NUREG/CR-4227
EGG-2388

Idaho National Engineering Laboratory
Operated by the U.S. Department of Energy

Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units

W. E. Gilmore

July 1985

Prepared for the
U.S. Nuclear Regulatory Commission

EG&G Idaho

NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street., N.W.
   Washington, DC 20555
2. The Superintendent of Documents, U.S. Government Printing Office, Post Office Box 37082, Washington, DC 20013-7082
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

NUREG/CR-4227
EGG-2388
RX

HUMAN ENGINEERING GUIDELINES FOR THE EVALUATION AND ASSESSMENT OF VIDEO DISPLAY UNITS

W. E. Gilmore

Manuscript Completed: June 1985
Date Published: July 1985

EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for the
Division of Risk Analysis and Operations
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN A6308

ABSTRACT

This report provides the Nuclear Regulatory Commission with a single source that documents known guidelines for conducting formal Human Factors evaluations of Video Display Units (VDUs). The handbook is a "cookbook" of acceptance guidelines for the reviewer faced with the task of evaluating VDUs already designed or planned for service in the control room. The areas addressed are video displays, controls, control/display integration, and workplace layout. Guidelines relevant to each of those areas are presented. The existance of supporting research is also indicated for each guideline. A Comment section and Method for Assessment section are provided for each set of guidelines.

FIN No. A6308--Display Design and Evaluation

EXECUTIVE SUMMARY

The use of computers and VDUs (Video Display Units) in process control systems has increased significantly in recent years. The primary function of these systems is to aid the operator in the operation of the plant. At the present time, there exists a need to establish useful guidelines for determining whether VDUs effectively accomplish the objective of aiding operator performance. The vendors of these computer based VDUs have produced a wide array of formats and varying levels of sophistication for the nuclear operator to choose from. The Nuclear Regulatory Commission (NRC) has been tasked with assessing the operability, utility, and adequacy of this assortment of display types in the control room. The objective of this report is to provide the NRC with a single source that documents known guidelines for conducting formal Human Factors evaluations of VDU systems.

This handbook is a "cookbook" of acceptance guidelines for the reviewer who is faced with the task of conducting an evaluation of VDUs already designed or planned for service in the control room.

The areas addressed within this handbook are:

- o Video Displays
- o Controls
- o Control/Display Integration
- o Workplace Layout

Guidelines relevant to each of these areas are presented. The existence of supporting research is also indicated for each guideline according to the following key:

Y = Evidence of formal experimentation is presented in the literature to validate the rationale for establishment of the criteria.

L = Only cursory informal experimentation or observations were conducted and more research is needed. Evidence of formal experimentation is extremely scarce.

N = No known research is available.

A general comment is provided at the end of each listing of guidelines to discuss the details, findings, and rationale for the guidelines.

The analysis of variables contained within each area is followed with a Method for Assessment section that describes the techniques for determining whether or not a particular guideline has been satisfied.

The application of this handbook by regulators, designers, and human factors practioners should result in the identification of human factors discrepancies in VDU systems.

The contents of this document are not static and suggestions for its improvement in future revisions are encouraged from the users. That feedback can be provided by filling out and returning the attached evaluation form located in Appendix A ("Evaluation of: Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units").

ACKNOWLEDGMENTS

The author gratefully acknowledges James P. Jenkins of the U.S. Nuclear Regulatory Commission for his assistance and support of this effort. A special thanks are due to Fred Cerven, Don L. Schurman, and Robert E. ("Corky") Ford of the Human Factors Engineering Branch at EG&G Idaho for their comments and preparations of specific sections.

Finally, I would like to acknowledge the contributions of Darwin M. Grigg of the Technical Publications Division at EG&G Idaho who dedicated numerous hours of technical editing on this report. His guidance and suggestions for organizing and formatting the contents are greatly appreciated.

CONTENTS

HUMAN ENGINEERING GUIDELINES FOR THE EVALUATION AND ASSESSMENT OF VIDEO DISPLAY UNITS

INTRODUCTION

Background

The Video Display Unit (VDU) is the most widely accepted input/output device for human interaction with computers. The implementation of digital computers and their associated VDUs as an integrated component of process control systems is rapidly gaining popularity in the industrial workplace. Current and future Nuclear Power Plants (NPPs) are and will be implementing some aspects of VDU technology. For example, there is a growing trend to provide the operator with information and to have him control some plant processes via a VDU. This is most evident in the placement of Safety Parameter Display Systems (SPDSs) in NPPs to provide the operator with safety related information. The long racks of hardwired analogue meters and controls which have historically constituted the mainstay of operator control will no longer be as common due to emerging applications for VDUs. Richard Dallimonti[1] noted, "The introduction of digital control systems based on microprocessors and serial data highway communication, brought with it the CRT console [VDU] as the new operator's 'window' to the process. As a result, hundreds of control centers have since been designed without the traditional panels full of individualized instruments--instead they are replaced by multiple CRT consoles [VDUs]." Some experts predict that 10% of all workplaces will be equipped with VDU systems in the near future.[2] However, the author perceives this figure to be somewhat conservative.

There are many reasons for the VDU's widespread presence in all areas of industry. Several arguments can be raised in favor of higher efficiency through the better use of resources that results when VDUs replace conventional means of displays and controls in the workplace. A significant decrease in computer hardware costs coupled with increasingly sophisticated display/input devices have resulted in the VDU emerging as a cheap, powerful, and flexible tool for control room applications. Unfortunately, human factors considerations for optimizing the user

interface have lagged behind the application of these systems. In the past, human factors engineering has not been a formal requirement in the product life cycle of VDUs or nuclear control room design. Therefore, there is a need for all disciplines (computer specialists, engineers, psychologists, and operations personnel) to take an active role in filling the voids where human factors guidelines are incomplete. In the interim, there is the need to review the guidelines that are available and to merge them into a single resource for the evaluator in the field. David Penniman,[3] writing for the User On-Line Interaction Group of the American Society for Information Sciences, suggested that interim guidelines are better than no guidelines at all. The evaluator or reviewer of these systems cannot afford to wait until all human interface issues have been resolved and the ultimate guidelines document written. Computer systems that utilize VDUs are being installed routinely in all areas of business and industry. It can be inferred that not all of these systems will incorporate established human engineering guidelines into the final design. There is, then, an immediate demand for a handbook to be used for the assessment of those systems currently in place, which led to the rationale for the writing of this document.

Purpose and Scope

The purpose of this report is to review the material available, synthesize it, and provide a handbook. A keynote to the work performed herein is "integrate." Many of the established guidelines are contradictory in their design recommendations across various sources. For example, the recommendations for symbol contrast ratios are highly variable and depend on the source which the user chooses for obtaining the information. It was determined that this handbook would not be complete if guidelines were incorporated that failed to consider alterative criteria or solutions. That is, the objective for this document was to consider all data pertaining to VDU design issues rather than to preclude guidelines based on subjective judgement.

The strength and validity of mary of these guidelines are variable. Some of the guidelines are supported by formal experimental research. On the opposite extreme, certain guidelines are the results of long standing

conventions and lack formal test validation. Many of the latter group of guidelines are the result of standing practices based on research from hardwired analogue displays and signs. Many of these extrapolations of this early research to CRT monitors may not be applicable. Human Factors Engineering is a relatively new discipline when compared with other sciences, and the existing data base is far from complete. Therefore, the holes in this data base are occasionally filled with one's best guess or conventions from similar research.

Many hard questions remain to be resolved in the human factors domain before the human factors data base is able to fully exploit this new VDU technology. The scope for this document is to cite the guidelines available while acknowledging that there are limitations to certain data.

Recomended Use of This Document

This document is intended to serve as an aid to those persons tasked with the function of reviewing, assessing, and evaluating VDUs currently in place or proposed for installation in NPPs. The users of this document will represent various disciplines of engineering and technical areas and may or may not possess specialized skills in human factors or computer systems. The intent is to provide the user with a "cookbook" of guidelines. The philosophy for use of this document can best be illustrated with what the document is.

This document IS:

- A set of human engineering guidelines addressing VDU systems in a ready-to-use format.
- An aid to the user for making a human factors appraisal of VDU systems.
- A reference guide to personnel involved in the procurement, selection, and design of VDU equipment.

Additional Literature Sources

Applicable NUREG Reports

This document is intended as a supplement to the following related NUREG reports currently available:

- NUREG/CR-2496, Human Engineering Design Considerations for Cathode Ray Tube-Generated Displays, April 1982.[4]
- NUREG/CR-3003, Human Engineering Design Considerations for Cathode Ray Tube-Generated Displays, Volume II, July 1983.[5]
- NUREG-0700, Guidelines for Control Room Design Reviews, September 1981.[6]
- NUREG-0696, Functional Criteria for Emergency Response Facilities, February 1981.[7]
- NUREG-0835, Human Factors Acceptance Criteria for the Safety Parameter Display System, December 1981.[8]
- NUREG-0801, Evaluation Criteria for Detailed Control Design Review, October 1981.[9]
- NUREG-0660, NRC Action Plan Developed as a Result of the TMI-2 Accident, Vol 1 and 2, May 1980.[10]
- NUREG-0737, Clarification of TMI Action Plan Requirements, November 1980.[11,12]
- NRC Regulatory Guide, 1.97, Revision 2, December 1980.[13]

General Human Engineering References

The content areas have been intentionally directed toward the assessment of VDUs. Therefore, many general human engineering guidelines which have limited bearing on VDU issues have been omitted from the document. A sample of references are listed below for the reader interested in obtaining general human engineering guidelines which are beyond the scope of this document.

Bailey, R. W., Human Performance Engineering: A Guide for System Designers.[14]

Department of Defense, Human Factors Engineering.[15]

Department of Defense, Military Standard, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, MIL-STD-1472C.[16]

Huchingson, R. D., New Horizons for Human Factors in Design.[17]

McCormick, E. J. and Sanders, M. S., Human Factors in Engineering and Design.[18]

Van Cott, H. P. and Kinkade, R. G., Human Engineering Guide to Equipment Design.[19]

Woodson, W. E., Human Factors Design Handbook.[20]

Eastman Kodak Co., Ergonomic Design for People at Work, Volume I.[21]

VDU BASICS

This section encompasses the fundamentals of VDUs. A definition of VDUs in the workplace is presented first. In addition, the operator's role in VDU systems will be discussed. Finally, this section concludes with the benefits that can be achieved for conducting a Human Factors assessment of VDU systems.

VDU Description

This section is intended to illustrate and define the physical characteristics of a VDU. The te~ms VDT (Video Display Terminal) and CRT Console are often encountered in the literature. In this report, it can be assumed that all those terms are synonymous in meaning with VDUs. A VDU is an input/output device which permits access to and dialogue with the storage and processing capacity of a computer. The VDU is a component of a system comprising a computer, terminals, and other peripheral equipment.[22] The "computer" may be a centrally located mainframe or a microprocessor installed directly into the unit. The latter comprises the "desktop" family of microcomputers. Therefore, a VDU can be (a) simply a "Dumb Terminal" where all system functions reside in a mainframe physically removed from the unit, (b) a self contained microcomputer which is stand alone or not dedicated to a central computer, or (c) some combination of both types where some functions are handled within the unit (similar to a microcomputer) and other functions are dedicated to the mainframe. For the sake of brevity and relevance, only the aspects of VDUs directly associated with the operator interface will be discussed. That is, specific features that are essentially invisible or transparent to the operator will be omitted.

The human factors guidelines for VDUs contained in this document will tend to emphasize design considerations that most directly relate to the elements of:

- o Display screen

- o Keyboard (and/or alternate input device)

- o Applications software.

The primary points of concern for the man/machine interface reside in those elements. The display screen usually consists of a CRT and functions as the operator's "window to the world." It serves as the primary "Output" device for display of information to the operator. It might be noted that the display screen also serves to provide feedback to the operator that a control function has been initiated. The keyboard is the primary Input device for the control, entry, modification, or alteration of data by the operator. The keyboard is probably the most established standard for data "Input," but its availability and general acceptance should not supersede consideration for alternate input devices (e.g., touch panel, mouse, joystick). The applications software includes all graphics, displays, and functions essential for the operator to communicate with the system. In other words, applications software is what the operator "sees" while interacting with the VDU. The major concern is with how a particular parameter is displayed to the operator. A large number of issues must be addressed prior to the development of effective applications software. For example, "Should the format for presentation of a variable set be in the form of a trend plot, bar chart, or digital display?" "Does the operator benefit from this information or is it just cluttering the screen?" If he does benefit from the information, when should it be displayed (i.e. on requestor, at all times)?"

In conclusion, any device that incorporates a CRT display screen, a "computer", software, and a keyboard (and/or other alternate input device) can be classified as a VDU. An example of a typical VDU is shown in Figure 1.

Figure 1. Example of a typical VDU.

Benefits from a Human Factors Assessment

The benefits of a Human Factors effort are best described by Meister,[23] "The goal of [Human Factors] is, therefore, to optimize the design of equipment from the standpoint of the equipment user so that his efficiency will be at its greatest. In a nutshell it [Human Factors] attempts to 'tailor' equipment to the capabilities and limitations of the user." A full Human Factors assessment aids in satisfying the objective of an effective Human Factors program: (a) improved human performance as shown by increased speed, accuracy, and safety and less energy expenditure and fatigue; (b) less training and reduced training costs; (c) improved use of manpower through minimizing the need for special skills and aptitudes; (d) reduced loss of time and equipment as accidents due to human errors are minimized; and (e) improved comfort and acceptance by the user/operator. Human Factors is concerned with improving the productivity of the operator by taking into account human characteristics in designing systems.[17] The final payoff is reduced risk and probability of human error that could lead to catastrophic incidents. The complexity of systems that humans are forced to cope with in this current technology has diminished older attitudes about the human interface. Typical responses, such as "the operator is highly adaptable to a poorly designed piece of equipment and has the capability to just muddle through, are rapidly losing ground. In further defense of minimizing human error through human factors efforts, why should millions of dollars be devoted to design for equipment reliability without considering the reliability of the human who must operate that system?

ASSUMPTIONS

The guidelines contained in this document are based on several assumptions about VDU equipment and the characteristics of the user population. They are presented below by category for "VDU Equipment" and the "User Population:"

VDU Equipment

- Control Room Environment--The environment will be close to that of a normal office (shirtsleeves environment). A direct analogy between NPP control rooms and a normal office (e.g.--noise and lighting may be different) may be debatable, but the assumption is to preclude the need for artic clothing or anticontamination suits by the operators under routine operations. Those requirements may effect display dimensions and selection of input devices.

- Display Medium--The guidelines are based on criteria applicable to a standard CRT monitor. This rationale is based on the general acceptance, versatility, and availability of the CRT monitor over other display technologies (e.g.--plasma displays, flat panel displays, LCDs, LEDs, fiber optics, etc.). At the present time, it is believed those alternate technologies are at least a decade away before they can significantly impact the direction towards replacement of the CRT monitor.[a] With minor exception, color and graphics capability are also assumed to be standard features for the CRT monitors. In addition to the CRT monitor as the primary display medium, a guidelines sections has also been devoted to hardcopy printer characteristics.

---

a. Apple Computer Corporation has recently developed a flat panel display for use with the Apple IIC computer. This device will become available Fall, 1984. Therefore, the implementation of these alternate technologies for industrial process control may occur at a faster rate than originally predicted.

- Keyboard Arrangement--The guidelines assume the keyboard layout for the alphanumeric characters will be of the standard QWERTY arrangement (for the first six letters on the top row of keys). This assumption does not rule out suggestions for altering placement of special function keys, cursor keys, character keys, or a numeric pad. Those features are not "fixed" into place or standardized as is the case for the alphanumeric keys. Therefore, tradeoff considerations between the QWERTY, Dvorak, Alphabetic, Klockenberg, and other alternative configurations will not be discussed.

User Population

- Physical Characteristics--The user is assumed to have normal (or correctible to normal) visual acuity and non color-deficient vision. The primary user will also be an adult without handicaps that require the use of special prosthetic devices.

- Education and Training--The user is NOT assumed to possess special training in computer science or typing skills. This type of ability will be strictly user dependent. Some will have formal training and a high degree of expertise in computer related skills, and others will have almost none. The majority of users, however, will most likely possess military and/or college coursework in engineering fundamentals with "hands on" experience with process control systems in a nuclear environment. A second level of users have been identified, but they are much more difficult to define. This group will consist of some combination of process engineers, managers, technicians, and maintenance personnel.

- Task Functions--The majority of users will be using a VDU for controlling and monitoring the status of a NPP plant or similar industrial system. The tasks are varied for the identified users and many of the guidelines are certainly applicable to a multitude of other applications.

ORGANIZATION OF THE DOCUMENT

Overview

The various guidelines have been sorted by VDU categories and then by variables within each of the categories. A "variable" within the context of this document is any parameter or item which may have an effect on human performance with specific application to VDU issues (e.g. brightness, contrast, flicker, etc.). The strategy, method, and format for selection and organization of those variables is presented below.

Strategy for Selecting the Variables

The VDU variables selected for this document were initially derived from a thorough review of the available literature. Human engineering guidelines, textbooks, and related materials were researched to identify the domain of variables related to design and assessment of VDUs, including those related to the workplace. Any variable which could significantly impact human performance was considered. The resulting list was then submitted for internal and external peer review. Recommendations were implemented and the final list of 92 variables were agreed upon for inclusion into the document.

Method for Presentation

Order and Classification

The VDU variables are classified within four major categories or functional areas. For each major heading, the variables are grouped by more specific subcategories. A complete listing is shown in Table 1.

It was determined that this organizational scheme would minimize the search time for those interested in guidelines for a particular variable. To further aid the user of this document, each category and its major subsections has been tabbed and each subsection is preceeded by a contents page.

TABLE 1. ORGANIZATION OF THE VDU VARIABLES

Visual Displays

A. Legibility and Visual Acuity

1. Flicker
2. Contrast ratio
3. Display luminance
4. Phosphor
5. Glare
6. Screen resolution.

B. Screen Structures and Content

1. Cursor
2. Text
3. Labels
4. Messages
5. Abbreviations
6. Error statements
7. Nontextual messages
8. Data display
9. Data entry
10. Instructions

C. Alphanumeric Characters

1. Font or style
2. Character size and proportion
3. Character case
4. Emitter size, shape, spacing

D. Screen Organization

1. Screen size
2. Grouping
3. Display density
4. Display partitioning
5. Frame specifications
6. Interframe considerations

E. Visual Coding

1. Color
2. Geometric/shape
3. Pictorial
4. Magnitude
5. Visual number
6. Inclination

TABLE 1. (Continued)

F. Enhancement Coding

1. Brightness
2. Blink
3. Image reversal
4. Auditory
5. Voice
6. Audio-visual
7. Other techniques

G. Dynamic Display

1. Display motion
2. Digital counters

H. Information Formats

1. Analog
2. Digital
3. Binary indicator
4 Bar/column chart
5. Band chart
6. Linear profile
7. Circular profile
8. Single value line chart
9. Trend plot
10. Mimic display

Controls

A. Keyboard Layout

1. Keystroke feedback
2. Key actuation force
3. Key roll-over
4. Key travel (displacement)
5. Key color/labeling
6. Key dimension/spacing
7. Keyboard slope
8. Keyboard thickness
9. Special function keys

B. Auxiliary Controls

1. Auxiliary numeric key set
2. Alternate input devices

TABLE 1. (Continued)

Control/Display Integration

A. User Dialogue

1. Question-and-answer
2. Form-filling
3. Menu design
4. Command language
5. Query language
6. Natural language

B. System Feedback

1. Display update rate
2. Response time
3. System status indication
4. Routine status information
5. Performance/job aids

C. Software Security

1. Data protection

Workplace Layout

A. Anthropometrics

1. Keyboard base
2. Working level
3. Keyboard home row
4. Screen
5. Viewing distance
6. Footrest
7. Reach envelope
8. Position and movement of the head
9. Leg, knee, and foot room
10. Screen orientation
11. Chair
12. Hardcopy printer
13. Health and safety

B. Environmental Factors

1. Background noise
2. Temperature and humidity
3. Lighting
4. Ventilation
5. Static electricity

A definition for each major category will now be discussed in order to acquaint the user with the organizational logic. A detailed definition for each sub-category is provided in the appropriate section prior to presentation of the subject variable set.

