware and software approaches shall be based upon demonstrated criteria that support the achievement of human task performance requirements. Criteria can be based upon test results, demonstrated experience, and trade studies of identified options.
7. HFE standards shall be employed in HSI selection and design. Human engineering guidance regarding the design particulars shall be developed by the HSI designer to (1) insure that the human-system interfaces are

designed to currently accepted HFE guidelines and (2) insure proper consideration of human capabilities and limitations in the developing system. This guidance shall be derived from sources such as expert judgement, design guidelines and standards, and quantitative (e.g., anthropometric) and qualitative (e.g., relative effectiveness of differing types of displays for different conditions) data. Procedures shall be employed to ensure HSI adherence with standards.

8. HFE/HSI problems shall be resolved using studies, experiments, and laboratory tests, e.g.

   - Mockups and models may be used to resolve access, workspace and related HFE problems and incorporating these solutions into system design
   - Dynamic simulation and HSI prototypes shall be evaluated for use to evaluate design details of equipment requiring critical human performance
   - The rationale for selection of design/evaluation tools shall be documented

9. Human factors engineering shall be applied to the design of equipment and software for maintainability, testing and inspection.

10. HSI design elements shall be evaluated to assure their acceptability for task performance and HFE, criteria, standards, and guidelines.

11. The effort shall be performed using the following documents as guidance:

NUREG-0696: *Functional criteria for emergency response facilities*, 1980, (U.S. Nuclear Regulatory Commission).

NUREG-0700: *Guidelines for control room design reviews*, 1981, (U.S. Nuclear Regulatory Commission).

NUREG-0800: *Standard review plan* (Rev 1), 1984, (U.S. Nuclear Regulatory Commission).

NUREG/CR-5908: *Advanced human-system interface design review guideline*, 1992, (U.S. Nuclear Regulatory Commission - O'Hara, et al.).

EPRI NP-4350: *Human engineering design guidelines for maintainability*, 1985, (Electric Power Research Institute - Pack R., et al.).

EPRI NP-3659: *Human factors guide for nuclear power plant control room development*, 1984, (Electric Power Research Institute - Kinkade, R.G., and Anderson, J.).

EPRI NP-3701: *Computer-generated display system guidelines (Vols 1&2)*, 1984, (Electric Power Research Institute - Frey, R. et al.).

IEC 964: *Design for control rooms of nuclear power plants* , 1989, (Bureau Central de la Commission Electrotrotechnique Internationale).

ANSI HFS-100: *American national standard for human factors engineering of visual display terminal workstations*, 1988, (American National Standards Institute).

Human-computer interface style guide (Version 1), 1992, (Department of Defense - Defense Information Systems Agency).

MIL-HDBK-759A: *Human factors engineering design for army materiel*, 1981, (Department of Defense).

MIL-STD-1472D: *Human engineering design criteria for military systems, equipment and facilities*, 1989, (Department of Defense).

DoD-HDBK-761A: *Human engineering guidelines for management information systems*, 1990, (Department of Defense).

ESD-TR-86-278: *Guidelines for designing user interface software*, 1986, (Department of Defense).

Implementation Plan

The plan shall describe the designer's approach to Human-System Interface Design. The Human-System Interface Design Implementation Plan shall address:

- I&C requirements analysis and design
  - Compare Task Requirements to I&C Availability
  - Modifications to I&C Inventory
- General HSI approach selection
  - Trade Studies
  - Analyses
- The criteria to be used to meet General Criterion (selection and design of HSI hardware and software approaches), described above
- HFE design guidance development and documentation
- HSI detailed design and evaluations
  - Use of design/evaluation tools such as prototypes shall be specifically identified and rationale for selection

Analysis Results Report

The report shall address the following:

- Objectives
- Description of the Methods
- Identification of any deviations from the implementation plan
- Results and Discussion
- Conclusions

- Recommendations/Implications for HSI Design

HSI Design Team Evaluation Report

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

3.7 Element 7 - Plant and Emergency Operating Procedure Development

DESIGN COMMITMENT:

Plant and Emergency Operating Procedures shall be developed to support and guide human interaction with plant systems and to control plant-related events and activities. Human engineering principles and criteria shall be applied along with all other design requirements to develop procedures that are technically accurate, comprehensive, explicit, easy to utilize, and validated. The types of procedures covered in the element are:

- plant & system operations (including start-up, power, and shutdown operations)
- abnormal & emergency operations
- preoperational, start-up, and surveillance tests
- alarm response

INSPECTION/TEST/ANALYSIS:

- A Plant and Emergency Operating Procedure Development Implementation Plan shall be developed.
- The procedures shall be developed in accordance with the plan and the results will be documented in a Procedure Development Report.
- The procedure development shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. The task analysis shall be used to specify the procedures for operations (normal, abnormal, and emergency), test, maintenance and inspection.

2. The basis for procedure development shall include:
   - Plant design bases
   - system-based technical requirements and specifications
   - the task analyses for operations (normal, abnormal, and emergency)
   - significant human actions identified in the HRA/PRA
   - initiating events to be considered in the EOPs shall include those events present in the design bases.

3. A Writer's Guide shall be developed to establish the process for developing technical procedures that are complete, accurate, consistent, and easy to understand and follow. The Guide shall contain sufficiently objective criteria so that procedures developed in accordance with the Guide shall be consistent in organization, style, and content. The

Guide shall be used for all procedures within the scope of this Element. The Writer's Guide shall provide instructions for procedure content and format (including the writing of action steps and the specification of acceptable acronym lists and acceptable terms to be used).

4. The content of the procedures shall incorporate the following elements:

- Title
- Statement of Applicability
- References
- Prerequisites
- Precautions (including warnings, cautions, and notes)
- Limitations and Actions
- Required Human Actions
- Acceptance Criteria
- Checkoff Lists

5. All procedures shall be verified and validated. A review shall be conducted to assure procedures are correct and can be performed. Final validation of operating procedures shall be performed in a simulation of the integrated system as part of V&V activities described in Element 8.

6. An analysis shall be conducted to determine the impact of providing computer-based procedures and to specify where such an approach would improve procedure utilization and reduce operating crew errors related to procedure use.

7. The effort shall be performed using the following documents as guidance:

NUREG-0899: *Guidelines for the preparation of emergency operating procedures*, 1982, (U.S. Nuclear Regulatory Commission).

NUREG-1358: *Lessons learned from the special inspection program for emergency operating procedures*, 1989, (U.S. Nuclear Regulatory Commission).

NUREG/CR-5228: *Techniques for preparing flowchart format emergency operating procedures* (Vols. 1&2), 1989, (U.S. Nuclear Regulatory Commission - Barnes, V. et al.).

NRC Regulatory Guide 1.33 (Rev. 2): *Quality assurance program requirements* , 1978, (U.S. Nuclear Regulatory Commission).

ANSI-N18. 7-1976: *Administrative controls and quality assurance for the operational phase of nuclear power plants*, 1976, (American National Standards Institute).

Implementation Plan

The Plant and Emergency Operating Procedure Development Implementation Plan shall address:

- Identification of source data/information to be used as a basis for procedure development
- Methodology for the evaluation of procedures (plan shall describe tests and analyses that will be used to evaluate procedures)
- Requirements for the effective development and use of a Procedural Writer's Guide
- Procedures for training program - procedure integration
- Verification and validation procedures
- Procedure development documentation requirements

<u>Procedure Development Report</u>

The report shall address the following:

- Objectives
- Description of the Methods Used
- Identification of any deviations from the implementation plan
- Results, including a list of procedures developed, and a discussion of the resulting procedures including sample procedures
- Conclusions
- Recommendations/Implications for HSI Design

<u>HSI Design Team Evaluation Report</u>

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

3.8 Element 8 - Human Factors Verification and Validation

DESIGN COMMITMENT:

The successful incorporation of human factors engineering into the final HSI design and the acceptability of the resulting HSI shall be thoroughly evaluated as an integrated system using HFE evaluation procedures, guidelines, standards, and principles.