Video Displays. This functional area includes all guidelines related to the presentation or output of information to the operator. The primary focus is the CRT screen. Issues that address software features such as screen content, structure, organization, coding, and layout are presented in this section. Hardware features that effect visual acuity and readibility of the screen are also included (e.g.--flicker, contrast, resolution, etc.).

Controls. In the context that Video Displays are related to the output of information, controls are the primary device for the input of information to the system. The emphasis for VDU issues will be specific to the layout and arrangement of the keyboard. However, alternate input devices are also discussed in this section.

Control/Display Integration. A large body of guidelines exists in the literature that involve the total integration of controls and displays to perform a specific task function. As a result, this section addresses those issues of controls and displays that are not feasible to examine in isolation. For example, user dialogue, data transmission, and feedback to user action are incorporated here.

Workplace Layout. This section attends to the issues which encompass the design, configuration, and environment for the VDU workstation.

Format for Presenting the Variables

The scheme for presenting the variables in the document is outlined below:

- The variables, as previously noted, are organized by major category and sub-category. Each sub-category is defined to familiarize the document user with the topic material. A complete listing of all variables is presented at the beginning of each sub-category section.

- The variable name is introduced on a separate line at the top of the page.

- Next, a comprehensive definition of the variable is provided.

- All guidelines relevant to the variable (including identification of the original source documents) are presented. Where appropriate, supplementary information is presented in a set of notes at the end of the guideline listing.

- The level of research support is presented with each guideline according to the following key: Y = Evidence of formal experimentation is presented in the literature to validate the rationale for establishment of the criteria; L = Only cursory informal experimentation or observations were conducted and more research is needed; evidence of formal experimentation is extremely scarce; N = No known research is available.

- A Comment section follows the guidelines. The purpose of the comment section is to discuss the rationale, limitations, specific applications, and caveats for the guidelines. The comments section provides guidance in drawing overall conclusions from the guidelines.

- Each variable concludes with a Method for Assessment section. Techniques for determining whether or not the variables are in compliance with the established guidelines are included in this section. A large portion of the variables are assessed for compliance by simple inspection. Other conditions require special equipment or access to the equipment procurement specification in order to determine compliance.

The following specific equipment should be available to the person making the assessment: (a) spot photometer, (b) ruler (millimeters and inches), (c) stop watch, (d) protractor, and (e) tape measure.

- o The figures and tables called out within the text are placed following the Method for Assessment section.

VIDEO DISPLAYS

Legibility and Visual Acuity

This subcategory emphasises guidelines pertaining to many of the various hardware aspects of VDUs. The following variables most directly affect display legibility, readibility, and discrimination:

Flicker

Definition. Flicker is the perception of rapid fluctuations in luminance level or position. It is characterized by an impression of uneven changes or jerky movements. As soon as a character is projected onto the CRT screen, it begins to fade at a rate depending on the persistence of the screen phosphor. To maintain visibility of the character on the screen, the signal must be continually regenerated or "refreshed." If the signal is not refreshed often enough the display will appear to blink or "flicker." If the regeneration frequency is adequate, the user will perceive the image as being steady, or fused, (critical fusion frequency). This is due, in part, to the psychophysiological phenomenon of persistence of vision.

Factors affecting the severity of flicker are intensity, visual angle, color, age of user, ambient illumination, and phosphor characteristics.

Guidelines.	Research Support	Source
1. The regeneration rate for a particular CRT display should be above the critical frequency of fusion so that the occurrence of disturbing flicker is not perceptible. (See Note 1.)	Y	6

NOTE 1: In order to produce a "flicker-free display ideal regeneration rates to 50-60 Hz have been recommended with 60 Hz as the preferred frequency.[14,21,22] Displays made with a refresh rate of under 20 Hz are usually very annoying to the viewer, and they are not flicker-free under about 50 Hz.[22]

Comment. It can be inferred from Note 1 that a minimum refresh rate of 60 HZ is the most acceptable criterion. However, the objective of these recommendations is to provide a flicker-free display. It would be more appropriate to state a functional requirement, namely (as in Reference 6), that the display should not appear to flicker under certain specified settings and ambient light conditions.

Extensive research has demonstrated degraded legibility of alphanumeric characters and graphic displays under flicker conditions. There are also negative physiological results from flicker that range from eye strain and headaches to induced epileptic seizures.

Method for Assessment. Visual observation of VDU display at the maximum and minimum possible luminance levels and contrast ratios.

Contrast Ratio

Definition. Contrast is the difference of luminance, or reflectance, between a figure and its background. The ratio between those two luminances or reflectances is called the contrast ratio. In the case of alphanumeric characters or graphic displays, the characters or lines are considered the figure. The background may be either dark or light, depending on whether positive or negative image polarity is used (see also image reversal coding in this report). The contrast ratio is usually reported with the larger number first, whether that number is the luminance of the figure or the background. Note that the contrast ratio numbers must be formed using common luminance units.

Even though the screen is self-luminescent, the contrast ratio of a CRT display screen is affected by ambient lighting conditions (darkened room or a brightly lit room). That is, ambient lighting will affect both the adaptation levels of the user's eyes and the reflected light from even nonglare screens.

Guidelines.	Research Support	Source
1. 3:1 minimum; 5:1 to 10:1 preferred; 15:1 maximum. (See Note 1.)	Y	16, 22, 24 25, 26, 27
2. Background levels 15 to 20 cd/m^2. (See Note 2.)	Y	22, 24

NOTE 1: Reference 25 states a preferred range of 6:1 to 10:1. Reference 26 recommends a 4:1 minimum in an ambient lighting environment of 75 to 100 fc. Reference 22 recommends 8:1 to 10:1 as the optimum. Reference 16 recommends a 10:1 minimum when using white characters on a block background and a 5:1 minimum when using black figures on a white background. Reference 27 gives a guideline of a modulation contrast (not a ratio) of above 0.9.

NOTE 2: Reference 24 recommends a background of at least 20 cd/m^2.

Comment. The VDU displays will be used in a broad range of lighting environments. Thus, to suit the ambient environment and user preferences, it seems most reasonable that the luminance levels and contrast ratios of the displays should be adjustable over the entire range listed in Guideline 1. We should note here that the actual luminance level at the retina of the eye is affected by physiological variables and by environmental characteristics such as the use of glasses, contact lenses, anti-glare filters, etc. The measured contrast ratio should be evaluated with anti-glare filters, etc. in place. Contrast ratios must be adjusted for the use of color displays because of differential sensitivity of the eye to various colors.

Method for Assessment. Luminance and reflectance levels should be read with a spot photometer. The light level should first be read with the display turned off to obtain the ambient lighting level. This ambient level should be subtracted from all subsequent levels before calculating contrast ratios. The display should then be turned on and a measurement taken for the ground luminance. The display should then be changed to the opposite polarity and another measurement taken. The obtained values should have the ambient subtracted from them and then the ratio should be formed. In the case of continuously adjustable displays, calculation of the available range of adjustment can be made from the electrical characteristics of the VDU display unit.

Display Luminance

Definition. The total light from a display. This light output may be either emitted light or reflected light. In the case of CRT displays, the light is emitted. The optimum luminance for CRT displays is partially determined by contrast ratios, ambient light levels, and operator variables. The display luminance can be calculated on the basis of the brightest portion of the display or on the basis of the integrated luminance over the entire area of the display.

Guidelines.	Research Support	Source
1. 45 cd/m^2 minimum, with 80 to 160 cd/m^2 preferred. (See Note 1.)	Y	22, 26, 28
2. 10 cd/m^2 minimum average level.	Y	27

NOTE 1: Reference 26 recommends a minimum of 85 cd/m^2.

Comments. Guideline 1 refers to the integrated level over the whole display screen when filled with text. The luminance level that will provide good acuity partially depends on the level of other work that must be referred to during the task (such as manuscripts, etc.). Too great a mismatch between the display screen and documents causes the operator to have to shift both focus and adaptation level--although this effect is not so great as had been previously thought.[29] Other factors in the surroundings and in the operator (fatigue, acuity, time of day, etc) also affect the optimum luminance level. The simple solution is probably to provide the operator with a means of adjusting the luminance level of the display. The range of adjustment should encompass the high and low values stated in Guideline 1.

Method for Assessment. A spot photometer of appropriate angle can be used to obtain the integrated luminance of the screen with typical material upon it. A spot photometer can be used to obtain the luminance level of a bright, blank screen. If an adjustable display is used, measurements should be made at each end of the range of adjustment to ensure that the entire range is covered. However, with an adjustable luminance level, simply calculating the range from the published manufacturer specifications should be satisfactory.

Phosphor

Definition. The phosphor specification is applicable only to monchome VDU displays. The phosphor determines the basic color of the display and its persistence.

Guidelines.	Research Support	Source
1. A green phosphor should be used. (See Note 1.)	Y	22
2. A medium persistence phosphor should be used. (See Note 2.)		30

NOTE 1: A green phosper is recommended since the human eye is most sensitive to light in this visible spectrum. However, there is no empirical evidence to indicate that alternative colors (orange, white, yellow) would be a hinderance to operator performance.[22]

NOTE 2: The major difference among phospors is persistence; that is, how long the image persists on the screen before fading away. High persistence phosphors tend to produce trails or after-images behind moving elements, but low persistence phosphors are more likely to cause flicker. Most general-purpose CRTs use medium persistence phosphors such as P1, P4, or P39. The particular phosphor chosen will also determine the expected phosphor life.[142]

Comment. Color choice is secondary to the factors of display clarity and contrast to ensure text legibility. Therefore, color is more a matter of personnel preference. In order to avoid bluring or smearing of images, medium persistence phospher is recommended.

Method for Assessment. Visual observation.

Glare

Definition. Glare is the presence of areas of high luminance reflectance on the display.

Guidelines.	Research Support	Source
1. The screen should be positioned so that sources of light and/or bright objects do not reflect into the expected viewing position. (See Note 1.)	Y	30
2. The surface of the VDU screen should be modified to reduce specular glare. (See Note 2.)	Y	30

NOTE 1: Specular glare sources may also be transient. A person wearing a white shirt and standing behind the VDU user will often create glare on the screen.

NOTE 2: Film coatings, roughened surfaces, and mesh filters appear to accomplish this job equally well. In each case the surface treatment may degrade the quality of the displayed elements but, for the occasional user, the reduction in glare far outweighs the slight fuzziness of the display.

Comment. Ideally, there should be no glare. Glare reduces contrast ratios and adversely affects purpil aperture size and focus. Caution should be used in selection of gauge glare-filter screens, however, because some of these screens reduce luminance and contrast ratios below the acceptable minimums.

Hoods are sometimes attached to the display to reduce glare; however this is not recommended.[30] Hoods are cumbersome and tend to restrict the viewing angle of the screen, whereas the screen treatments are inexpensive and can be added to any existing equipment.

Methods of Assessment. Visual observation. Placing a mirror in the proposed screen position can be useful in locating sources of glare.

Screen Resolution

Definition. Screen resolution determines the fineness of detail that can be displayed.

Guidelines.	Research Support	Source
1. Regardless of whether the display is raster scanned or directly addressed, it should maintain the illusion of a continuous image; the viewer should not have to resolve scan lines or matrix spots.	L	31

Comment. Screen resolution is totally dependent on what displays are desired. That is, screen resolution should be sufficient for the level of detail required for the task at hand. Commercially available television monitors are sufficient for the purpose of reading text and coarse drawings.

Method of Assessment. Visual observation.

blank page

Screen Structures and Content

This sub-category includes all elements that comprise a screen. That is, the various components or building blocks that are used to design a screen will be presented in this section. For example, a typical data file might contain labels, messages, and specific columns of numbers. A message or error statement might also be included. Any screen can be partitioned into its component "primitives." Specific applications for organizing, grouping, and layout of the screen will be discussed in a later section (Screen Organization and Layout). Even though there is no clear distinction, special coding and highlighting techniques have also been reserved for a later section.

In this subsection, the following variables are examined:

Cursor

Definition. A cursor is a dot, block, or special marker. The cursor can be used to indicate the position on the screen where the operator's attention should be focused. It also serves as the carriage position on a typewriter. Continuing with the typewriter analogy, the cursor indicates the position in the display where the next character will appear. There are several general guidelines related to cursor design and its characteristics.

Cakir et al.[22] have identified three categories for cursor classification:

> "Depending upon their effect on the symbols they mark, cursors can be divided into three categories, i.e., superimposing, replacing or enhancing cursors. Superimposing cursors do not alter the appearance of the symbol, e.g. a box drawn around the symbol. A replacing cursor is one that actually replaces the marked symbol by a special graphic symbol, e.g., a cross, thus obliterating the original symbol. To overcome the problem of obliteration, the cursor symbol can be alternated with the marked character. An enhancing cursor is one that applies some form of graphic attribute to the marked character, e.g., by intensifying its brightness or by displaying the character in a reverse video block."

Guidelines.	Research Support	Source
1. The cursor) should be easily seen but should not obscure the reading of the character or symbol it marks.	Y	21, 22
2. The cursor should be easy to find at any location on the VDU screen and be easy to move from one position to another.	Y	21, 22

	Research Support	Source
3. The cursor should be easily tracked as it is moved from one position to another.	Y	21, 22
4. The cursor should blink at about 3 Hz if it is used to attract the operator's attention on a monitoring task.[32]		21
5. The cursor should not be so distracting as to impair the searching of the display for information unrelated to the cursor. (See Note 1.)	Y	21, 22
6. The cursor should not be represented by a graphic technique or symbol that is used for some other purpose in the display.	Y	22

NOTE 1: An override to suppress the cursor is a desirable feature.[21]

Comment. In conjunction with the guidelines listed above, Cakir et al.[22] generally believe the cursor (for most applications) should be in the form of a box or block with a 3 Hz blink rate to be preferred. The underscore cursor is not recommended if underscoring is used to serve another function on the display.

Method for Assessment. Visually inspect and operate the display to verify compliance with the above guidelines.

Text

Definition. This rather broad variable includes the multitude of factors which effect the legibility and comprehension of textual information. From the perspective of screen design, perhaps the two most relevant factors are those associated with textual format and content. In short, "textual format" describes essentially "how" the text should best be presented, and "textual content" entails "what" should be displayed. Basic structural features are also primary characteristics to be addressed. In this section, the emphasis of text characteristics is limited to prose. Other variables, such as message and labels, will be discussed separately.

Guidelines.	Research Support	Source
1. The textual content should be concrete rather than abstract. (See Note 1.)	L	33
2. The textual content should lie within the scope of the user's existing knowledge. (See Note 2.)	L	33
3. The textual content should be logically and systematically structured. (See Note 3.)	L	33
4. Consistent format should be maintained from one display to another.	Y	34
5. Prose should be displayed conventionally, in mixed upper and lower case. (See Note 4.)	Y	34
6. Displayed text should be left justified to maintain constant spacing between words, leaving right margins ragged if that is the result.	Y	34

	Research Support	Source
7. In textual material, words should be displayed intact wherever possible, with minimal breaking by hyphenation between lines.	Y	34
8. Displayed paragraphs should be separated by at least one blank line.	Y	34
9. In textual display, every sentence should end with a period.	Y	34
10. In textual display, the main topic of each sentence should be placed near the beginning of the sentence.	Y	34
11. In textual display, short, simple, concise sentences should be used.	Y	34
12. When speed of display output for textual material is slower than the user's normal reading speed, an extra effort should be made to word the text concisely.	Y	34

NOTE 1: Research indicates that concrete content is easier to comprehend than abstract content. It is quite possible that the difference between concrete and abstract content is related to the reader's prior knowledge.[33]

NOTE 2: A text which can be easily placed within a given frame of reference is also easily comprehended. Concrete content may be found more frequently in reader's prior knowledge than abstract content. Texts giving details are easier to understand when the details can be referred to in an integrated whole which already exists. Texts giving overviews are easier to understand when the particulars are already known.[33]

NOTE 3: A well-structured text is easier to comprehend than an ill-structured text. For example, systematic groupings produce better recall than random arrangements of information. Segmentation of the material may help reading comprehension if the segments correspond to meaningful units. The introduction of a topic and sequencing of a text is also important for comprehension. Adequate headings make texts easier to understand. When the sequencing of a text corresponds to some familiar scheme, such as those which can be found in narratives or research reports, reading is also facilitated. Introductory passages which familiarize the reader with the general idea of the text facilitate reading and comprehension, particularly where meaningful learning is concerned. Careful consideration of form and sequencing will be more important the less prior knowledge one expects the reader to have of the subject.[33]

NOTE 4: Upper case should be used when lower case letters will have decreased legibility, which is true on display terminals that cannot show descenders for lower case letters.[34]

Comment. The reading of textual information is a primary task requirement in several applications (e.g. word processing, instructions, procedures, etc.). The interplay of such diverse factors as character size, contrast, image stability, and character spacing impact the overall legibility of textual information. In many cases, the interplay of those factors make it extremely difficult to develop guidelines for optimizing text legibility and comprehension. Preliminary research indicates that there is no comprehension difference between text presented on a CRT screen when compared with printed pages.[35]

Other research has been devoted to the development of "readability formulas," or mathematical equations consisting of various properties considered in text legibility (e.g., word length, sentence structure). The utility of those formulas as a valid method is still a matter of much debate.

In conclusion, with the exception of text structure, specific guidelines are not presently available for textual form and content. Such guidelines as do exist are entirely too general to be of much use to the

evaluator. In addition to the high interplay of various factors, the unique task-dependent nature of textual comprehension on a VDU screen may also hinder the development of suitable guidelines.

Method for Assessment. Verification of the text structure can be accomplished by visual inspection. The other characteristics (form and content) are less tangible. At the present time, no proven practical methods are known other than informal operator interview regarding the textual content and form.

Labels

Definition. Labeling is the unambiguous designation of structures and functions presented on VDU displays. It also refers to the act of placing a descriptive title, phrase, or word adjacent to a group of related objects or information.[36] The Eastman Kodak edition of "Ergonomic Design for People at Work"[21] defines labels (and signs as well) as "short messages used to transfer information about policies or equipment use between people." That document also identifies three considerations in label design: (a) comprehensibility--a measure of how reliably the receiver interprets the information, (b) legibility--the user's ability to discriminate among or recognize letters or numbers, and (c) readability--the ease of reading words or labels assuming that the requirements for specific legibility are satisfied.

There is considerable overlap in the guidelines between labels and associated variables such as "text" and "messages". Therefore, the reader is referred to these relevant variables for additional information as needed. In general, perhaps the most relevant factor for making a distinction between "text", "messages", and "labels" can be derived by applying the following rule of thumb based on word length. Text can be defined as any prose of three lines or longer. Labels are usually confined to less than one line. A message is any string of words falling between the criteria for text and label.

In addition, the font or style chosen for the alphanumerics also interplay with labeling guidelines. That is especially noticable in the factor for legibility cited above. The reader is also referred to that variable for further detail.

It should also be noted that the guidelines for labels were selected according to their applicability to presentation on VDU screens.