INSPECTION/TEST/ANALYSIS:

- A Human Factors Verification and Validation Implementation Plan shall be developed.
- An analysis of Human Factors Verification and Validation shall be conducted in accordance with the plan and the findings will be documented in an Analysis Results Report.
- The analyses shall be reviewed by the HSI Design Team and shall be documented in an Evaluation Report.

DESIGN ACCEPTANCE CRITERIA:

General Criteria

1. The evaluation shall verify that the performance of the HSI, when all elements are fully integrated into a system, meets (1) all HFE design goals as established in the program plan; and (2) all system functional requirements and support human operations, maintenance, test, and inspection task accomplishment.

2. The evaluation shall address:

   - Human-Hardware interfaces
   - Human-software interfaces
   - Procedures
   - Workstation and console configurations
   - Control room design
   - Remote shutdown system
   - Design of the overall work environment

3. Individual HSI elements shall be evaluated in a static and/or "part-task" mode to assure that all controls, displays, and data processing that are required are available and that they are designed according to accepted HFE guidelines, standards, and principles.

4. The integration of HSI elements with each other and with personnel shall be evaluated and validated through dynamic task performance evaluation using evaluation tools which are appropriate to the accomplishment of this objective. A fully functional HSI prototype and plant simulator shall be used as part of these evaluations. If an alternative to a HSI

prototype is proposed its acceptability shall be documented in the implementation plan. The evaluations shall have as their objectives:

- Adequacy of entire HSI configuration for achievement of safety goals
- Confirm allocation of function and the structure of tasks assigned to personnel
- Adequacy of staffing and the HSI to support staff to accomplish their tasks.
- Adequacy of Procedures
- Confirm the adequacy of the dynamic aspects of all interfaces for task accomplishment
- Evaluation and demonstration of error tolerance to human and system failures

5. Dynamic evaluations shall evaluate HSI under a range of operational conditions and upsets, and shall include:

   - Normal plant evolutions (e.g., start-up, full power, and shutdown operations)
   - Instrument Failures (e.g., Safety System Logic & Control (SSLC)Unit, Fault Tolerant Controller (NSSS), Local "Field Unit" for MUX system, MUX Controller (BOP), Break in MUX line)
   - HSI equipment and processing failure (e.g., loss of VDUs, loss of data processing, loss of large overview display)
   - Transients (e.g., Turbine Trip, Loss of Offsite Power, Station Blackout, Loss of all FW, Loss of Service Water, Loss of power to selected buses/CR power supplies, and SRV transients)
   - Accidents (e.g., Main steam line break, Positive Reactivity Addition, Control Rod Insertion at power, Control Rod Ejection, ATWS, and various-sized LOCAs)

6. Performance measures for dynamic evaluations shall be adequate to test the achievement off all objectives, design goals, and performance requirements and shall include at a minimum:

   - System performance measures relevant to safety
   - Crew Primary Task Performance (e.g., task times, procedure violations)
   - Crew Errors
   - Situation Awareness
   - Workload
   - Crew communications and coordination
   - Anthropometry evaluations
   - Physical positioning and interactions

7. A verification shall be made that all issues documented in the Human Factors Issue Tracking System have been addressed.

8. A verification shall be made that all critical human actions as defined by the task analysis and PRA/HRA have be adequately supported in the

design. The design of tests and evaluations to be performed as part of HFE V&V activities shall specifically examine these actions.

9. The effort shall be performed using the following documents as guidance:

NUREG-0700: *Guidelines for control room design reviews*, 1981, (U.S. Nuclear Regulatory Commission).

NUREG-0800: *Standard review plan* (Rev 1), 1984, (U.S. Nuclear Regulatory Commission).

NUREG/CR-5908: *Advanced human-system interface design review guideline (Draft)*, 1992, (U.S. Nuclear Regulatory Commission - O'Hara, et al.).

EPRI NP-3701: *Computer-generated display system guidelines (Vols 1&2)*, 1984, (Electric Power Research Institute - Frey, R. et al.).