Guidelines.	Research Support	Source
1. Labels should be provided whenever it is necessary for personnel to identify, interpret, follow procedures, or avoid hazards. (See Note 1.)	Y	6, 16
2. Labels should convey the basic information needed for proper identification, utilization, actuation, or manipulation of the item.	Y	16
3. Labels should be consistent with such factors as: a. Accuracy of identification required b. Time available for recognition or other responses c. Distance at which the labels must be read d. Illuminance level and color e. Criticality of the function labeled f. Vibration/motion environment of the user.	Y	16
4. Labels should be horizontal and read from right to left. (See Note 2.)	Y	16
5. Labels should be placed on or very near the items which they identify.	Y	16
6. Labels should be located so as not to obscure any other information needed by the user.	Y	16

	Research Support	Source
7. Labels should be located in a consistent manner throughout the equipment and system.	Y	16
8. Labels should normally be placed above the controls and displays they describe. (See Note 3.)	Y	16
9. Labels should be used to identify functionally grouped controls and displays. (See Note 4.)	Y	16
10. For single data fields, the label should be placed to the left of the data field.	N	14
11. For repeating data fields, the label should be placed above the data fields.	N	37
12. Ease of control operation should be given priority over visibility of control position labels.	Y	16
13. Labels should primarily describe the functions of items. (See Note 5.)	Y	16
14. Each control and display should be labeled according to function.	Y	16
15. When controls and displays must be used together (in certain adjustment tasks), appropriate labels should indicate their functional relationship. The selection and use of terminology should be consistent.	Y	16

	Research Support	Source
16. Control labeling should indicate the functional result of control movement (e.g., increase, ON, OFF).	Y	16
17. Labels should be as concise as possible without distorting the intended meaning of information and should be unambiguous. (See Note 6.)	Y	16
18. Control and display labels should convey verbal meaning in the most direct manner, by using simple words and phrases. Abbreviations may be used when they are familiar to operators (e.g., psi, km).	Y	16
19. Words should be chosen on the basis of operator familiarity whenever possible, provided the words express exactly what is intended. (See Note 7.)	Y	16
20. Similar names for different controls and displays should be avoided.	Y	16
21. Instruments should be labeled in terms of what is being measured or controlled, taking into account the user and purpose.	Y	16
22. The units of measurement (e.g., volts, psi, meters) should be labeled on the panel.	Y	16
23. Labels should be printed in all capitals; periods should not be used after abbreviations.	Y	16

	Research Support	Source
24. To reduce confusion and operator search time, labels should be graduated in size. (See Note 8.)	Y	16
25. Do not form "unique" words or messages from restricted alphabetic sets. (See Note 9.)	Y	36
26. Label names should be easily discriminated from surrounding labeled fields or messages.	Y	36
27. Each select mode list should have a heading or title that reflects the "question" for which an answer is sought.	L	36
28. Labels for data fields should be distinctively worded so that they will not be readily confused with data entries, labeled control options, guidance messages, or other displayed material.	L	14
29. Where entry fields are distributed across a display, a consistent format should be adopted for relating labels to entry areas.	Y	14
30. Where a dimensional unit (gpm, cm, deg, etc.) is consistently associated with a particular data field, it should be part of the fixed label rather than have it entered by the user.	L	14

NOTE 1: References 6 and 16 provide an exception to Guideline 1 in cases when it is obvious to the user what an item is and what he or she is to do

with it. However, Reference 14 recommends that all items be labeled and cautions against assuming that the user will be able to identify individual items because of past experience.

NOTE 2: Labels and information thereon should be oriented horizontally so that they may be read quickly and easily from left to right. Vertical orientation may be used only when labels are not critical for personnel safety or performance and where space is limited. When used, vertical labels should read from top to bottom.[16]

NOTE 3: When the panel is above eye level, labels may be located below if label visibility will be enhanced thereby.[16]

NOTE 4: The labels should be located above the functional groups they identify. When a line is used to enclose a functional group and define its boundaries, the label should be centered at the top of the group either in a break in the line or just below the line. When colored pads are used, the label should be centered at the top within the pad area.[16]

NOTE 5: Engineering characteristics or nomenclature may be described as a secondary consideration.[16]

NOTE 6: Redundancy should be minimized. Where the general function is obvious, only the specific function should be identified (e.g., frequency as opposed to frequency factor).[16]

NOTE 7: Brevity should not be stressed if the results will be unfamiliar to operating personnel. For particular users (e.g., maintenance technicians), common technical terms may be used even though they may be unfamiliar to nonusers. Abstract symbols (e.g., squares and Greek letters) should be used only when they have an accepted meaning to all intended readers. Common, meaningful symbols (e.g., % and +) may be used as necessary.[16]

NOTE 8: The characters in group labels should be larger than those used to identify individual controls and displays. The characters identifying controls and displays should be larger than the characters identifying control positions. With the smallest characters determined by viewing conditions, the dimensions of each character should be at least approximately 25 percent larger than those of the next smaller label.[16]

NOTE 9: Except for mathematical notation, labels should be formed from standard alphabetic characters.[36]

Comment. The majority of these guidelines are extracted from the standards established in MIL-STD-1472C[16] and NUREG-0700.[6] Their origins are founded in hardware labels as opposed to VDU labels. However, they should still be applicable to VDUs. The guidelines from References 14, 36, and 37 are more solidly founded in specific VDU applications. In spite of some overlap, they comprise a relatively comprehensive set of guidelines for labeling.

Method for Assessment. Visually examine the screens. Verify each guideline for compliance.

Messages

Definition. A VDU system communicates with users through messages. A message may be a prompt, a diagnostic message generated by an error condition, or an information or status message. By applying the rule of thumb discriminating between the variables "text," "labels," and "messages," any word string greater than one line but less than three can be classified as a message. Thus, a message is more detailed than a label and tends to provide description or direction. In comparison, a label is a simple identifier of some object or entity. Message "length" and "load" are two concepts frequently addressed when message comprehension issues are examined. Huchingson[17] defines "length" as "the number of words, or characters, that are displayed at once on one or more lines of a sign or sequence." "Load" is described as "the number of units of information displayed (within a message)." Units are the basic elements or building blocks which make up the information given. Each unit provides an answer to a question (e.g., what, where, who). Manipulation of those factors drive the message design. The reader is referred to the variables, "text" and "labels" and the subcategory "Alphanumeric Characters" for additional information relevant to messages.

Guidelines.	Research Support	Source
1. The computer should be capable of providing two levels of detail. (See Note 1.)	N	14
2. Messages should be strictly factual and informative. (See Note 2.)	N	36, 37
3. Message dialogue should not be hostile to the user.	N	14
4. Messages should be constructed using short, meaningful, and common words.	L	37

	Research Support	Source
5. The message should consider the prior knowledge of the user and the user's context.	L	38
6. Sentences should be kept as simple in structure as possible.	L	17
7. Messages should require no transformations, computing, or interpolation. (See Note 3.)	L	36
8. Messages should be stated in the affirmative and preferably in the active voice.	Y	14
9. Items to be remembered by the user should be placed at the beginning of the message.	Y	39
10. Items to be recalled by the user should be placed at the end of the message.	Y	39
11. Items of lesser importance should be placed in the middle of the message.	Y	16

NOTE 1: The "rule of two" suggests that the computer have the capability of providing two levels of detail: Level 1--directed to inexperienced user containing detailed messages. Level 2--directed to experienced users containing abbreviated messages.[14]

NOTE 2: Guideline 2 is intended to prevent making the computer appear human (i.e., to avoid emotional implication).

NOTE 3: Searching through reference material to translate a message is unacceptable.[36]

Comment. The key point for these guidelines revolves around the question of comprehension. In other words, is the message under evaluation immediately understood by the user? Does the user understand what the message designer meant? A clarification of those basic questions with the potential users should ensure the overall usefulness of the message set being scrutinized.

Method for Assessment. Examine a representative sample of the messages presented on the VDU screen. Verify the messages comply with the above guidelines. Interview one or more users to ensure that the messages are truly understood and comprehended according to their intent.

Abbreviations

Definition. Abbreviating is simply the process of reducing words or phrases into a shortened form while retaining the meaning of the whole. This shortened form is a highly effective method for presenting a concept where space is limited and/or speed of recognition is essential.

The challenge to designing effective abbreviations resides in the ability to shorten words/phrases while still retaining their intended meaning to the users.

Guidelines.	Research Support	Source
1. Only standard and commonly accepted abbreviations should be used.	Y	6, 16
2. Abbreviations should be short, meaningful, and distinct. (See Note 1.)	L	34, 40
3. The system should permit abbreviations of inputted commands. (See Note 2.)	L	40
4. Whenever possible, experienced users should be provided with a set of abbreviations for frequency used commands.	Y	14
5. In text and labels, complete words should be used in preference to abbreviations. (See Note 3.)	Y	34
6. Abbreviations should be consistent in form.	Y	34
7. If an abbreviation deviates from the consistent form, it should be specially marked whenever it is displayed.	Y	34

	Research Support	Source
8. A dictionary of abbreviations should be available for on-line user reference.	Y	34
9. Abbreviations and acronyms should not include punctuation. (See Note 4.)	Y	34

NOTE 1: Resist the temptation to use abbreviations the user is not likely to understand or remember just to make room for more data on the display.[40]

NOTE 2: The system should recognize a command from the first 1, 2, or 3 letters (as necessary to make it distinct from other commands). Novice users can type in the entire command, while experienced users can abbreviate or truncate it. The system should accept either form of the command.[40]

NOTE 3: Abbreviations may be displayed if they are significantly shorter, save needed space, and will be understood by the prospective users. Also, when abbreviations are required (or useful) for data entry, then corresponding use of those abbreviations in data display may help a user learn them for data entry.[34]

NOTE 4: For example, the acronym for cathode ray tube should be "CRT" and not "C.R.T."

Comment. Research points out that rule-based abbreviations are more easily comprehended when compared with nonrule-based. Bailey[14] has developed a general set of rules for abbreviating single words and word groups and a more specific set of rules for abbreviating commands. As an aid to the user of this document, those sets of rules are summarized below. Note that the method of creating abbreviations differs between the two sets of rules.

Bailey recommends the following for abbreviating words and word groups in general.

- When abbreviating a single word:

  - Determine the number of characters required in the abbreviated term.

  - Remove suffixes such as -ed, -es, -er, and -ing from the word to be abbreviated. (Make sure they are suffixes, as in "waxing," and not an integral part of the word, as in "spring.")

  - Choose the first letter and last consonant of the word to be abbreviated as the first and last letter of the abbreviation. For example, Boulevard would be B--D.

  - Fill the remaining spaces with the consonants in the order in which they appear in the word. Avoid the use of double consonants in the abbreviation. For example, a five-character code for boulevard would be BLVRD, a four-character code would be BLVD, and a three-character code would be BLD.

  - If there are insufficient consonants, use the first vowel in the order in which it appears in the word. For example, a six-character code for boulevard would be BOLVRD.

- When abbreviating two-word groups:

  - Determine the number of characters required in the abbreviated term.

  - Take half of the characters from the first word and the other half from the second word, using the above abbreviation methodology for single words. If an odd number

of total characters is needed, take the "odd" character from the longer word. For example, a seven-character code for PROGRAM TEST would be PRGM TST.

- o When abbreviating groups of three or more words:
  - Form an acronym by using the first letter of each word. For example, Central Processing Unit would be CPU, and as soon as possible would be ASAP.
  - If additional letters are required to improve readability, they should be taken from the last word in the manner described for single word abbreviation. For example, PROGRAM RUN TEST would be PR TST.

Bailey recommends the following for abbreviating commands:

- o For terms consisting of more than one word, create an acronym by taking the first letter of each word.
- o When abbreviating monosyllabic words:
  - Take the initial letter of the word and all subsequent consonants.
  - Make double letters single.
  - If more than four letters remain, retain the fifth letter if it is part of a functional cluster (such as th, ch, sh, ph, or ng); otherwise, truncate from the right. Delete the fourth letter if it is silent in the word.
- o For polysyllabic words:
  - Take the entire first syllable.

- If the second syllable starts with a consonant cluster, add it.

- If the first syllable is a prefix and the second syllable starts with a vowel, add the second syllable.

- Make final double consonants single.

- Truncate to four letters (but always retain the entire first syllable).

Bailey notes that exceptions should be made only when special significance is achieved in selecting one letter or group of letters over another. These rules are meant only for the development of new abbreviations and should not be applied to existing standard abbreviations.

Two general observations can be drawn from the guidelines: (a) ensure that abbreviations are understood by and meaningful to the user and (b) verify that the abbreviations are standardized and consistent.

Method for Assessment. Inspect a sample of abbreviations used for both command and presentation on the VDU screen. Verify that the abbreviations are in compliance with the above guidelines. Query a group of users on this sample set of abbreviations to ensure that the their meaning is understood. If there is evidence of lack of clarity in the meanings of these abbreviations, recommend a redesign according to a rule based procedure such as that outlined in the above "comments" section.

Error Statements

Definition. The computer system's major mode of communication with the user is accomplished through various messages which are presented on the screen (e.g., normal prompts, advisory messages, system response to commands). The development of useful and meaningful error statements are generally considered the most critical to user interaction. This section emphasizes that special class of messages. General principles of message design have been examined in a previous section. The reader is referred to that section for supplemental guidelines. The issue of errors in VDU system guidelines is enormous. It should be noted that error statements are only one component of this greater domain. This handbook omits the cognitive processes associated with error guidance, correction, and control of error. These sections will focus on the specific structures for presenting error statements to the user.

Guidelines.	Research Support	Source
1. Operator inputs, responses, or actions which could significantly degrade computer system or plant performance should not be dependent on a single keystroke.	L	6
2. The computer system should contain prompting and structuring features by which an operator can request corrected information when an error is detected.	L	6
3. When the computer detects an entry error, an error message should be displayed to the user stating what is wrong and what can be done about it.	L	34

	Research Support	Source

USE: Unmatched left parenthesis

DON'T USE: What? or Syntax Error

	Research Support	Source
4. Error messages should be worded as specifically as possible, based on computer analysis of data handling transactions. (See Note 1.)	L	34, 40

USE: No record for file No. 6342, check number

DON'T USE: No record for inquiry.

	Research Support	Source
5. The wording of error messages should be appropriate to a user's task and level of knowledge.	L	34, 40

USE: Unrecognized contract number; check file and enter a current number.

	Research Support	Source
DON'T USE: Entry Blocked. Status flag 4.		
6. When a data entry or (more often) a control entry must be made from a small set of alternatives, those correct alternatives should be indicated in the error message displayed in response to a wrong entry.	L	34
7. Error messages should be brief and consistent while being informative. (See Note 2.)	L	34, 40
USE: Error 445. Entry must be a number.		
DON'T USE: Alphabetic entries are not acceptable here because this entry will be processed arithmetically. Entry must be numeric.		
8. Error messages should be stated in polite but neutral wording, without implications of blame to the user, without personalization of the computer, and without attempts at humor.	L	34, 40

		Research Support	Source
USE:	Error 234. Entered name is not in the file. Enter a name which is in the file.		
DON'T USE:	Gotcha! That name is not in the file. Enter a name which is in the file.		
9.	Following the output of simple error messages, the user should have the option of requesting more detailed explanation for errors (e.g., successively deeper levels of explanation should be provided in response to repeated user requests for HELP).	L	34, 40
10.	When multiple errors are detected in a combined user entry, some indication should be given to the user, even though complete messages for all errors cannot be displayed together.	L	34
Example:	Date should be numeric (+ 2 others).		
11.	When an entry error is repeated, some noticeable change in the displayed error message should be provided.	L	34

	Research Support	Source
12. Error messages should be output after a user's entry has been completed. (See Note 3.)	L	34
13. An error message should be displayed approximately two seconds after the user entry in which the error is detected.	L	34
14. System documentation should include, as a supplement to on-line guidance, a listing and explanation of all error messages. (See Note 4.)	L	34
15. When an error has been detected in a data/command entry, the cursor should be automatically positioned at the point of the first error (data field or command word) in addition to the display of an error message.	L	34, 40
16. Following error detection, users should be prompted to re-enter only the portion of a data/command entry that is not correct.	L	6, 34, 40
17. When a user entry can be recognized as doubtful, in terms of defined data/command validation logic, a cautionary message should be displayed asking the user to confirm that entry.	L	34

Example: 8.2 in. is outside the normal operating range for SG LVL confirm or change entry.

	Research Support	Source
18. In addition to a clear text error message, an error identification number (ID) should precede each message. (See Note 5.)	L	40
19. Error messages should always state or clearly imply at least a minimum of:	L	40

o What error has been detected.
o What corrective action to take.

USE: Error 344. Code number format requires two letters, then three digits.

DON'T USE: Invalid input.

20. If an error is detected in a group of stacked entries, the system should process correct commands until the error is displayed. A suitable error message should be presented and no more inputs processed until the error is corrected. The page displayed should be the one requiring correction, and when the error is corrected, the system should continue processing any stacked inputs in order until done or until another error is detected.	L	40

NOTE 1: Error messages are intended to guide new, inexperienced, and (occasionally) expert users in the efficient use of a system. Clear,

concise, and meaningful error messages will increase user acceptance and user ratings of a display system as well as the speed with which the process are completed.[40]

NOTE 2: Explanatory information can be presented in greater detail in the system documentation or through online HELP messages.[40]

NOTE 3: In general, the display of error messages should be timed so as to minimize disruption of the user's thought process and task performance.[34]

NOTE 4: Documentation of error messages will facilitate review of that aspect of user interface design, since it is difficult to generate all possible error messages by actually making errors in on-line transactions.[34]

NOTE 5: An error identification number permits the experienced user to recall the kinds of procedural errors that might have been made, and also allows the novice user to refer to documentation for more details on the possible reasons for the message, the place the error was made, and the possible remedies. Error messages are distinct from edit prompts which refer to format or spelling errors. The form of the error ID (usually only one error message at a time) is: Error nnn. (MESSAGE). A space of three digits should be provided for the ID. Leading zeroes or spaces should not be required in referring to an error message.

USE:	Error 1.	Enter digits only.
	Error 2.	No spaces are permitted.
	Error 13.	Value must be 1 to 31.

DON'T USE	Error 001.	Enter digits only
	Error 002.	No spaces are permitted.
	Error 013.	Value must be 1 to 31.

NOTE 6: Allowance for the capabilities of skilled users is important. System design should allow skilled users to make inputs faster than they can be processed and displayed by the system. This can be done by allowing the user to make entries to screen options which are not yet displayed by "stacking" entries (i.e., answering several screens ahead).[40]

Comment. The basis of these guidelines is a reflection of the general principles for message design; this is to be expected since errors are indeed a type of message. Similar observations are echoed throughout both variables: make the error message meaningful, understandable, brief, and comprehensible to the user. The guidelines tend to circle around this central issue with an assortment of techniques for satisfying those requirements.

Method for Assessment. Inspect a sample of errors on the VDU system. That can be accomplished by examining a hardcopy printout of the computer code. Check the errors for compliance according to the guidelines presented above. Keep in mind the general criteria summarized in the above "Comment". Query a group of users and verify that they understand the meanings implied in the sample of error statements.

Nontextual Messages

Definitions. Text refers to alphabetic character strings arranged to form a meaningful word or words. These guidelines refer primarily to nontextual information commonly referred to as alphanumeric coding. That is, alphanumeric strings of a nontextual nature, which are arranged to form an identifiable "code," are addressed in this section. This group includes natural codes taken from common usage and arbitrary codes which usually require learning.

Further classifications of these alphanumeric codes can also be associative or transformational. Associative coding serves as a stimulus with some unique response. Telephone numbers generally fall into this category. Transformational coding applies a strict set of rules to the data in order to derive a code. For example the code CV-P004-091 designates the system, location, and type of control valve in a nuclear power plant. This section will only focus on coding principles and nontextual data which involve the use of alphanumerics. Special types of guidelines for other types of coding (e.g., color, brightness, blinking) will be addressed in a later sub-category.

Guidelines.	Research Support	Source
1. Alphanumeric characters can be used in effectively unlimited combinations, and should be considered for auxiliary coding in display applications where basic data presentation is not already alphanumeric (e.g., graphics).	L	34
2. When using alphanumeric codes, a consistent convention should be adopted that all letters shall be either upper case or else lower case. (See Note 1.)	L	34

	Research Support	Source
3. When codes combine letters and numbers, characters of each type should be grouped together rather than interspersed.	L	21, 37, 40

USE: HW5

DON'T USE: H5W

4. Meaningful codes should be adopted in preference to arbitrary codes. (See Note 2.)	L	37, 40

Example: A three-letter mnemonic code (DIR = directory) is easier to remember than a three-digit numeric code.

5. Codes should be assigned so as to conform with conventional population stereotypes, accepted abbreviations, and general user expectations.	L	37, 40

Example: "M" for Male, "F" for Female.

6. When arbitrary codes must be remembered by the user, they should be no longer than 4 to 5 characters. (See Note 3.)	L	21, 34, 37, 40

	Research Support	Source
7. Code length and format should be constant throughout any single category.	Y	37
8. Codes should contain predictable letter sequences. (See Note 4.)	Y	37
9. Long codes (seven or more characters) should be broken into three- or four-character groups, i.e., separate groups by a hyphen or blank space.	Y	21, 36, 37
10. Frequently confused characters and character pairs should be eliminated from code vocabularies. (See Note 5.)	Y	37
11. If a numerical code system contains several digit sequences that occur very frequently, they should comprise the first or last section of the code.	L	21
12. For long alphanumeric codes, digits should be used in the last few positions.	L	21

NOTE 1: However, upper case labels will be somewhat more legible. For data entry, computer logic should not distinguish between upper and lower case codes, because the user will find it hard to remember any such distinctions.[34]

NOTE 2: Codes based on common English usage are the most easily used because they require minimum learning. Arbitrary codes are seldom easy to use.[37]

NOTE 3: Reference 37 recommends a maximum of six characters. However, that reference also cautions that as the length of a field increases, errors in its use will also increase. Reference 21 recommends that an all-digit code should be used where possible.

NOTE 4: Codes containing predictable letter sequences can be keyed more rapidly. The letter combinations "TH" and "IN" are much more predictable than "YX" or "JS," for example, and can be keyed faster.[37]

NOTE 5: Reference 37 notes that about half of all coding errors could be eliminated if "O" and "1" were not in the alphanumeric code vocabulary. In addition about two thirds of all errors could be eliminated if "1," "O," "8," zero, and "B" were not used in codes. Reference 21 recommends that the letters B, D, I, O, Q, and Z and the numbers 0, 1, and 8 should be avoided.

Comment. The main scope for these guidelines seems to center around suggestions and techniques for minimizing errors in data entry and comprehension (e.g., errors of omission, addition, substitution, and transposition). It should also be pointed out that it is extremely difficult to change a coding system once the code has become part of the production process. Therefore, caution should be exercised when making recommendations for altering an alphanumeric (as well as all modes of coding) scheme after it is in place. Many of the guideline sources are in agreement with each other with one exception pertaining to the mixing of digits and alphabetic characters. Galitz[37] and Brown et al.[40] suggest character types and numerals should be grouped together (e.g., HW5 rather than H5W). In contrast, Huchingson[17] pointed out that, for three digit numeric codes, a letter between two numbers would minimize the danger of "transposition" errors. For example, 3H1 is more accurately recalled than 31H. More research is needed before that conflict can be resolved.

Method for Assessment. Inspect a sample of the alphanumeric codes which are being utilized. Verify the codes are in compliance with the guidelines cited above.

Data Display

Definition. This variable examines the various techniques and approaches for the presentation of data so that the operator can obtain the needed information in a timely and accurate manner. In addition to timeliness and accuracy, efficient information assimilation and minimal memory load on the operator are other desirable features of effective data display. Data can be presented via a CRT monitor or a hardcopy printer. "Data," as it applies to the guidelines in this section, refers to the fundamental building blocks or raw materials the operator needs to obtain the needed information. The terms information and data are often used interchangeably, but basic differences exist in their meanings. As previously described, data are merely the building blocks of information, whereas information may be regarded as the answer to a question based on the extraction of the raw materials comprising the data. Data display differs from text display in content and structure. The guidelines for text display generally assume a prose style comprised of alphabetic characters. In data display, the arrangement and order of numbers (and coded messages) are emphasized.

Guidelines.	Research Support	Source
1. Displayed data should be tailored to user needs, providing only necessary and immediately usable information at any step in a transaction sequence.	L	34, 40

USE: Choose data to be displayed.

CODE	DATA TYPE
1.	Summary
2.	Detailed list
3.	Sequences

	Research Support	Source

DON'T USE: Choose data to be displayed.

CODE	DATA TYPE	DATE IMPLEMENTED
1.	Summary	5-16-79
2.	Detailed list	9-25-79
3.	Sequences	11-19-79

	Research Support	Source
2. Data should be displayed to the user in directly usable form. (See Note 1.)	L	34, 37
3. Data should be consistent, following standards and conventions familiar to the user.		34
4. When protection of displayed data is essential, maintain computer control over the display and do not permit a user to change controlled items.	L	34
5. In general, do not require the user to rely on memory, but recapitulate needed items on the succeeding display. (See Note 2.)	L	34
6. The detailed internal format of frequently used data fields should be consistent from one display to another.	L	34

Examples: (a) Telephone numbers should be consistently hyphenated, as 213-394-1811.

	Research Support	Source
(b) Time records might be consistently formatted with colons, as HH:MM:YY, or HH:MM, or MM:SS.S.		
(c) Data records might be consistently formatted with slashes, as MM/DD/YY.		
7. Long data items of arbitrary alphanumeric characters should be displayed in groups of three of four separated by a blank. (See Note 3.)	L	34, 37
8. In tabular displays, columns and rows should be labeled following the same guidelines proposed for labeling the fields of data forms.	L	34, 40
9. In tabular displays, the units of displayed data should be consistently included in the column labels, or following the first row of entry.	L	34

Example:

Time (s)	Velocity (m/s)	Temperature (°C)
5	8	25
21	49	29
43	87	35

	Research Support	Source

or	Time	Velocity	Temperature
	5 s	8 m/s	25°C
	21	49	29
	43	87	35

		Research Support	Source
10.	Columns of numeric data without decimals should be displayed right-justified; numeric data with decimals should be justified with respect to the decimal point. (See Note 4.)	L	34, 37, 40

USE:

```
  1.5
 15.98
649.76
```

DON'T USE:

```
1.5
 15.98
 649.76
```

		Research Support	Source
11.	Lists of alphabetic data should be vertically aligned with left justification to permit rapid scanning; indentation can be used to indicate subordinate elements in hierarchic lists. (See Note 5.)	L	34, 37

	Research Support	Source

USE: ALP
COBOL
FORTRAN
PL1

DON'T USE: ALP
COBOL
FORTRAN
PL1

	Research Support	Source
12. Data lists should be organized in some recognizable order, whenever feasible, to facilitate scanning and assimilation.	L	34, 37

Example: Dates may be ordered chronologically, names alphabetically.

	Research Support	Source
13. When listed data are labeled by number, letter, etc., the list format should be distinctive from lists of menu options.	L	34
14. When listed items are labeled by number, the numbering should start with "1," and <u>not</u> "0,"	L	34

	Research Support	Source
15. For hierarchic lists with compound numbers, the complete numbers should be used, rather than omitting the repeated elements.	L	34

USE:

2.1 Position Designation
2.1.1 Arbitrary Positions
2.1.1.1 Discrete
2.1.1.2 Continuous
2.1.2 Predefined Positions
2.1.2.1 HOME
2.1.2.2 Other

DON'T USE:

2.1 Position Designation
  1. Arbitrary Positions
    1. Discrete
    2. Continuous
  2. Predefined Positions
    1. HOME
    2. Other

	Research Support	Source
16. In dense tables with many rows, a blank line (or some other distinctive feature) should be inserted after every fifth row as an aid for horizontal scanning. (If space permits, a blank line after every third row is even better.[37])	L	34, 37

	Research Support	Source
17. When data are displayed in more than one column, the columns should be separated by at least 3 to 4 spaces if right-justified, and by at least 5 spaces otherwise.	L	34
18. Column spacing should be consistent from one display to another.	L	34
19. When tables are used for referencing purposes, such as an index, the indexed material should be displayed in the left column, the material most relevant for user response in the next adjacent column, and associated but less significant material in columns further to the right.	L	34
20. Items tnat must be compared on a character-by-character basis should be displayed with one directly above the other.	L	34
21. Longer series of strings or lists of data should be organized in columns to provide better legibility and faster scanning.	L	40

USE: Job functions are

Purchasing and Procurement
Engineering Systems and Design
General Management
Manufacturing and Quality Control

	Research Support	Source
DON'T USE: Job functions are Purchasing and Procurement, Engineering Systems and Design, General Management, and Manufacturing and Quality Control		
22. Use all upper-case or all lower-case letters within a code that is made up of more than one letter.	L	40

USE: ABCD
abcd

DON'T USE: AbCd
abCD

23. Data should be arranged on the screen so that observation of similarities, differences, trends, and relationships is facilitated for the most common uses.	L	40

					Research Support	Source

Example:	Actual Cost	Predicted Cost	Difference in Cost	Actual Output	Predicted Output	Difference in Output
	947	901	+46	83	82	+1
	721	777	-56	57	54	+3
	475	471	+4	91	95	-4

	Research Support	Source
24. If data are to be entered from paper forms, the design of the input screen and the layout of the paper form should correspond. (See Note 6.)	L	40
25. Each list of selections should have a heading that reflects the question for which an answer is sought.	L	40

Select organization type

USE:

1. Responsible
2. Performing
3. Assigned

Select

DON'T USE:

1. Responsible
2. Performing
3. Assigned

	Research Support	Source
26. When listing or enumerating items, each one should start on a new line. (See Note 5.)	L	40

USE: Good screen design can
- o reduce errors
- o improve performance
- o increase satisfaction

DON'T USE: Good screen design can reduce errors, improve performance, and increase satisfaction.

	Research Support	Source
27. Numbers, not letters, should be used to enumerate items for input selection. (See Note 7.)	L	40

USE: Pick next action:

1. Choose new subset.
2. Select data.
3. Write to file.

.

.

.

8. Save on tape.

	Research Support	Source

DON'T USE: Pick next action:

A. Choose new subset.
B. Select data.
C. Write to file.
.
.
.
H. Save on tape.

	Research Support	Source
28. In a list of options, the most frequently used options should be placed at the top of the list. (See Note 8.)	L	40

USE: Choose vehicle type.

1. Passenger car.
2. Pick-up truck.
3. Bus.

DON'T USE: Choose vehicle type.

1. Pick-up truck.
2. Bus.
3. Passenger car.

	Research Support	Source
29. Selection numbers should be separated from text descriptors by at least one space. Include space after the period, if used. Right-justify selection numbers.	L	40

USE: Pick one:

 1. Choose new subset.
 2. Select data.

 .

 .

 .

10. Write file.

DON'T USE: Pick one:

 1.Choose new subset.
 2.Select data.

 .

 .

 .

10.Write file.

---

30. When lists or data tables extend beyond one display page, the user should be informed when a list is or is not complete (See Note 9.)	L	40

	Research Support	Source

Example: ______________ (Next display page)

Name	Name
J. J. Jackson	S. S. Stevens
M. T. Barnes	P. R. Townes
F. D. Smith	
J. P. Black	-- END OF LIST --
-- CONTINUED --	

	Research Support	Source
31. Information should be fully spelled out in a language natural to the screen user.	L	37
32. Labels for single data fields should be located to the left of the data field and separated from the data field by a unique symbol (such as a colon) and at least one space. (See Note 10.)	L	37

Example: T I T L E : x - - - - - - -

	Research Support	Source
33. Labels for multiple occurrence fields centered above the top-most data field. (See Note 10.)	L	37

	Research Support	Source

Example: C L A I M N U M B E R

- - - - - - - -

- - - - - - - -

- - - - - - - -

	Research Support	Source
34. Identical data should be consistent despite its origin.	L	37

USE:
COMPANY: ATLAS STEEL
COMPANY: ATLAS STEEL
COMPANY: ATLAS STEEL

DON'T USE:
COMPANY: ATLAS STEEL
COMPANY: 71
COMPANY: AS

	Research Support	Source
35. Visual emphasis should be provided to the data fields.	L	37
36. Accepted data organizations and formats should be used. Change them only if they cannot be clearly differentiated from other formats.	L	37

	Research Support	Source

Example: NAME:
STREET:
CITY, STATE, ZIP:

37. Data should be organized to be meaningful and consistent with human expectancies.	L	37
38. Captions and data fields should be vertically aligned into columns.	L	37

Example:
```
POLICY NUMBER:     ----------
ACCOUNT NUMBER:    --------
EFFECTIVE DATE:    --------
EXPIRATION DATE:   --------
POLICY STATUS:     --------
```

39. When caption sizes are relatatively equal, both captions and data fields should be justified left. One space should be left between the longest caption and the data field column.	L	37

	Research Support	Source

Example:
```
POLICY NUMBER:      -----------
ACCOUNT NUMBER:     ---------
EFFECTIVE DATE:     ------
EXPIRATION DATE: x------
POLICY STATUS:      ---------
```

40. When caption sizes vary greatly, captions should be justified right and the data fields should be justified left. One space should be left between each caption and data field. (See Note 11.)	L	37

Example:
```
                 CORPORATION: x-------
                       TITLE: x-------
      SOCIAL SECURITY NUMBER: x-------
```

41. A field group heading should be centered above the captions to which it applies. It should be completely spelled out and related to the captions by a broken dashed line. (See Note 12.)	L	37

	Research Support	Source

Example:

```
----- CLAIM -------

NUMBER  AMOUNT     DATE

-------- ------- ---------
-------- ------- ---------
-------- ------- ---------
```

	Research Support	Source
42. When section headings are located on the line above related screen fields, the captions should be indented a minimum of five (5) spaces (xxxxx) from the start of the heading. (See Note 13.)	L	37

Example:

```
COVERAGES
xxxxxPROPERTY:  ---------
     LIABILITY: ---------

PREMIUMS
xxxxxBASIC:       ------
     TOTAL:       ------
```

	Research Support	Source
43. When section headings are placed adjacent to the related fields, they should be located to left of the top-most row of related fields. The column of captions should be separated from the longest heading by a minimum of three (3) blank spaces (xxx). (See Note 13.)	L	37

```
Example:  C O V E R A G E S x x x P R O P E R T Y :   - - - - - - - - -
                                  L I A B I L I T Y : - - - - - - - - -

          P R E M I U M S         B A S I C :         - - - - - -
                                  T O T A L :         - - - - - -
```

		Research Support	Source
44.	At least one space line should appear between columnized groups of related information. For long columns of related elements, a space line should appear after every fifth item (after every third item if space permits). (See Note 14.)	L	37

```
Example:  P O L I C Y   N U M B E R :       - - - - - - - - - - -
          A C C O U N T   N U M B E R :     - - - - - - - - -
          E F F E C T I V E   D A T E :     - - - - - -
          E X P I R A T I O N   D A T E :   - - - - - -
          P O L I C Y   S T A T U S :       - - - - - - - - -
```

	Research Support	Source

```
P O L I C Y  F O R M :        - -
P R O P E R T Y :             - - - - - - -
L I A B I L I T Y :           - - - - - - -
D E D U C T I B L E :         - - - -
E N D O R S E M E N T :       - - - - - - - - -

                    M O D E L

                  :  - - - - - - - -
                  :  - - - - - - - -
                  :  - - - - - - - -


                  :  - - - - - - - -
                  :  - - - - - - - -
                  :  - - - - - - - -
```

	Research Support	Source
45. At least five (5) spaces (xxxxx) should appear between the longest data field in one column and the right-most caption in an adjacent column. (See Note 14.)	L	37

```
Example:  M A K E :   - - - - - - - - - x x x x x D A T E :  - - - - - -
          M O D E L :  - - - - - -                T I M E :  - - - - -
```

	Research Support	Source
46. At least five (5) spaces (xxxxx) should appear between the longest data field in one column and the section heading in an adjacent column. (See Note 14.)	L	37

	Research Support	Source

```
Example:  COVERAGES               xxxxxPREMIUMS
               PROPERTY:  --------xxxxx      BASIC:  ------
               LIABILITY: --------           TOTAL:  ------

          COVERAGES  PROPERTY:  --------xxxxxPREMIUMS  BASIC:  ------
                     LIABILITY: --------               TOTAL:  ------
```

47. Where space constraints exist, vertical lines may be substituted for spaces for separation of columns of fields.	L	37

```
Example:  COVERAGES                PREMIUMS
               PROPERTY:   --------x x  BASIC:  ------
               LIABILITY:  --------x x  TOTAL:  ------
```

48. For multiple occurrence fields without group headings, at least three (3) spaces (xxx) should exist between the columns of fields. (See Note 15.)	L	37

```
Example:    M A K E            M O D E L         Y E A R
          - - - - - - - - x x x - - - - - - x x x - - - -
          - - - - - - - -       - - - - - -       - - - -
          - - - - - - - -       - - - - - -       - - - -
```

	Research Support	Source
49. For multiple occurence fields with group headings, at least three spaces (xxx) should appear between columns of related fields and at least five spaces (xxxxx) should appear between groupings. (See Note 15.)	L	37

```
Example:  - - - HOMEOWNERS - - - -      - - - - AUTOMOBILE - - -

          NUMBER  AMOUNT   PREMIUM    NUMBER  AMOUNT   PREMIUM
          ------xxx------xxx------xxxxx------xxx------xxx------
          ------   ------   ------     ------   ------   ------
          ------   ------   ------     ------   ------
```

NOTE 1: The user should not be required to transpose, compute, interpolate, translate displayed data into other units, or refer to documentation to determine the meaning of displayed data.[34]

NOTE 2: If data must be remembered from one display to another, no more than 4 to 6 items should be displayed.[34]

NOTE 3: As an exception to Guideline 7, words should be displayed intact, whatever their length. Also, grouping should follow convention where a common usage has been established, as in the NNN-NN-NNNN of social security numbers.[34]

NOTE 4: Do not add or remove zeros arbitrarily after a decimal, since in some applications the zeros may [illegible] the meaning in terms of significant figures.[40]

NOTE 5: In the interests of compact display format, a short list (of just 4 to 5 items) may be displayed horizontally on a single line if done consistently.[34]

NOTE 6: Guideline 24 helps the user to find and keep a location while looking back and forth from the form to the terminal.[40]

NOTE 7: For short selection lists, single letter mnemonics may sometimes be used.[40]

NOTE 8: Reference 37 recommends that, for lists of up to seven (7) alternatives, the most probable alternative be placed at the top. In longer lists, or in short lists when there is no obvious frequency or pattern, the items should be placed in alphabetical order.

NOTE 9: Lists or data tables often extend beyond the amount that can be shown on one display page. The user must be informed when a list is or is not complete. Unless the list is short and it is obvious that it does not fill the available space, it should be marked with the message -- END OF LIST --. Incomplete lists should be marked -- CONTINUED ON NEXT PAGE --. If the message is too long and it would reduce the display capacity, it may be shortened to -- CONTINUED --.[40]

NOTE 10: Caption rules are most similar to those for data entry screens without source documents. For multiple occurrence fields the caption will be <u>centered</u> above its related data field and the data field need not be preceded by a unique symbol such as a colon. Presence of a field will be communicated by the display of data itself. If the field contains no data, it is irrelevant to the user. The overriding caption consideration is that it be clear and easily identifiable as a caption. As will be seen, in many instances captions play only a supporting role to displayed data itself.[37]

NOTE 11: Left justification of captions and right justification of data fields will usually yield a more "balanced" display.[37]

NOTE 12: Occasionally, a field group heading above a series of related captions may be needed. When included, it may be centered above the captions to which it applies and related to them through a broken dashed line. It should be spelled out fully.[37]

NOTE 13: 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. Guidelines 42 and 43 are intended to provide easily-scanned headings.[37]

NOTE 14: The design goal is visual separation of columns of fields. NOTE that these separation guidelines are minimums. If wider spacing is feasible, utilize it.[37]

NOTE 15: Multiple occurrence fields must also provide adequate visual separation of columns of fields.[37]

Comment. The most comprehensive treatment of the guidelines for Data Display is presented in Reference 37. In spite of this variable's relative impact on operator performance, the majority of this criteria is based on convention and general aesthetics rather than formal experimentation. A useful abbreviated overview of these guidelines have been summarized by Smith and Aucella[34] and Galitz.[37] These represent the primary issues one should consider when involved in designing effective screens for data display. Their observations are presented below:

- o Data displays must always be interpreted in the context of task requirements and user expectations.