IEEE Std 845-1988: *IEEE guide to evaluation of man-machine performance in nuclear power generating station control rooms and other peripheries*, 1988, (IEEE).

IEC 964: *Design for control rooms of nuclear power plants* , 1989, (Bureau Central de la Commission Electrotrotechnique Internationale).

AR 602-1: *Human factors engineering program*, 1983, (Department of Defense).

TOP 1-2-610: *Test operating procedure* - Parts 1 & 2, 1990, (Department of Defense).

DODI 5000.2: *Defense acquisition management policies and procedures*, 1991, (Department of Defense).

Implementation Plan

The plan shall describe the designer's approach to Human Factors Verification and Validation. The Human Factors Verification and Validation Implementation Plan shall address:

- HSI element evaluation
  - Control, Data Processing, Display audit
  - Comparison of HSI element design to HFE guidelines, standards, and principles
- Dynamic performance evaluation of fully integrated HSI
  - General Objectives
  - Test methodology and procedures
  - Test participants (operators to participate in the test program)
  - Test Conditions
  - HSI description
  - Performance measures

- Data analysis
- Criteria for evaluation of results
- Utilization of evaluations

- Documentation requirements

  - Test & Evaluation Plans and Procedures
  - Test Reports

Analysis Results Report

The report shall address the following:

- Objectives
- Description of the Methods
- Identification of any deviations from the implementation plan
- Results and Discussion
- Conclusions
- Recommendations/Implications for HSI Design

HSI Design Team Evaluation Report

The report shall address the following:

- The review methodology and procedures
- Compliance with Implementation Plan Procedures
- Review findings

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Attachment

Operating Experience Review Issues

Operating Experience Review Issues

The accident at Three Mile Island in 1979 and other reactor incidents have illustrated significant problems in the actual design and the design philosophy of NPP HSIs. There have been many studies as a result of these accidents/incidents. Utilities have implemented both NRC mandated changes and additional improvements on their own initiative. However, the changes were formed based on the constraints associated with backfits to existing control rooms (CRs) using early 1980s technology which limited the scope of corrective actions that might have been considered, i.e., more effective fixes could be used in the case of a designing a new CR with the modern technology typical of advanced CRs. Problems and issues encountered in similar systems of previous designs should be identified and analyzed so that they are avoided in the development of the current system or, in the case of positive features, to ensure their retention.

Many of the issues identified below are broad and involve system design considerations that are broader than human factors alone. However, each has a human factors component which should not be overlooked by the COL during the design and implementation process. Thus for each issue identified below, a brief explanation of the HFE aspects of the issue are provided. These explanations are provided as examples only and are not intended to be a complete specification of the HFE components of the issue (which should be addressed by the COL in the design specific treatment of the issue). Each of the issues listed below should be included in the Operating Experience Review as part of the COL's design and implementation process.

The issues are organized into the following categories, based on the issues source:

1. USI Issues
2. TMI Issues
3. NRC Generic Letters
4. AEOD Studies
5. Low Power and Shutdown Issues

1. USI ISSUES

1. A-44, Station blackout: This is a large and significant issue with many human factors related aspects, including controls, displays, training, and procedures.

2. A-47, Safety implications of control systems: This issue relates to the implications of failures of non-safety related control systems and their interaction with control room operators.

3. B-17, Criteria for safety related operator action: This issue involves the development of a time criterion for safety-related operator actions including a determination of whether automatic actuation is required.

4. B-32, Ice effects on safety related water supplies: The build-up of ice on service water intakes can occur gradually and can require improved instrumentation to allow operators to detect its occurrence before it causes system inoperability.

5. GI-2, Failure of protective devices on essential equipment: A large number of LERs have noted the incapacitation of safety-related equipment due to the failure of protective devices such as fuses and circuit breakers. Operators are not always aware of the failure of the equipment due to the design of the instrumentation.