- o A means must be found to provide and maintain context in data displays so that the user can find the information he needs for his job. Task analysis may point the way here, indicating what data are relevant to each stage of task performance.

- Design guidelines must emphasize the value of displaying no more data than the user needs, maintaining consistent display formats so that the user always knows where to look for different kinds of information, using consistent labeling to help the user relate different kinds of information, and using consistent labeling to help the user relate different data items, on any one display and from one display to another.

- Flexibility is needed so that data displays can be tailored on-line to user needs.

- In tasks where a user must both enter and retrieve data, which is often the case, the formatting of data displays should be compatible with the methods used for data entry. Display design should also be compatible with dialogue types used for sequence control and with hardware capabilities.[34]

- Limit the screen (or transaction) to that information necessary to perform actions, make decisions, or answer questions.

- For multiple-screen transactions requiring searching through several screens, locate the most frequently requested information on the earliest transaction screens.

- Do not pack the screen with information. Use spaces and lines to perceptually organize the screen in a balanced manner.

- Group information in a logical and orderly manner with the most frequently requested information in the upper left hand corner.

- Columize, maintaining a top-to-bottom, left-to-right orientation.

- Information contained on an inquiry screen should only be that which is relevant.

- On inquiry screens the displayed data should be emphasized, since this is what the experienced user is scanning, usually by context. In looking for a date, for instance, a person's visual search usually involves scanning for numeric characters in a certain structure (such as 09/21/63), while a name search might involve scanning for a recognizable combination of alphabetic characters of an approximate size and format (such as "Johnson, Carl").[37]

Method for Assessment. Obtain a sample of displayed data used in the VDU system being examined. Check for its compliance with the guidelines presented above.

Data Entry

Definition. The availability of guidelines in the area of Data Entry warrant this variable to be separated from that for Data Presentation. Data Entry refers to input by the user of data items to be processed. Data Presentation usually entails the display of data when it is queried by the operator. Therefore, the majority of guidelines for Data Entry tend to emphasize input field size, layout, and design for operator transaction. Data Entry screens are designed primarily to collect large amounts of information quickly and accurately. Galitz[37] noted that the most important variable in data entry screen design is the availability of a specially designed source document from which data is keyed. This distinction is an important consideration because it determines whether keying aids are built into the screens or into the source document.

Guidelines.	Research Support	Source
1. In a form-filling dialogue, entering logically related items should be accomplished by a single, explicit action at the end, rather than by separate entry of each item.	L	34
2. When multiple data items are entered as a single transaction, as in form filling, the user should be allowed to RESTART, CANCEL, or BACKUP and change any item before taking a final ENTER action.	L	34
3. Whenever possible, multiple data items should be entered without the need for special separators or delimiters, either by keying into predefined entry fields or by including simple spaces between sequentially keyed items.	L	34, 37

	Research Support	Source
4. When a field delimiter must be used for data entry, a standard character should be adopted for that purpose; a slash (/) is recommended.	L	34
5. For all dialogue types involving prompting, data entries should be prompted explicitly by displayed labels for data fields and/or by associated user guidance messages.	L	34

USE:

```
NAME: _ _ _ _ _ _ _ _ _ _ _ _ _
ORGANIZATION: _ _ / _ _
PHONE: _ _ _ - _ _ _ _
```

DON'T USE:

```
NAME, ORGANIZATION AND PHONE

_ _ _ _ _ _ _ _ _ _ _ _
_ _ / _ _
_ _ _ - _ _ _ _
```

6. Field labels should consistently indicate what data items are to be entered.	L	34

Example: A field labeled NAME should always require name entry, and not sometimes require something different.

	Research Support	Source
7. In ordinary use, field labels should be protected and transparent to keyboard control, so that the cursor skips over them when spacing or tabbing.	L	34
8. Special characters should be used to delineate each data field; a broken-line underscore is recommended. (See Note 2.)	L	34

USE: Enter account number: _ _ _ _ _

DON'T USE: Enter account number:

	Research Support	Source
9. Implicit prompting by field delineation should indicate a fixed or maximum acceptable length of the entry. (See Note 3.)	L	34, 40

USE: Enter ID: _ _ _ _ _ _ _ _ _ _ _

DON'T USE: Enter ID (11 characters):

	Research Support	Source
10. Field delineation cues should distinguish required from optional entries.	L	34, 37

Example: A broken underscore might be used to indicate required entries, with a dotted underscore to indicate optional entries:

LICENSE NUMBER: _ _ _ _ _ _
MAKE: . . . .
YEAR/MODEL: . . . .

	Research Support	Source
11. When some of the entries are optional and some are mandatory, the input prompts should indicate which are optional. Mandatory fields should be located ahead of optional ones. All inputs should be mandatory unless they are marked optional.	L	40

Example: Enter license number: _ _ _ _ _ _ _
Enter make (optional): _ _ _ _ _ _ _ _ _ _
Enter year model (optional): _ _ _ _

	Research Support	Source
12. When item length is variable, the user should not have to justify an entry either right or left and should not have to remove any unused underscores; computer processing should handle those details automatically.	L	34, 37

	Research Support	Source
13. When multiple items (especially those of variable length) will be entered by a skilled touch typist, each data field should end with an extra (blank) character space; software should be designed to prevent keying into a blank space, and an auditory signal should be provided to alert the user when that happens. (See Note 4.)	L	34
14. Labels for data fields should be distinctively worded so that they will not be readily confused with data entries, labeled control options, guidance messages, or other displayed material.	L	34
15. When displayed data forms are crowded, auxiliary coding should be adopted to distinguish labels from data. (See Note 5.)	L	34

Example: A recommended practice is to display fixed, familiar labels in d'm characters, with data entries in bright characters.

	Research Support	Source
16. In labeling data fields, only agreed terms, codes, and/or abbreviations should be used. (See Note 6.)	L	34, 40

	Research Support	Source

USE: WEEK: _ MONTH: _ _ YEAR: _ _
SOCIAL SECURITY NUMBER: _ _ _ - _ _ - _ _ _ _

DON'T USE: DATECODE: _ _ _ _ _
SSAN: _ _ _ _ _ _ _ _ _

	Research Support	Source
17. The label for each entry field should end with a special symbol, signifying that an entry may be made. (See Note 7.)	L	34, 37

Example: A colon is recommended for this purpose, e.g.:

NAME: _ _ _ _ _ _ _ _ _ _ _

	Research Support	Source
18. Labels for data fields may incorporate additional cuing of data formats when that seems helpful.	L	34

Example: (a) Example: DATE (M/D/Y): _ _ / _ _ / _ _

(b) DATE: _ _ / _ _ / _ _
M M D D Y Y

	Research Support	Source
19. When a measurement unit is consistently associated with a particular data field, it should be displayed as part of the fixed label rather than entered by the user. (Data should be keyed without dimensional units, e.g., $, mph, etc.)	L	34, 37

Example: (a) COST: $ _ _ _ _
(b) SPEED (MPH): _ _ _

20. When alternative measurement units are acceptable, space should be provided in the data field for user entry of a unit designator.	L	34

Example: DISTANCE: _ _ _ _ (MI/KM) _ _

21. Data should be entered in units that are familiar to the user. (See Note 8.)	L	34, 40

USE: SPEED LIMIT: _ _ Miles per hour
FUEL USE: _ _ _ miles per gallon

	Research Support	Source

DON'T USE: SPEED LIMIT: _ _ feet per second
FUEL USE: _ _ gallons per minute

	Research Support	Source
22. The display format for data entry should be compatible with whatever format is used for display output, scanning, and review of the same data; item labels and ordering should be preserved consistently from one display to the other. (See Note 9.)	L	34
23. When data entry involves transcription from source documents, form-filling displays should match (or be compatible with) paper forms; in a question-and-answer dialogue, the sequence of entry should match the data sequence in source documents. (See Note 10.)	L	34
24. If no source document or external information is involved, the ordering of multiple-item data entries should follow the logical sequence in which the user is expected to think of them. (See Note 11.)	L	34
25. When a form for data entry is displayed, the cursor should be positioned automatically in the first entry field. (See Note 12.)	L	34

	Research Support	Source
26. When sets of data items must be entered sequentially in a repetitive series, a tabular format where data sets are keyed row by row should be used. (See Note 13.)	L	34
27. Justification of tabular data entries should be handled automatically by the computer; the user should <u>not</u> have to enter any leading blanks or other formatting characters.	L	34, 37, 40

Example: If a user enters "56" in a field four characters long, the system should not interpret "56__" as "5600".

	Research Support	Source
28. It should be possible for the user to make numeric entries (e.g., dollars and cents) as left-justified, but they should be automatically justified with respect to a fixed decimal point when a display of those data is subsequently regenerated for review by the user.	L	34
29. For entry of tabular data when vertical repetition of entries is frequent, the user should be provided a DITTO key to speed entry of duplicative data.	L	34

	Research Support	Source
30. For dense tables (those with many row entries), some extra visual cue should be provided to guide the user accurately across columns. (See Note 14.)	L	34
31. Software for automatic data validation should be incorporated to check any item whose entry and/or correct format or content is required for subsequent data processing. (See Note 15.)	L	34
32. When required data entries have not been entered, but can be deferred, data validation software should signal that omission to the user, permitting either immediate or delayed entry of missing items.	L	34
33. When entry of a required data item is deferred, the user should have to enter a special symbol in the data field to indicate that the item has been temporarily omitted rather than ignored.	L	34
34. In a repetitive data entry task, data validation for one transaction should be completed and the user allowed to correct errors before another transaction begins. (See Note 16.)	L	34
35. If item-by-item data validation within a multiple-entry transaction is provided, it should only be as a selectable option. (See Note 17.)	L	34

	Research Support	Source
36. When helpful values for data entry cannot be predicted by user system interface (USI) designers, which is often the case, the user (or perhaps some authorized supervisor) should have a special transaction to define, change, or remove default values for any data entry field.	L	34
37. On initiation of a data entry transaction, currently defined default values should be displayed automatically in their appropriate data fields. (See Note 18.)	L	34
38. User acceptance of a displayed default value for entry should be accomplished by simple means, such as by a single confirming key action or simply by tabbing past the default field. (See Note 19.)	L	34, 37
39. A user should be able to replace any data entry default value with a different entry, without necessarily changing the default definition for subsequent transactions.	L	34
40. A user should not be required to enter "bookkeeping" data that the computer could determine automatically. (See Note 20.)	L	34

	Research Support	Source

Example. A user generally should not have to identify his work station to initiate a transaction, nor include other routine data such as transaction sequence codes.

41. A user should not be required to enter redundant data already accessible to the computer. (See Note 21.)	L	34

Example: The user should not have to enter both an item name and identification code when either one defines the other.

42. Data entries made in one transaction should be retrieved by the computer when relevant to another transaction, and displayed for user review if appropriate. The user should <u>not</u> have to enter such data again.	L	34
43. Whenever needed, automatic computation of derived data should be provided so that a user does not have to calculate and enter any number that can be derived from data already accessible to the computer.	L	34

	Research Support	Source
44. Whenever needed, automatic cross-file updating should be provided so that a user does not have to enter the same data twice.	L	34

Example: Assignment of aircraft to a mission should automatically indicate that commitment in squadron status files as well as in a mission assignment file.

45. When data entry requirements may change, which is often the case, some means should be provided for the user (or an authorized supervisor) to make necessary changes to data entry procedures, entry formats, data validation logic, and other associated data processing.	L	34
46. Areas of the screen not containing entry fields (i.e., protected fields) should be inaccessible to the operators, not requiring repeated key depressions to step through.	L	37
47. Optimally, a minimum of three spaces should appear between one entry field and the caption of the following field. One space is acceptable if space constraints exist.	L	37

Example: E F F - D T : - - - - - - x x x E X P - D T : - - - - - - x x x

	Research Support	Source
48. Space lines should be incorporated where "visual" breaks or spaces occur on the source document.	L	37
49. A field group heading should be centered above the captions to which it applies and related to these captions by a broken dashed line. (See Note 22.)	L	37

```
Example: - - - - - H O M E O W N E R S - - - - -

         E F F - D T : - - - - - -   E X P - D T : - - - - - -

         Multiple Occurrence Fields

         - - - - H O M E O W N E R S - - - -

           F O R M       E F F - D T       E X P - D T

         : - - - - - - -   : - - - - - -   : - - - - - -

         : - - - - - - -   : - - - - - -   : - - - - - -
```

---

50. Field group headings should be fully spelled out.	L	37

	Research Support	Source
51. Optimally, the entire field should be identified by underscores.	L	37

Example: A C C T : x _ _ _ _ _ _ _ _ _ _

52. Minimally, the starting point of a field should be identified with unique symbol (separated by one space) (x).	L	37

Example: A C C T : x

53. Optimally, the ending point of long, non-underscored fields should be identified with a unique symbol (such as semi-colon). The symbol should be separated from the field by one space (x).	L	37

Example: A D D R : x x ;

54. A section heading should be located directly above its associated data fields. (See Note 23.)	L	37

	Research Support	Source
55. Related field captions or row headings should be indented a minimum of three (3) spaces (xxx) from the beginning of the section heading. (See Note 23.)	L	37
56. Section headings should be fully spelled out. (See Note 23.)	L	37

Example: C U S T O M E R I N F O R M A T I O N

```
           N A M E : - - - - - - - - - - - - - -
x x x B T H - D T : - - - - - -
              O C C : - - - - - - - - - - - - - -
```

---

57. Row headings should be located to the left of row of associated entry fields. (See Note 24.)	L	37
58. If row headings are directly adjacent to entry field, they should be separated from entry field by a unique symbol (such as a colon) and one space (x). (See Note 24.)	L	37

Example: I N V - C D

```
1 : x - - - - - - - -
2 : x - - - - - - - -
3 : x - - - - - - - -
```

	Research Support	Source
59. If row headings are adjacent to the field caption, the related caption should be indented a minimum of three (3) spaces (xxx). (See Note 24.)	L	37

Example:

```
PROPERTY            BLDG: ---------
LIABILITYxxx         MED: ---------
```

	Research Support	Source
60. Input prompts should be placed so they are easily located at a glance and easily discriminated from other data on the same screen. (See Note 25.)	L	40
61. When possible, stacking of input or multiple entries should be permitted. (See Note 26.)	L	36, 40

Example:

Code	Category
LXX	Labor
MXX	Material

Selection Code: LXX; LRX; LRT (The last two codes normally are displayed at the next two menu levels, but three entries are stacked here to save time.)

	Research Support	Source
62. The user should be able to alter input during and after entry. (See Note 27.)	L	40
63. In a variable-length entry, the user should be required to enter only the relevant input data. (See Note 28.)	L	40
64. When possible, a system should recognize common misspellings of a command and execute the command as if it had been spelled correctly. (See Note 29.)	L	40
65. Misspelling of similar commands should not cause errors. (See Note 30.)	L	40
66. Keying should be minimized. (See Note 31.)	L	40
67. The user should not be required to reenter parameters that have not changed since the previous interaction. (See Note 32.)	L	40

NOTE 1: Guideline 1 permits user review and possible data correction prior to entry and also clarifies for the user just when grouped data are processed. It also permits efficient cross validation of related data items by the computer.[34]

NOTE 2: Implicit prompts help reduce data entry errors by the user.[34]

NOTE 3: Prompting by delineation is more effective than simply telling the user how long an entry should be. Underscoring gives a direct visual cue as to the number of characters to be entered, and the user does not have to

count them. Similar implicit cues should be provided when data entry is prompted by auditory displays. Tone codes can be used to indicate the type and length of expected data entries.[34,40]

NOTE 4: Guideline 13 permits consistent use of tab keying to move from one field to the next.[34]

NOTE 5: For novice users, it may sometimes be helpful to have brighter labels if that could be provided as a selectable option.[34]

NOTE 6: Do not create new jargon; if in doubt, pretest all proposed wording with a sample of qualified users.[34,40]

NOTE 7: A symbol should be chosen that can be reserved exclusively for prompting user entries or else is rarely used for any other purpose.[34,37]

NOTE 8: Data conversion, if necessary, should be handled by the computer.[34,40]

NOTE 9: When a display format optimized for data entry seems monitored for data display, or vice versa, some compromise format should be designed taking into account the relative functional importance of data entry and data review in the user's task.[34]

NOTE 10: When paper forms are not optimal for data entry, consider revising the layout of the paper form. When data entries must follow an arbitrary sequence of external information (e.g., keying telephoned reservation data), some form of command language dialogue should be used instead of form filling, to identify each item as it is entered so that the user does not have to remember and re-order items.[34,37]

NOTE 11: Alternatively, data entry can sometimes be made more efficient by placing all required fields before any optional fields.[34]

NOTE 12: As an exception to Guideline 25, if a data form is regenerated following an entry error, the cursor should be positioned in the first field in which an error has been detected.[34]

NOTE 13: As an exception to Guideline 26, when the items in each data set will exceed the display capacity of a single row, tabular entry will usually not be desirable. Row-by-row entry will facilitate comparison of related data items and permit potential use of a DITTO key for easy duplication of repeated entries.[34]

NOTE 14: A blank line after every fifth row is recommended. Alternatively, adding dots between columns at every fifth row may suffice. This practice is probably more critical for accurate data review and change than it is for initial data entry, but is desirable in the interest of compatible display formats.[34]

NOTE 15: Do not rely on the user always to make correct entries. When validity of data entries can be checked automatically, such computer aids will help improve accuracy of data entry. Some data entries, of course, may not need checking or may not lend themselves to computer checking, such as free text entries in a COMMENT field.[34]

NOTE 16: Guideline 34 is particularly important when the user is transcribing data from source documents, so that detected entry errors can be corrected while the relevant document is still at hand.[34]

NOTE 17: Item-by-item validation will sometimes help a novice user, who may be uncertain about what requirements are imposed on each data item; it may slow a skilled user if the computer processing delays next item entry.[34]

NOTE 18: The user should not be expected to remember default values. It may be helpful to mark or highlight default values in some way to distinguish them from new data entries.[34,37]

NOTE 19 : Similar techniques should be used in tasks involving user review of previously entered data.[34,37]

NOTE 20: Complicated data entry routines imposed in the interest of security may hinder the user in achieving effective task performance; other means of ensuring data security should be considered.[34]

NOTE 21: As an exception to Guideline 41, redundant data entry may be used for resolving ambiguous entries, for user training, or for security (e.g., user identification). Verification of previously entered data is often better handled by review and confirmation rather than by reentry.[34]

NOTE 22: Occasionally a group heading above a series of related captions may be needed. When included, it may be centered above the captions to which it applies and be related to them through a broken, dashed line. Field group headings will normally be fully spelled out.[37]

NOTE 23: Most source documents will contain section headings identifying related groups of document fields. These section headings may be incorporated on the screen following the rules prescribed in Guidelines 54, 55, and 56. Note that, with varying size captions, the three space indentation is to the longest caption.[37]

Note 24: Some source documents contain one or more row headings to describe the subject of the entry fields in that row. These headings may be included on screens if space constraints permit. Row headings are optional and can be either abbreviated or fully spelled out.[37]

NOTE 25: Highlighting methods (blinking, reverse video, color, or double brightness) can make them stand out. All capital letters on a screen which normally has upper- and lower-case letters can also serve to highlight prompts.[40]

NOTE 26: When an experienced user is responding to the first of a sequence of selection screens and he knows before seeing them how he will respond to the next several screens, he should be able to input several entries at the same time. Sequential entries can be separated by a special character; a semicolon is recommended.[36,40]

NOTE 27: For instance, a system should allow erasure or cursor repositioning to overwrite previously entered input. The input specifications should remain on the screen when the requested data are displayed so the user can easily alter portions of the input without having to re-enter all of it to generate a slightly different subset of the requested data.[40]

NOTE 28: Do not require the user to erase field length indicators (e.g., erase underscores), to right- or left-justify the entry, etc. If the entry is shorter than the maximal field length, its position in the field should not matter.[40]

NOTE 29: Permitting abbreviated commands can also serve this function by ignoring all non-critical characters in a command. Another method is to equate selected anticipated misspellings to the correctly spelled command.[40]

NOTE 30: While the system should be tolerant of common misspellings, spelling errors should not produce valid system commands or initiate processing sequences which are different from those intended. Consider possible confusions with existing commands when selecting new command words.[40]

NOTE 31: Make input keywords short and have them approximate real words to minimize the amount of typing required. When possible, allow the user to select the item number rather than require the entry of a longer item code or words.[40]

NOTE 32: Also avoid requirements for user entry of information already available to the system, such as the current date.

Comment. The extensive set of guidelines tend to emphasis the design of effective input procedures. This is accomplished in the guidelines by making the operator/computer interface accessible to both skilled and novice users. Adherence to these guidelines should provide an interface that will minimize the potential for human error and time to enter data. A summarization of these guidelines has been examined by Galitz[37] and Brown et al.[40] This overview of the primary considerations is presented below:

- o Entries should be made by selecting from a list of digits rather than by a typed command to minimize opportunities for typing errors.[40]
- o Where to key data should always be obvious, ideally through the use of underscores to define field sizes. If underscores are not possible, the use of a caption symbol (such as the colon) to signify the starting point of an entry field is acceptable.
- o The entry field will usually start immediately after the symbol and one blank space.
- o Absolute identification of field length is not essential if the system is operating with manual tabbing; the terminal will identify the end by locking the keyboard.
- o With horizontally arranged fields using a source document, it is preferable to leave three blank spaces between the last character of one field and the caption of the next. If space constraints exist, one blank space is acceptable.
- o Vertical spacing between rows of fields on a screen will follow the spacing conventions of the source document. This is another method of maintaining an image relationship between document and screen.[37]

Method for Assessment. Inspect a sample of the screens which require data entry. Verify that the data entry formats are in compliance with the criteria from the above guidelines.

Instructions

Definition. This section examines the techniques and methods for presentation of printed instructional materials on a CRT screen. A primary goal for developing guidelines for effective presentation of instructions is to ensure the user will not encounter difficulty in performing a task in the absence of clear, accurate, and complete instructions. This section does not dwell on the fundamentals of programmed instruction or Computer Aided Instruction (CAI). A review of this extremely large aspect of human computer interaction is beyond the scope of this document. Instead, the emphasis is on the various guidelines for displaying instructions to the user. For example, these guidelines will be applicable to presenting CRT-generated operating procedures and information requirements for interaction with the computer. This section is also highly related to variables previously examined such as "Messages" and "Text Characteristics." Therefore, the reader should review those additional sections for further detail.

Guidelines.	Research Support	Source
1. Words in instructions should be meaningful to the user. (See Note 1.)	Y	14, 21
2. Short words should be used in instructions. (See Note 2.)	L	14
3. Active voice and the affirmative case should be used in instructions. (See Note 3.)	Y	14, 21
4. Instructions should be patterned. (See Note 4.)	Y	14

	Research Support	Source

Example: (a) Now is the TIME for all
GOOD men to come to the
AID of their country.

(b) Now is the time for all good men
to come to the aid of their country.

(c)

Now is	for all	to come to	of their
the time	good men	the aid	country.

(d) When you read a road map that you have chosen
and are about to begin your comparison
of the map with the ground,
you must first orient your map.
To do this you turn the map around
until it "agrees with the ground."

	Research Support	Source
5. Sentences of instructions should be formatted into thought units (segments). (See Note 5.)	Y	14
6. When appropriate, illustrations should be used as the primary vehicle for information rather than words. (See Note 6.)	L	14
7. Illustrations should be appropriate for the type of information it conveys. (See Note 7.)	L	14
8. Illustrations should be placed close to the corresponding text. (See Note 8.)	L	14

	Research Support	Source
9. Wording on illustrations should be minimized. (See Note 9.)	L	14
10. Tables and graphs should be captioned. (See Note 10.)	L	14
11. Instructions should be well organized. (See Note 11.)	L	14
12. When instructions must be rapidly accessed, a table of contents and/or an index should be provided. (See Note 12.)	L	14
13. The literary style of a set of instructions should be appropriate to its intended use. (See Note 13.)	L	14
14. Instructions should have a clearly stated beginning and a well-developed summary. (See Note 14.)	Y	14
15. Paragraphs of text should be short and should contain a single idea. (See Note 15.)	L	14
16. Instructions should be simple. (See Note 16.)	L	14
17. Instructions should state important items more than once. (See Note 17.)	L	14
18. Instructions should contain only essential information. (See Note 18.)	L	14
19. The amount of detail should be appropriate to the experience of the user. (See Note 19.)	L	14

	Research Support	Source
20. Instructions should motivate the user. (See Note 20.)	L	14
21. The sequence of the instructions should follow the sequence of actions required.	L	21
22. Short sentences, flow diagrams, algorithms, lists, and tables are superior to prose.	Y	14, 21
23. The main topic of the instruction should appear at the beginning of the sentence.	Y	14, 21
24. All instructions should be tested on naive users before being finalized.	Y	21
25. Many-step instructions should use a two-column format. (See Note 21.)	L	21
26. In a list of specifications for service or supply, more than a part number should be given. (See Note 22.)	Y	21

	Action Step	Further Information
Example:	1. Press two-sided button	Check display on panel to see that two-sided light is on

NOTE 1: Word Meaning is related to such variables as word frequency, overall familiarity, and complexity. The meaningfulness of words is usually defined in terms of their associative value. Meaningful words generally evoke greater imagery and understanding than less meaningful words.[14] Reference 41 can be consulted to find the meaning of certain words.[21]

NOTE 2: Consideration should be given to the use of words containing few syllables. However, it is better to use multisyllable words when they can convey the intended meaning more readily than words with fewer syllables.[14]

NOTE 3: As a general rule, positive active (or affirmative) sentences are the easiest to understand. Introducing the passive or the negative creates problems, either by slowing people down or by causing them to make errors.[14]

NOTE 4: Patterning refers to the use of underlining, boldface type, uppercase, or any other techniques to emphasize certain words in order to stress their importance. Patterning provided by capitalizing the word or words that are most important in each sentence tends to help people comprehend more.[14]

NOTE 5: The spaced unit format places extra spaces between thought units in a sentence. Square-span formats use the same principle of breaking sentences up into thought units. In addition, each unit is written on two lines in order to allow the reader to use the vertical visual span as well as the horizontal. Findings show there is little improvement between spaced-unit and square-span over conventional formats. This may be due to people's familiarity with conventional formats over the new formats.[14]

NOTE 6: In many situations illustrations can be used as the primary form of communicating information, with words used as a secondary approach. Before using illustrations, a writer should consider whether they will add to the understanding of an instruction. If this is so, a designer has to decide what form of illustration will best convey the information.

Illustrations generally should not be included if they repeat in some graphical form what has been said adequately in words. Thus, the use of illustrations should depend on the illustration adding something to the meaning of an instruction. More specifically, illustrations should be used to show details that are difficult to describe verbally. For example, tables generally present detailed numerical information in a compact and organized way. Probably the best approach to incorporating illustrations in instructions is to determine the illustrations first and then write around the illustrations with whatever narrative is then needed.[14]

NOTE 7: One of the most difficult problems with providing adequate illustrations in a set of instructions is determining the most appropriate illustration for a particular type of information. Tables work well when large amounts of specific numerical data must be presented. (See Data Display for additional guidelines.)[14]

NOTE 8: Illustrations should not be saved up and then presented as a set at the end of a text. The only exception might be when an illustration needs to be consulted throughout a set of instructions.[14]

NOTE 9: A designer should seek to keep wording on an illustration to a bare minimum. In addition, illustrations should not be overloaded with data or have multiple subjects covered on a single display.[14]

NOTE 10: Tables and graphs most effectively communicate when they are accompanied by good titles or captions. Titles should be placed above tables and below graphs or other figures. Tables and graphs particularly should be numbered and have titles that are descriptive of the content. In addition, words used in titles and labels of illustrations should be consistent with the words used in the text. Titles should be short; between 5 and 11 words tend to be remembered best. If a subtitle is used to help clarify the title, the subtitle should be placed beneath the title and have lettering that is smaller than the size of the title letters.[14]

NOTE 11: The ways instructions are organized can obviously influence the speed and accuracy of their understanding. Introductions, headings,

titles, topic sentences, and summaries can all be used to help enhance the effectiveness of instructions. Organization of instructions depends on the potential readers of those instructions. Although there are a few basic rules to keep in mind, the designer should be willing to adapt any set of instructions to fit the reading habits of the intended audience.[14]

The title of a set of instructions deserves careful attention. The title can either enhance or impede the memory of material. Effective titles can also help in look-up tasks. In addition, providing a well worded introduction helps to facilitate comprehension, learning, and retention of instructions. This introduction could contain an outline of what is to come and the most important facts to be learned. Also of assistance in helping to improve comprehension and retention of instructions are well thought-out section headings and good topic sentences. All of these "early" parts of a set of instructions help the reader to call up appropriate schema (relevant past experiences). That is, the reader is able to pull together any appropriate information already known concerning the instructions to be given. A designer should work hard to find key cues and good introductory statements that will enable people to quickly and accurately comprehend and retain instructions.[14]

NOTE 12: Where it is necessary for a set of instructions to be rapidly accessed, a table of contents or indexes or both should be included. It may be useful for both the traditional hierarchical and the "key word" types of indexing to be included.

It is usually not possible for designers to anticipate all requirements for looking up material in a set of instructions. However, through a carefully conducted test of the new system, the designer can get a good idea of the majority of words that will be used as key words.[14]

NOTE 13: There are many different approaches that can be used for presenting a set of instructions. For example, when introducing and describing new equipment, an effective approach is to begin with a nontechnical description followed by a semitechnical and finally by the most technical description required for an understanding of instructions.

In other situations, an inductive approach, building up from the specific to the general, may be more useful to a reader. The latter approach is used frequently when instructions tend to be complex. Probably the most frequently used approach is a narrative one in which instructions are presented in a chronological sequence. The narrative approach is obviously very useful for procedural instructions, although it frequently does not allow a designer to show the relative importance of various items.[14]

NOTE 14: Material at the beginning and end of a set of instructions tends to be learned most rapidly and recalled more easily. This places great emphasis on a clearly stated beginning for a set of instructions and, possibly, a well-developed summary at the end.[14]

NOTE 15: Generally, paragraphs should contain between 70 and 200 words and should deal with a single logically presented idea. Shorter paragraphs tend to facilitate comprehension better than longer paragraphs.[14]

NOTE 16: It seems that the greater the amount of information that must be processed within a given period of time, the poorer the performance. This unwanted effect may be intensified still further if relevant information is not clearly differentiated from irrelevant information. The designer, therefore, is well advised to simplify the presentation of instructions to their essential points, to avoid unnecessary detail, and to maximize the ability to identify and understand critical material.[14]

NOTE 17: Redundancy may be achieved in two ways--by repetition of the same material or by providing alternative ways of looking at the same information (e.g., with examples).

For the designer, presenting information in terms of various frames of reference and providing numerous illustrative examples of critical points will aid greatly in the understanding of instructions. Positive examples are more effective than negative ones. The musical admonition to "accentuate the positive" seems to be the best rule for designers to follow. Remember, with a set of easy to understand instructions, simple repetition is likely to bore the user.[14]

NOTE 18: To communicate instructions effectively, the designer must be very selective of the information available. Attempting to transmit all available information to a user would in most systems produce only confusion. A designer first should consider all available information, decide what information is relevant to the user, and then determine how best to organize the information. Unfortunately, there are some designers who feel that the best way to achieve an acceptable level of performance is to dump everything known about the task on an unsuspecting user.[14]

NOTE 19: Experienced users perform better when given more general instructions, while users with less experience seem to derive more benefit from very specific instructions. However, instructions that are too specific may impede generalization to other activities. In the same light, a designer must provide preliminary instructions that are neither too concrete nor too abstract. Concrete, specific instructions seem best suited to situations requiring precise performance of a set of well-ordered activities. More general instructions encourage response flexibility. A general type of instruction may be preferable in situations demanding originality or creativity on the part of a user.[14]

NOTE 20: Instructions are most effective when the reader is motivated to learn and understand them. Readers who approach instructions with a definite intent to learn will remember the material better than those who do not. Even though designers generally have a limited amount of control over reader motivation, they should attempt to develop instructions that are interesting.[14]

NOTE 21: The two column format is an appropriate design for many-step instructions. The second column (Further Information) is especially useful during an operator's learning phase on the equipment.

NOTE 22: For instance, the specification should be supplemented with a short description (#23417--2-oz ink remover), which relieves the operator from memorizing the five-digit code when following the instructions. If there are any hazards to warn the operator about, highlight the warnings and describe the potential consequences of not following the instructions.

Comment. Bailey[14] provides a fairly comprehensive review of the guidelines for effective presentation of instructions. A sizable proportion demonstrate evidence of formal research support while others rely on general human engineering practices and convention. The research support has also been gleaned from hard copy experimentation and not on CRT-generated displays. However, it is not clear how this factor would compromise the guidelines application to CRT-presented information. The guidelines are also highly subjective as directly usable data for assessing instructional information. A certain level of interpretation is required. These limitations, as pointed out previously, are not imposed by lack of available research. Rather, these limitations are due to the difficulty of developing a comprehensive set of generic guidelines suitable for all tasks. That is, instructions must be custom developed in most cases. From the design perspective, the following questions should be answered before the guidelines can be applied: (a) Who are the users? (b) What is the relative importance of each instruction? (c) What is the proper location for the instructions? (d) How much information redundancy is appropriate? (e) What is the most effective method and format of presentation (diagrams, photographs, prose)? (f) How intelligible are the instructions? (g) Is the appropriate nomenclature used?

Method for Assessment. The potential of these guidelines as usable input for assessment are highly subjective. In spite of these limitations, the user is encouraged to review the guidelines listed above and apply them to a sample of instructional material to ensure that some aspect of compliance is satisfied.

blank page

Characteristics of Alphanumeric Characters

This subcategory examines the various dimensions pertaining to characters and character sets that contain letters and/or numbers. Guidelines for determining maximally legible alphanumerics are classified and discussed under the variables:

Font or Style

Definition. Font is the typeface used, which encompasses several styles of type and refers to the fundamental geometry of the letters and numbers. Fonts, or typefaces, are generally referenced by standard names and by the type size (in points). For example, Roman 12 pt or 8 pt agate. The number of fonts available on CRT are limited and often are dot matrix with or without ascenders and descenders (tails).

Guidelines.	Research Support	Source
1. The font used should be one of the following:		
(a) NAMEL (Alphabet)	Y	42
(b) AMEL or AND (Numerals)	Y	42
(c) Leroy	Y	43
(d) Lincoln/MITRE (L/M)	Y	44

Comments: Examples of these recommended fonts are shown in Figure 2. The font, or style, of alphanumeric characters is typically a hard-wired feature of the computer obtained. Selection of character generation characteristics is usually performed at the time of selecting or ordering computer hardware. Evaluation of character fonts as an after-the-fact process is therefore a problem, since retrofit is a very expensive proposition. The basic evaluation criterion should probably be legibility and, for most computers, is more influenced by character size, spacing, and interline spacing than by font styles. Preference should be given to simple styles with straight lines and clear differences between "O" and zero and between "S" and "5".

Method of Assessment. The display should be observed for legibility.

Figure 2. Recommended fonts for use on CRTs.

Character Size and Proportion

Definition. Both character size and proportion are indexed to the height of the characters. Standard sizes are measured in millimeters, fractions of an inch, or else in the visual angle subtended at some given viewing distance. The direct linear measurements are meaningful only in terms of a fixed viewing distance, usually the standard reading distance of 18 to 24 inches. The visual angle subtended changes with changes in viewing distance. Thus, to maintain a stable viewing angle, the size of the characters must change as the viewing distance changes. This relationship is illustrated in Figure 3.

Because apparent visual size of objects changes as a function of viewing distance, the standards must reference some stable unit. The unit of choice in visual size has been the height of the object, with all other dimensions referenced to it. Therefore, this section will begin with a standard for character height and all other dimensions will be referenced to it. Standards for height are based on capital letters.

Guidelines.	Research Support	Source
1. Character height should be 16 minutes of arc to 26.8 minutes of arc, with 20 minutes of arc preferred. (See Note 1.)	Y	16, 22, 24 25, 26, 44, 45
2. The ratio between character height and width should be from 1:1 to 5:3. (See Note 2.)	Y	6, 38, 42, 46
3. The ratio between character height and stroke width should be from 5:1 to 8:1. (See Note 3.)	Y	6, 43, 47, 48
4. The minimum spacing between characters should be one stroke width. (See Note 4.)	Y	6, 22, 24, 25, 42

	Research Support	Source
5. The minimum spacing between words should be one character width.	Y	6, 42
6. Spacing between lines should be from 50 to 150% of the character height. (See Note 5.)	Y	6, 22, 24, 49

NOTE 1: Reference 25 recommends 18 minutes of arc for viewing distances greater than 50 cm and 2.6 mm minimum for viewing distances less than 50 cm. Reference 26 recommends a minimum of 3.5 mm. Reference 22 recommends 2.3 to 29 mm, depending on viewing distance. Reference 16 recommends 16.4 minutes of arc to 26.8 minutes of arc, depending on contrast level for a viewing distance of 16 inches. Reference 44 and 45 recommend 20 minutes of arc for luminance levels of 0.01 to 10 ftL and 10 minutes of arc for luminance levels of 10 to 50 ftL.

NOTE 2: References 6 and 42 note as exceptions the characters "M," "W," and "4," which should have a height-to-width ratio of 5:4, and "1," which should be one stroke wide. Reference 46 recommends a height-to-width ratio of 4:3.

NOTE 3: References 6, 47, and 48 recommend a height-to-stroke width ratio from 6:1 to 8:1. Reference 43 recommends a ratio of 5:1.

NOTE 4: References 6 and 42 recommend a minimum of one stroke width between characters. Reference 24 recommends a minimum of one-half character height between characters. Reference 25 recommends a minimum of 10% of the character height between characters. Reference 22 recommends from 20 to 50% of character height between characters.

NOTE 5: Reference 6 recommends from 10 to 65% of character height between lines (considering ascenders and descenders). Reference 24 recommends one-half of character height between lines. Reference 49 recommends one character height between lines. Reference 22 recommends from 100 to 150% of character height between lines.

Comments. Character size and spacing must be evaluated in the context of the purpose of the display. That is, labels for displays or isolated words in menus can be best seen and understood when set in larger size with greater spacing, while long paragraphs of text are most easily read and understood with smaller size and closer spacing.[29,50] The legibility of closely spaced characters is also affected by use of upper and lower case (see below).

Method for Assessment. The linear measurement of the major dimensions of characters can be accomplished with a ruler (preferably a millimeter rule). These measures can be converted to visual angle by use of the following formula: $\alpha = \tan^{-1} H/D$ where α is the visual angle, H is the character dimension (in cm), and D is the viewing distance (in cm). This formula introduces a slight error in that the correct formula would take into account that the character dimension is bisected by the line of sight, but the error is less than rounding error for most cases.