6. GI-23, Reactor coolant pump seal failures: This is a multi-faceted issue, which includes a number of proposed resolutions. One sub-issue is the provision of adequate seal instrumentation to allow the operators to take corrective actions to prevent catastrophic failure of seals.

7. GI-51, Improving the reliability of open cycle service water systems: The build-up of clams, mussels, and corrosion products can cause the degradation of open cycle SW systems. Added instrumentation is one means of providing operators with the capability to monitor this build-up and take corrective action prior to loss of system functionality.

8. GI-57, Effects of fire protection system actuation on safety-related equipment: This issue resulted from spurious and inadvertent actuations of fire protection systems, often resulting from operator errors during testing or maintenance. Design of systems should prevent such errors to the extent possible.

9. GI-75, Generic implications of ATWS events at the Salem NPP: This GI has many sub-issues, several of which are related to human factors, for example, scram data for post-scram analysis, capability for post-maintenance testing of RPS, and a specific sub-issue titled "review of human factors issues."

10. GI-76, Instrumentation & control power interactions: This issue raises several concerns, including control & instrumentation faults the could blind or partially blind the operators to the status of the plant.

11. GI-96, RHR suction valve testing: The design of the RHR suction valves with respect to valve position indication and instrumentation to detect potential leakage from high to low pressure areas is important to the prevention of ISLOCAs. This is important for normal operations and for testing.

12. GI-101, Break plus single failure in BWR water level instrumentation: This issue attempts to ensure that robust information is available to the operators for both reactor water level and for plant status during the progression of an accident.

13. GI-105, Interfacing system LOCA at BWRs: This issue relates to pressure isolation valves for BWRs. Many failures in this area were due to personnel errors. The design should address human factors considerations to correct these potential errors. (The NRC work in the ISLOCA area has generally

determined that human factors is an area needing considerable attention and which has contributed to a number of the ISLOCA precursor events.)

14. GI-110, Equipment protective devices of engineered safety features: There have been failures and incapacitation of ESF equipment due to the failure or intentional bypass by protective devices. Both the design of these protective devices and the appropriate indication to control room operators is important.

15. GI-116, Accident management: This issue relates to improved operator training and procedures for managing accidents beyond the design basis of the plant.

16. GI-117, Allowable equipment outage times for diverse, simultaneous equipment outages: A key aspect of this item is providing operators with needed assistance in identifying risk significant combinations of equipment outages. The information needed would include valve alignments, switch settings, as well as components declared inoperable.

17. GI-120, Online testability of protection systems: The designs for online testability should be careful to include appropriate human factors to ensure safe testing.

18. GI-128, Electrical power reliability: This issue includes power to vital instrument buses, DC power supplies, and electrical interlocks. All of these issues are strongly dependent on proper indication and operator action for high reliability.

19. GI-130, Essential service water pump failures at multi-plant sites: This issue relates to the arrangement of SW pumps and piping, including cross-ties at multi-unit sites. Both the arrangement and the operators' ability to monitor the status of cross ties is important. This item mentions potential applicability to single unit sites also.

2. TMI ISSUES

1. lv, HPCI and RCIC separation: the design should consider control room alarm and indication of the initiation levels and low:level restart values.

2. lvi, Reduction of challenges to SRVs: the design should consider control room alarm and indication of SRV status and important parameters.

3. lvii, ADS study: determination of the "optimum" ADS for elimination of manual activation should consider the operator's need to monitor the system and should include an analysis of the time required for operators to perform manual back:up if required.

4. lviii, Automatic restart of Core Spray and LPCI: this issue involves allocation of function considerations in terms of automatic restart of a system following manual stoppage by the operators. Considerations of whether

automatic restart should be available, how it should be implemented, and what alarm and indications are needed in the control room are required.

5. 1xi, Depressurization by means other than ADS: consideration of depressurization will involve the provision of alarms and indication in the control room. Some methods may also require operator actions which should be subject to the full design and implementation process.

6. 1xii, Alternate hydrogen control systems: the evaluation of design alternatives for hydrogen control systems should include the information needs of the operators to assess the conditions which would require system initiation and the degree of automation of the systems.