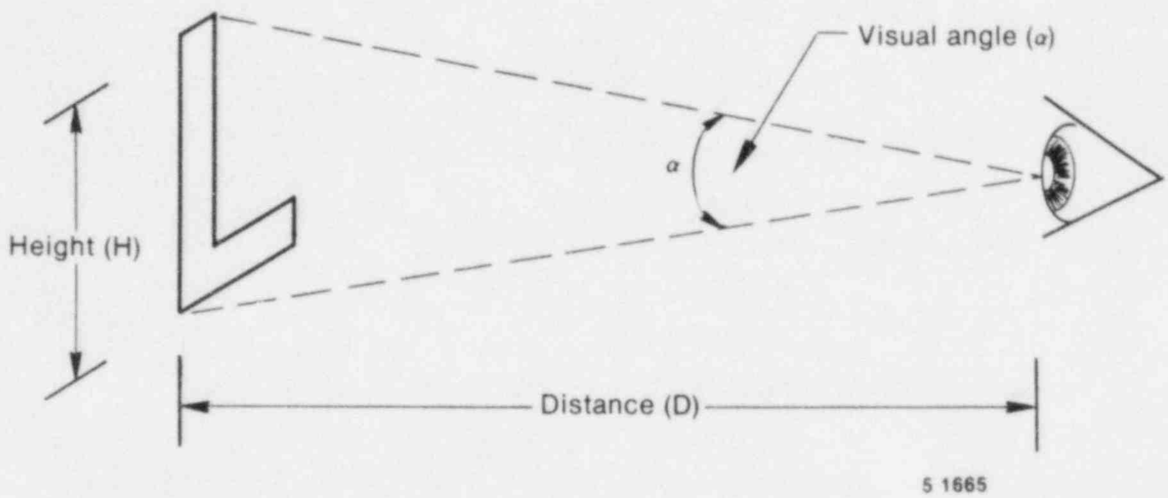


Figure 3. Visual angle as a function of distance and character height.

Character Case

Definition. Case refers to the use of different styles of upper and lower (capital and small) alphabetical symbols. This subject has been very poorly researched for CRT displays; the one relevant standard[51] assumes that the general reading research is relevant.

Guidelines.	Research Support	Source
1. Labels or statements should be in upper case.	Y	40
2. Text should be displayed in both upper and lower case.	Y	40

Comments. Research on fonts and styles for CRT displays have concentrated on upper case (capital) letters. Lower case letters, requiring ascenders and descenders, were often avoided in early computer systems. However, the development of hardware character generators and typewriter-style printers has made the subject more germane. Good research is needed on the effect of character case on human performance.

Method for Assessment. Visual observation.

Emitter Size, Shape, Spacing

Definition. Emitter size, shape, and spacing refer to the system by which characters are generated and displayed on a CRT, i.e., the dots, lines, etc., that make up the characters. The first characters were simply made up of round dots. Later, the technology to make oblong dots and square dots (pixels) was developed.

Guidelines.	Research Support	Source
1. Characters should be formed from a minimum of 5 x 7 dots in matrix with 9 x 11 preferred, using round dots--evenly spaced.	Y	44, 52
2. Characters should be formed from a minimum of 5 x 7 dots in a matrix with 7 x 9 or 9 x 11 preferred, using square dots close together.	Y	29

Comment. This aspect of character generation is usually fixed at the time that the computer is chosen, since it is often part of the hardwired programming.

Overall, it appears that the square dots with a large number of dots in the matrix is superior because it most closely approximates solid lines. Solid lines (similar to printed type) appear to enhance reading speed and accuracy.

Method for Assessment: It is probably best to rely on manufacturer specifications and visual inspection to evaluate this factor.

Screen Organization and Layout

The screen designer is limited in the ability to specify the size of the screen needed to effectively present information to the user. Therefore, given a set screen size (which is almost never large enough), the designer is tasked with the function of fitting information on the screen in a manner that ensures easy assimilation by the user. That is, the mode for organizing and layout of information must be in a form appropriate to satisfy the task requirements of the user. This subcategory addresses the variables which discuss the various techniques employed to organize information on the screen. The specific structures for the optimal presentation of information to the user have been described in the previous subcategory. This subcategory describes how these various structures can best be organized.

In this subsection, the following variables are examined:

Screen Size

Definition. The physical size of the CRT screen is examined in this section. The value for area is usually specified in terms of the diagonal size (i.e., corner-to-corner dimension of the screen or by the height and width dimensions of the viewing area.[22] Diagonal size and height and width dimensions are shown in Figure 4. Most desk top screen sizes have a diagonal dimension of 12 in. or 15 in.

Another common measurement is the aspect ratio of the screen. This is expressed as the ratio between the height and width of the viewing area. An aspect ratio of 3:4 is most commonly encountered for most horizontally mounted VDU screens. The units of measure can be inches, centimeters, and in some cases the number of pixels. A distinction should be made between screen size and "viewing area". Viewing area is always somewhat less that the size of the screen; manufacturers will vary this difference for one or more of the following reasons: (a) to provide as large a viewing area as possible, (b) to minimize distortion at the edges of the screen, and (c) to achieve a particular aspect ratio. Screen designers should be aware of this minor distinction when specifying a particular screen size.

Guidelines.	Research Support	Source
1. The screen should be the smallest size which will allow required information to be seen clearly and easily by the viewer. (See Note 1.)	N	40, 53
2. Test characters should not be larger than about 50 minutes of visual arc.	Y	40
3. The faster scan lines should not be obvious to the user.	L	40

NOTE 1: Screen size affects the interaction with the operator and the perceived resolution of the display. In an absolute sense, resolution also affects the required bandwidth or data throughput rate of the monitor and interface circuits, and ultimately the size and cost of the display memory, although these will already have been taken into account in the design of a complete colorgraphics display system.[53]

The principal advantage to be gained by increasing the size of the screen is simply a larger spatial distribution of the display.[53] Too large a display may cause problems with flicker, sharpness of image, color registration, glare, etc.[40]

Smaller screen sizes compact image elements and may cause overlap and loss of information if too small. The consensus of human factor principles call for the smallest size which will allow required information to be seen clearly and easily by the viewer.[53]

Comment. A survey of the literature reveals no specific guideline set for screen size. This is probably due to the task dependency requirements for determining screen size. The limited guidelines in this area tend to regard screen size as more a function of viewing distance, visual angle, and visual arc of the characters/symbols displayed on the screen. MIL-STD-1472C,[16] Section 5.2.5, discusses guidelines pertaining to "Large Screen Displays," but no specific dimensions are discussed, i.e., how big is an acceptable large screen size? To summarize, the guidelines indicate that too large a screen size is not practical, but the screen should not hinder legibility by being too small.

Method for Assessment. The apparent lack of useful guidelines and the task dependency of this variable will require subjective assessment. The reviewer should visually inspect the screen from the viewing distance specified for normal operation. If all information is discriminative and legible from this distance, then the screen size is adequate for the performance of the operator's function.

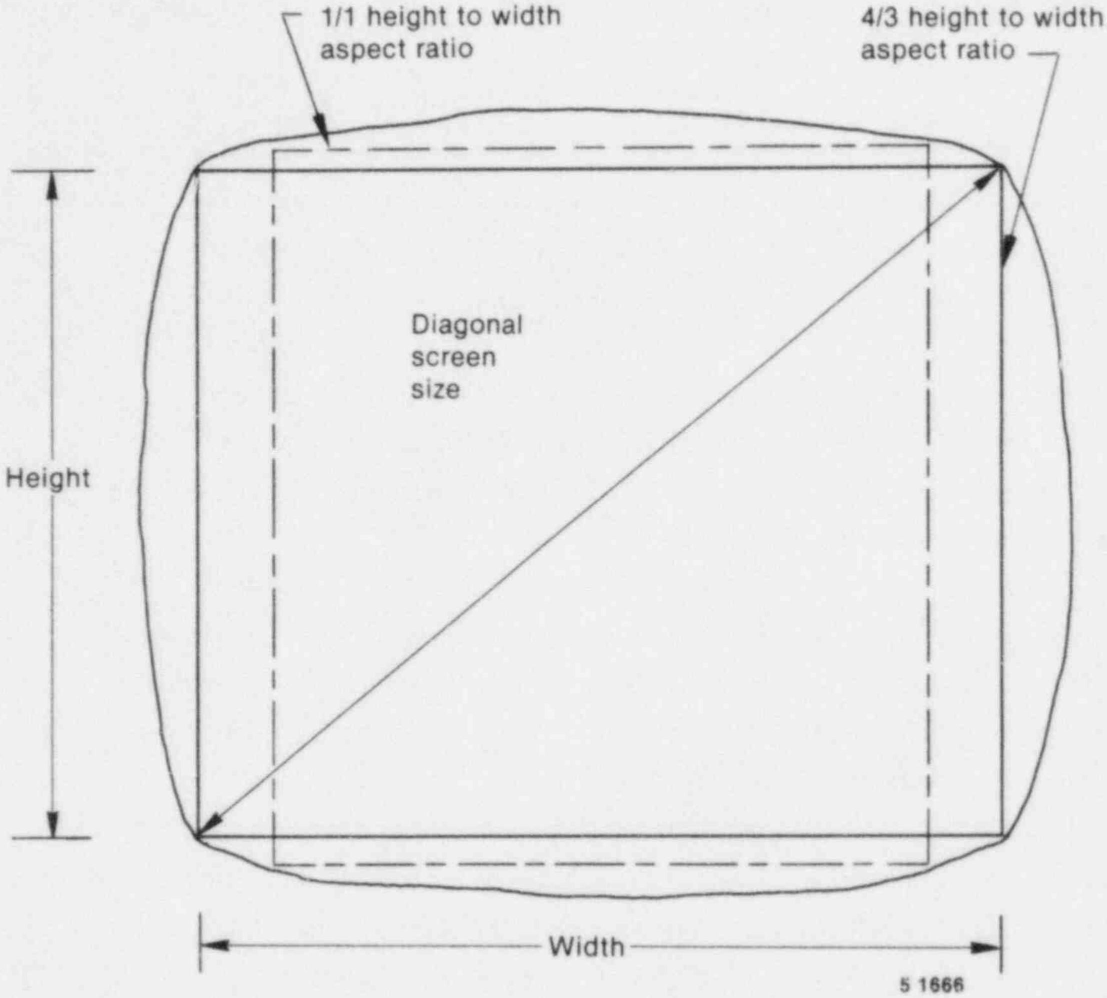


Figure 4. Display dimensions for various CRT screen sizes (Source: Reference 53).

Grouping

Definition. Within the context of screen organization, grouping refers to the placement of data into functional or otherwise meaningful sets.[5] There are generally four techniques for organizing data: (a) sequence, (b) frequency, (c) function, and (d) importance. The division of data into groups of data or information fields is necessary because the human information processing mechanism has limits on the number of items it can efficiently process at one time. In a manner similar to the presentation of non-textual information, the process of grouping information on a computer display uses our knowledge of the "chunking" process to build displays that aid the absorption of information by the user.

Guidelines.	Research Support	Source
1. Information that is continually being transmitted or received should be sequentially grouped. (See Notes 1 and 5.)	Y	14, 34, 40
2. Information should be grouped in the order of its frequency of use. (See Notes 2 and 3.)	Y	14, 34, 40
3. If frequency of use is not a major concern, information should be functionally grouped. (See Notes 3 and 5.)	Y	14, 34, 40
4. When some items are more critical than others to the success of the systems, the information should be grouped by importance. (See Notes 4 and 5.)	Y	14, 34, 40
5. Screens should provide cohesive groupings of screen elements. (See Note 6.)	Y	14, 22, 34 36, 37, 40
6. Grouped data should be arranged in the display with consistent placement of items. (See Note 7.)	Y	34, 40

		Research Support	Source

Example:

Cost			Output		
Actual Cost	Predicted Cost	Difference in Cost	Actual Cost	Predicted Cost	Difference in Cost
947	901	+46	83	82	+1
721	777	-56	57	54	+3
475	471	+ 4	91	95	-4

		Research Support	Source
7.	When there is no appropriate logic for grouping data (sequence, function, frequency, or importance), some other principle should be adopted, such as alphabetical or chronological grouping.	L	34, 40
8.	Similar information should be displayed in groups according to the left-to-right or top-to-bottom rules.	L	16
9.	All displayed data necessary to support an operator activity or sequence of activities should be grouped together.	L	16

NOTE 1: Sequential grouping is based on the principle of grouping together items in the order they are transmitted or received. For example, if a designer is developing a video display that must be used with information that always arrives, then the display should be designed so that the data can be entered in the same sequence. For output data, sequential grouping

would dictate that the data be output in the order of use. The first information needed should be the first shown at the top of the display, the second item used should be the second one shown, and so forth.

This principle not only applies to item sequence, but also to the sequence of item groups. An example would be a procession in which the user is required to verify all historical data before going on to other sections of the displays. The historical data should not only be grouped together, but be placed in a prominent position near the top of the display.

The natural order of data is another basis for sequential grouping. Other factors being equal, some sequences seem more natural than others. For example, name groups are usually alphabetical by last name, and number groups are usually placed in ascending order.

One method of establishing sequential groupings is by using a technique called procedural flow analysis. Closely analyzing the procedural flow determines what functions a display serves and what processes are performed on the data at each point in the flow of information. With this information the designer could elect to group together those items of information that need to be processed at about the same time. The order of the item groups would then follow the same sequence as the processing steps. The sequence of items within a grouping would also parallel the sequence of processing steps.

NOTE 2: The frequency-of-use technique is based on the principle that items used most often should be grouped together. If a designer develops a display completely on the basis of this technique, it would be, in effect, a rank order listing of the items according to their frequency of use. The most frequently used item would be at the top and the least frequently used at the bottom. For example, a preprinted mark-sense form for keeping a record of tool use might be designed so that the most frequently used tools are grouped near the top of the form.[14]

Another application might be to arrange items within the groups established by the sequential grouping technique. After sequentially grouping the items, place items most frequently used at the beginning of each group.[14]

One of the most common methods used to establish frequency of use is link analysis.[54] Briefly, link analysis is a technique for determining the connections between various items and/or procedures, and expressing these connections or linkages in terms of relative frequency. Using link analysis, a designer could not only determine and chart the existence of links, but also compute the frequency with which the various links occur. Of course this requires a final set of work modules so that all links are relatively stable. Through such an analysis a designer may find that Item A is used 60% of the time and Item B only 25% of the time. However, even more important, the designer may find that after Item X is used, Item A is used only 20% of the time, but Item B is used 95% of the time.[14]

NOTE 3: A functional grouping technique may also be used. A designer may consider grouping items according to special needs of the activity being performed. For example, it may be advantageous to group all of the items that pertain to inventory in one location, and those related to requisition in another location. If the sequence of frequency of use is not too important, then layout based on functional relationships may be the best criterion for grouping. Items grouped on this basis should be identified as such.[14]

NOTE 4: One technique is to group items according to how important they are to the success of the system. If a certain item or items are critical, then it may be best to place the critical items in the base position on the display so that they are not overlooked.[14]

NOTE 5: Grouping items on a video display is a delicate process of elimination, weighting, and judgment. The designer should determine which of the techniques just discussed actually apply to the items. Of those that apply, determine how much weight each should carry in the final decision, and determine weighting on the basis of eliciting the best possible human performance. When determining the best grouping, give

precedence to human performance requirements over any other requirements--for example, software or hardware requirements. After accomplishing these steps, perform tradeoffs in terms of applying one technique in one case and another technique in another case. The object, of course, is to arrive at an arrangement of items that has the highest probability of eliciting an acceptable level of human performance.[14]

NOTE 6: Screens should provide cohesive groupings of screen elements so that people perceive large screens as consisting of smaller identifiable pieces. People prefer viewing groups or chunks of data.[37]

Providing perceptual structure on the screen can be done in a variety of ways, ranging from some arbitrary but consistent grouping to an optimal designed functional grouping based upon frequency of usage data. In any case, one must take into account the characteristic of human visual perception.[36]

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.[22]

NOTE 7: Grouped data should be arranged in the display with consistent placement of items, so that user detection of similarities, differences, trends, and relationships is facilitated.[34,40]

Comment. Many of the methods for grouping are discussed in an assortment of human engineering design documents. The approaches were originally derived from guidelines for the arrangement of video displays and controls on a control panel. However, there is no rationale for limiting these methods to their original application. The generalization of these techniques to CRT screens appears to be a valid assumption. Bailey's guidelines[14] are supported by the authors of several other design documents.[34,36,40] MIL-STD-1472C[16] and Galitz[37] recommend some type of grouping strategy, but fail to be any more specific. Bailey's guidelines are based on the concept that the designer (or reviewer) knows

what the user is going to do with the information presented on the screen. Therefore, sequential task analysis, information requirements analysis, and procedural flow analysis are necessary requirements. The data from the task and/or information analysis are also useful in determining function and importance groupings.

Method for Assessment. There is a pressing need to access Task Analysis data or information analysis to ensure that a useful grouping strategy has been implemented. The Task Analysis data could serve as the foundation to research grouping strategies. If Task Analysis data (or other related data) are not available, similar information could be obtained by conducting an informal walk-through of operating sequences with operations personnel.

Display Density

Definition. This section scrutinizes all guidelines relevant to the quantity of information that can be presented on a single screen. In most cases, screen designers are not provided the luxury of unlimited screen size. All too often, the designer tends to pack too much information on a screen at one time. At some point, the packing density of information begins to adversely affect operator performance. It is often difficult to determine just what is "too much". Galitz[37] notes, "How much display information is 'too much' has not been determined. An ultimate answer must undoubtedly reflect, among other things, the requirements of the application and how the screen is formatted." Density, in the context of screen design, is often refered to as the amount of space used expressed in a percentage of the total screen area. Displays of 30, 50, and 70% packing density are shown in Figure 5. There is an optimal percentage of information that can be effectively presented to the operator on a single screen. However, that optimal value is highly dependent on the specific operator's task. Danchak[55] states, "It is intuitively obvious that an upper limit exists on the amount of active screen area. Quantifying this is another matter." In the literature, the term density is often synonymous with display loading or "clutter."

Guidelines.	Research Support	Source
1. Screen packing density should not exceed 50%, and preferably should be less than 25%. (See Notes 1 and 2.)	Y	6, 21, 55
2. No more than 18.75% of the screen should contain information of continued interest to the operator.	Y	55
3. Display screens should be perceived as "uncluttered." (See Notes 3 and 4.)	Y	36, 40

	Research Support	Source
4. Provide only information that is essential to making a decision or performing an action. (See Note 5.)	L	34, 37
5. All data related to one task should be placed on a single screen. (See Note 6.)	L	34, 37
6. For critical task sequences, screen packing density should be minimized. (See Note 7.)	Y	16
7. Where user information requirements cannot be accurately determined in advance of interface design or are variable, on-line user options should be provided for data selection, display coverage, and suppression.	L	34
8. For simple user-system dialogues, each line of display should provide a single item of information.	L	34

NOTE 1: Reference 21 notes that readability of status information or other text drops off rapidly at screen packing densities greater than 50%. Reference 55 recommends a maximum of 25%. Reference 6 excludes demarcation lines (lines separating groups of data) from determination of packing density.

NOTE 2: The cleanliness of a display determines the operator's ability to successfully perform his search and identify tasks. When he scans the display for a specific parameter (target), all other information on the screen is noise. The upper limit on the amount of active screen area is difficult to quantify. Experience shows that display loading (the percentage of active screen area) should not exceed 25%. This may seem extremely low until one considers that a well-designed page of printed

material has a loading of only 40%. An analysis of existing CRT displays that were qualitatively judged "good" revealed a loading on the order of 15%. The remaining area constitutes "white space" that is essential for clarity in any display. The amount of variable data on these displays never exceeded 75% of the total active area.