7. 2iv, SPDS: the selection and display of important safety parameters and their integration into the overall design of the control room is a primary HFE issue.

8. 2v, Automatic indication of bypassed and inoperable systems: providing operators with the capability to monitor the status of automatic systems is an important function of the control room information display system and an important component to the maintenance of the operators' situation awareness.

9. 2vi, Venting of noncondensible gases: operator monitoring of the status of noncondensible gases in the reactor coolant system and having clear, unambiguous indication of the conditions under which gas release must be initiated should be evaluated for HFE design implications.

10. 2xi, Direct indication of SRVs in control room: the alarming and indication of SRV status should be clear and unambiguous and should be evaluated for HFE design implications.

11. 2xvi, Number of actuation cycles for ECCS and RPS: as part of the specification allowable actuation cycles, the method that cycles will be defined, recorded, and tracked by the operating crew should be evaluated for HFE design implications.

12. 2xvii, Control room instrumentation for various parameters: the selection and display of important parameters and their integration into the overall design of the control room is a primary HFE issue.

13. 2xviii, Control room instrumentation for inadequate core cooling: the selection and display of important parameters and their integration into the overall design of the control room is a primary HFE issue.

14. 2xix, Instrumentation for post:accident monitoring: the selection and display of important parameters and their integration into the overall design of the control room is a primary HFE issue.

15. 2xxi, Auxiliary heat removal systems design to facilitate manual/auto actions: the specification and evaluation of manual and automatic actions should be subject to the function allocation analyses performed as part of the design and implementation process.

16. 2xxiv, Recording of reactor vessel level: the selection and display of important parameters and their integration into the overall design of the control room is a primary HFE issue.

17. 2xxv, TSC, OSC and EOF: the design of the TSC, OSC and EOF should include HFE considerations to assure that the personnel located in these facilities can most effectively perform their safety:related functions. Poor HFE design of these facilities may interfere with the performance of operators in a well:designed control room.

18. 2xxvii, Monitoring of in:plant and airborne radiation: the selection and display of important parameters and their integration into the overall design of the control room is a primary HFE issue.

19. 2xxviii, Control room habitability: while potential pathways for radioactivity to impact control room habitability may be identified and design solutions developed to preclude such problems may be developed, the control room operating crew should be aware of potential pathways If warranted, evaluations of methods to monitor in the control room the integrity of the design solutions and the presence of radiation in the pathways should be considered.

3. NRC GENERIC LETTERS

1. 91-06, Resolution of Generic Issue A-30, "Adequacy of Safety-Related DC Power Supplies," Pursuant to 10 CFR 50.54(f). In this generic letter, NRC proposes certain monitoring, surveillance, and maintenance provisions for safety-related DC systems.

2. 91-07 GI-23, "Reactor Coolant Pump Seal Failures" and its possible effect on Station Blackout.
This generic letter discusses the interaction between GI-23 and A-44, both of which have human factors aspects.

3. 91-11 Resolution of Generic Issues 48, "LCOs for Class 1E Vital Instrument Buses," and 49, "Interlocks and LCOs for Class 1E Tie Breakers" Pursuant to 10 CFR 50.54(f). This generic letter addresses several issues related to electrical systems including the reduction of human errors, control of equipment status, and testing.

4. AEOD STUDIES

The NRC's Office for Analysis and Evaluation of Operational Data (AEOD) conducted a program to identify human factors and human performance issues associated with operating events at nuclear power plants (e.g., Meyer, 1991). These reports should be reviewed by the COL in order to determine human factors issues that may impact the development, design, and evaluation of the ABWR.

5. LOW POWER AND SHUTDOWN ISSUES

A current area of active NRC work is that of the risk associated with operation during low power and shutdown. The NRC has identified the operator-centered and human factors issues as particularly important in this area. The COL applicant should address those human factors finally developed by the NRC as a resolution to this issue. The most current status of these issues is contained in Draft NUREG-1449, "Shutdown and Low-Power Operation at Commercial Nuclear Power Plants in the United States."