NOTE 3: Avoid overcrowded and cluttered displays. Present data using spacing or grouping or in columns to produce an orderly and legible display. Do not try to present too much data on a single screen. One source suggests that no more than 60% of the available character positions be used. Distribute the unused area to separate logical groups, rather than having all unused area on one side.[40]

NOTE 4: One of the biggest problems of a small screen display (with a capacity of up to 4000 characters) arises when the developer of a frame puts too much on the screen at one time. Recommendations have been given about putting one logically connected thought or step on the screen at one time. This advice must take into account both the level of complexity of the step and the capacity of the display. Putting too much on the screen leads to confusion and an increased error rate. If the luxury of a large screen or wasteful usage of a small screen cannot be justified, the layout of the screen must be structured so that the amount of confusion to the user is diminished.[36]

NOTE 5: Screens should provide only relevant information because the more information, the greater the competition among screen components for a person's attention. Visual search times will be longer and meaningful patterns more difficult to perceive if the screen floods the user with too much information.[37]

NOTE 6: One should not have to remember data from one screen to the next.[37]

NOTE 7: 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.[16]

Comment. The observations derived from the above guidelines indicate screen density values for presentation of alphanumeric information. There are no known guidelines for graphic or symbolic data. As a result, these guidelines are of little use when alternative coding techniques are implemented. However, Eastman Kodak[21] recommends the use of coded information in order to pack more data on the screen without losing the desired spacing. Other methods for the reduction of information density include (a) developing a hierarchy of information needs (display information routinely only for the higher priorities and relegate the other information to routines that can be called up as needed) and (b) using graphics to display events that are changing in time. It is interesting to call attention to the diversity in these guidelines. For example, Galitz[37] suggests methods for qualifying what information should be displayed to avoid clutter. Other sources, such as NUREG-0700,[6] place a quantitative value on screen loading. Danchak[55] even indicates a value for both static and dynamic information. As evidenced from the variety of percentage values in the guidelines, a single value (as described earlier in the Definition section) is difficult to derive. The author concludes that a single value is too restrictive. Instead, the reviewer should be aware of the experimental evidence which indicates a significant decrement in operator performance for screen loadings greater than 50%. Emphasis should be placed on minimizing this value (preferably less than 25%).

Method for Assessment. The assessment techniques for ensuring that the VDU screens being examined are in compliance with the above guidelines will be both quantitative and qualitative. A percentage of the screen area can be calculated to provide a "ballpark" value for screen density. Other guidelines are subject to a qualitative judgment.

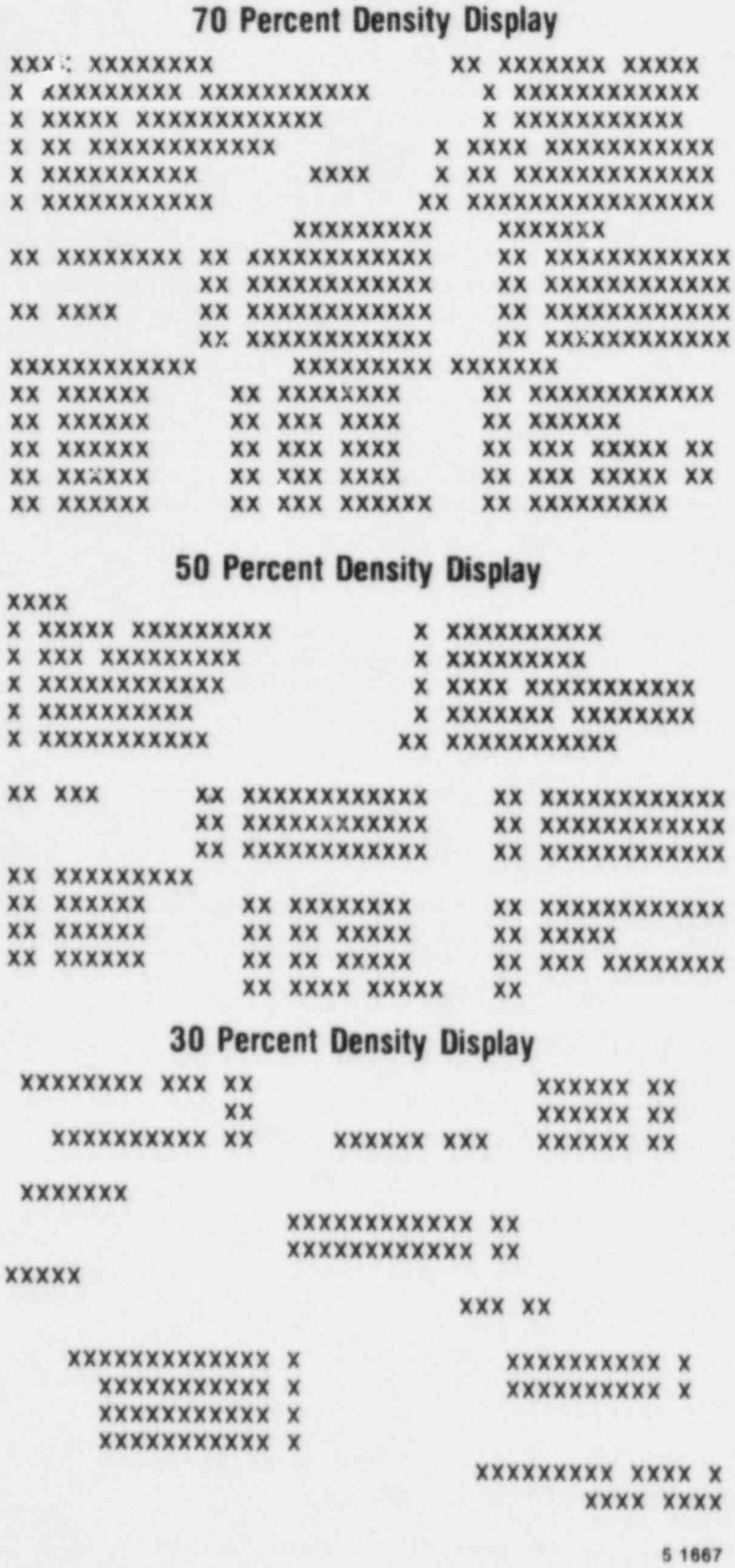


Figure 5. Display packing densities of 30, 50, and 70 percent (adapted from Reference 21).

Display Partitioning

Definition. This section focuses on the various techniques that can be applied to enhance the logical organization of the screen elements. This includes the various methods for separating groups of information into functional areas. Techniques are discussed which are applied to help the user visually perceive that the screen is structured in some logical format.

Guidelines.	Research Support	Source
1. Screens should be divided into windows that are clearly perceptible to the user. (See Note 1.)	L	6, 34, 36, 37
2. On large, uncluttered screens, windows should be separated using three to five rows or columns of blank space.	L	6, 36, 37
3. 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.	L	37
4. When a display window must be used for data scanning, the window size should be greater than one line.	L	34
5. The screen shoulc not be divided into a large number of small windows.	L	37
6. When the body of the display is used for data output, the screen should be coherently formatted and not partitioned into several small windows. (See Note 2.)	L	34

NOTE 1: Reference 36 suggests several ways of increasing the user's perception of structure. On a large uncluttered screen, areas (that is, windows) may be separated by blank spaces in sufficient quantity (3 to 5 rows and/or columns) to state unequivocally that each area is confined within those blank spaces. On smaller and/or more cluttered screens, where an excess of unused spaces cannot be tolerated, the user's perception of structures among the different areas and/or objects on the screen can be assisted by the use of a variety of techniques, including different surrounding line types (solid, dashed, dotted, etc.), line widths, intensity levels, geometric shapes, colors, numbers, and letters. Barmack and Sinaiko[56] compared the efficiency of some of these codes and recommended a maximum number of levels of coding for each code type. Barmack and Sinaiko suggest other methods of coding that may also be considered:

1. Motion (2 to 10 coding levels)
2. Focus or distortion (2 levels)
3. Line type, dashed, solid (3 to 4 levels)
4. Line length, (2 to 4 levels)
5. Line width, boldness (2 to 3 levels)
6. Orientation, location on the display surface (4 to 8 levels).

NOTE 2: To reduce search time, Reference 57 recommends that tabular displays be broken into meaningful blocks whenever possible; however, tables should not be divided into blocks to provide the impression of an organization when none exists.

Comment. The above guidelines tend to exhibit three underlying recommendations for partitioning of displays:

1. On large uncluttered screens, break it into windows using blank spaces of sufficient quantity.

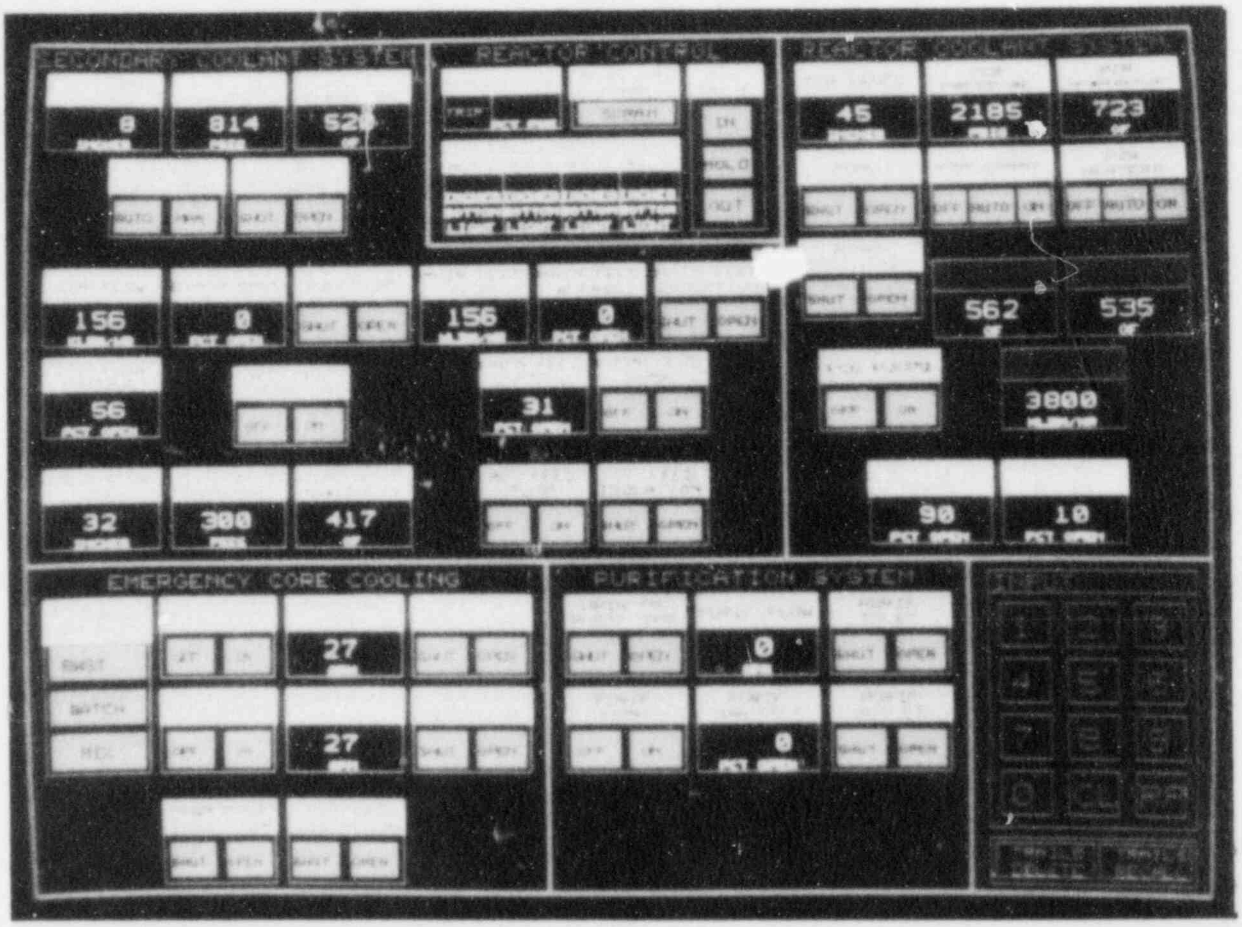
2. If screens are cluttered with a great deal of information, which probably happens more frequently than the latter, apply one of the techniques recommended by Barmack and Sinaiko.[56]

3. Do not break the screen into too many small windows.

An example of a display utilizing the guidelines for Display Partitioning is shown in Figure 6. As with many of these guidelines, there is limited research to support them and they are somewhat vague (how does one determine how many windows are too many?) They are established more from convention and human engineering criteria for layout of instrument panels. For example, the use of demarcation lines or "dog ears" to logically group related displays on single panel.[16]

This does not imply they are not practical, but due caution should be exercised in their application to CRT displays. In reference to the methods suggested by Barmack and Sinaiko[56] (refer to Note 1), Methods 3 through 6 seem to be most appropriate. Method 1 (Motion), with an upper boundary of 10 levels of motion, may be unreasonably high for graphic displays of nuclear systems and might contribute to "perceptual clutter".

Method for Assessment. The reviewer should visually inspect the screen(s) from the viewing distance specified for normal operation. If all information is discriminative and legible from that distance, the screen size is adequate. If deficiencies are noted, provide recommendations to minimize them based on the above guidelines.



5 1920

Figure 6. CRT generated control panel operated with touch screen overlay. Windowing and demarcation lines have been implemented to partition the display into an effice and usable configuration.

Frame Specifications

Definition: After information requirements have been defined for a particular screen or set of screens and a grouping strategy for placement of the information has been defined--the next question is usually "Where to place the information on the screen." The location requirements will, in most cases, be task specific and a function of human/computer dialogue. That is, information will be placed on the screen as the dialogue scenario develops. Nevertheless, there are some general guidelines in the literature which identify where information should be placed to best facilitate the operator. This section also includes specific guidance for the placement of invariant information (common to all screens, e.g., title, page number, etc.) and, to some degree, what that information should be and how it should be structured.

Guidelines.	Research Support	Source
1. An obvious starting point should be provided in the upper-left corner of the screen.	Y	58
2. 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.	Y	36, 40, 58
3. The screen should be symmetrically balanced. (See Note 1.)	Y	58
4. Instructions on how to use a screen or process information should precede the screen text or be at the top of the text.	Y	58
5. Both the items on display and the displays themselves should be standardized. (See Note 2.)	Y	6, 14, 16

	Research Support	Source
6. 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. (See Note 3, Table 2, and Figure 7.)	Y	40, 57
7. The last four lines (at least) of each display page should be reserved for variant fields. (See Note 4.)	Y	17, 40, 57
8. Procedures for user actions should be standardized. (See Note 5.)	Y	40
9. Each display frame should have a unique identification (ID). (See Note 6.)	Y	40
10. Every frame should have a title on a line by itself.	Y	17
11. Every nonmenu frame should have an abbreviated reference to an operating manual and paragraph number (on same lines as the title).	Y	17
12. When an output frame contains more than one page, the notation "page of" should appear right justified on the last line.	Y	17
13. If the full number of frame lines is not needed, the frame layout should be balanced and uncluttered.	Y	17
14. The manner of presentation of identical data should be based on the way the operator will use that data.	Y	6

	Research Support	Source
15. Information of a critical nature should be located toward the center of the screen.	Y	21
16. Status information should be displayed near the top-right corner of the screen. (See Note 7.)	Y	21
17. Code information, sampling plans, and other information that the operator may need to call up should be located on one of the sides of the screen near the top. (See Note 8.)	Y	21
18. Location coding should be employed to reduce operator information search time. (See Note 9.)	Y	16

NOTE 1: Provide symmetrical balance by: centering titles and illustrations on the vertical axis, placing like elements on both sides of the axis, placing lighter elements further from the vertical axis, and placing larger elements closer to it.

Eyeball fixation studies indicate that initially the human eye usually moves to the upper-left center of a display. The eyes then move in a clockwise direction. During and following this movement, people are influenced by the display's symmetrical balance and the weight of its titles, graphics and text. The human information processing system also tries to impose structure when confronted with uncertainty. It seeks order and meaning and will quickly discern whether a screen has a meaningful form or is cluttered.[58]

NOTE 2: 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.[14]

By standardization of items we mean that all items in the system with the same information should have the same name. They should also be coded the same way and be given the same field length (if appropriate). In many systems, a large number of different people use the same items for a variety of different reasons. Frequently, a large number of the items have more than one name. This, of course, could produce considerable confusion and lead to degraded human performance.[14]

When using the same items on different displays, they should be located in the same place on all displays. People tend to have good "location" memories. They can remember where an item is located, even though they cannot recall the item itself. In addition, group those same items in the same groups and give them the same headings and the same basic design and style.[14]

Screen formats which are designed with a specific task in mind should be consistent:

- Between different displays engaged in the same task
- With other modes of handling the same task
- With the input requirements of subsequent stages in handling data.[22]

NOTE 3: Invariant fields, or fields that contain the same type of information for each display page, should include the page title, an alphanumeric designator, and the time and date. Such fields indicate "header" information and should be presented at the top of each page. Ensure that the page title indicates 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. Ensure that the designator is meaningful enough to be easily learned and remembered, as well as being compatible with the designation scheme applied to hardwired instruments on panels.[57]

NOTE 4: Variant fields are fields reserved for information that may not be present on a given page (Reference 40 refers to variant fields as "functional fields"). When such information is displayed on a page, the assigned screen location should always be used. Variant information might include alarm messages, data source identification, the page number (e.g., Pn of N) for consecutive pages, system messages (e.g., work orders, standby subsystems), error messages, response entry prompts, and program messages. Help identify required information for variant fields by reviewing information requirements and consulting people who are representative of operational personnel. Then prepare recommended specifications for the location and format of variant field information.[57]

NOTE 5: To ensure consistency when the user must perform similar activities on different screens, certain procedural conventions are standardized and presented as requirements. 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.[40]

NOTE 6: Identify each screen or display frame with a unique ID. The screen ID should be an alphanumeric code or abbreviation which is prominently displayed in a consistent location. It should be short enough (four characters) or meaningful enough to be learned and remembered easily. The unique screen ID provides a convenient means for:

- Identifying which screen is being displayed

- Requesting display of a specific screen

- Referring to a screen in discussions
- Reporting trouble or problems in formats.[40]

NOTE 7: Display status information at the top of the screen, toward the right side. The location of this information will vary according to the type of operations performed, but it should be found in the same general part of the screen across all terminals in a manufacturing system.[21]

NOTE 8: This material should not interfere with the information being used by the operator to troubleshoot a problem or perform a data entry task.[21]

NOTE 9: It has been shown that search times are significantly faster than the average for targets in the upper right quadrant and slower for the lower right. No difference exists for the left two quadrants. These findings can be used to advantage by placing the most important information the upper right and least important in the lower right quadrants.

Preferred quadrant (in order of preference): upper right, upper left, lower left, lower right.[55]

Comment: The guidelines which address information location provide a great deal of variance in level of detail. Certain guidelines emphasis some level of standardization between similar screens. Other guidelines extend this standardization to the point of specifying which line should be dedicated to each element. It is the opinion of the author that many of these latter guidelines are somewhat overly restrictive. They were also laid out by a designer who had a specific system in mind. Therefore, there is little potential for adapting them to a generic situation. Perhaps the most pervasive observation of these guidelines is to adapt some mode of consistency and standardization for the elements across all screens, i.e., "location coding", and that certain pieces of guidance information should be placed on all screens. There is also some discrepancy for placement of priority information on the screen. More research is needed before prioritizing information according to screen quadrants.

Methods for Assessment. Inspect a representative sample of the screens employed in the system being evaluated. If it is convenient, a hard copy of each screen might be useful for making direct comparisons. The assessment process will take on two phases: (1) first examine the screens and identify information for the variant fields (as described in Note 4) and ensure that each screen has the required invariant information; then (2) ensure that these information elements are consistent and standardized across all similar screens.

TABLE 2. EXAMPLE OF A STANDARDIZED FORMAT (Source: Reference 40)

Information	Row	Column	Remarks[a]
Screen (frame) ID	1	2-5	Unique screen ID for menus
Screen Identifying Information	1	8-69	Name of Data Base project, topic, etc.
Date	1	72-80	Day Mo Yr nn aaa nn Example: 25 OCT 80
Screen Identifying Information	2	2-64	
Page Number	2	66-73	"PAGE" and the page number of this screen (single digits start in column 73).
Page Count	2	74-80	Reserved for "OF nnn". Where supported by software, this shows the number of pages of this data.
Key Assignments	23	2-59	For Program Functions (PF keys 1-6): when used, the assignments are displayed on every screen.
Request for next Screen	23	61-80	This field allows the user to request any screen from the display of any other screen by entering an ID. (Columns 61-76. "NEXT SCREEN ID:"
Program or System Messages	24	2-80	Messages on system status or error messages from the application program appear as necessary. Any system messages have priority.

a. In input format, "n" indicates a numeric character is required, "a" indicates an alphabetic character is required, and "x" indicates any alphanumeric character may be used.

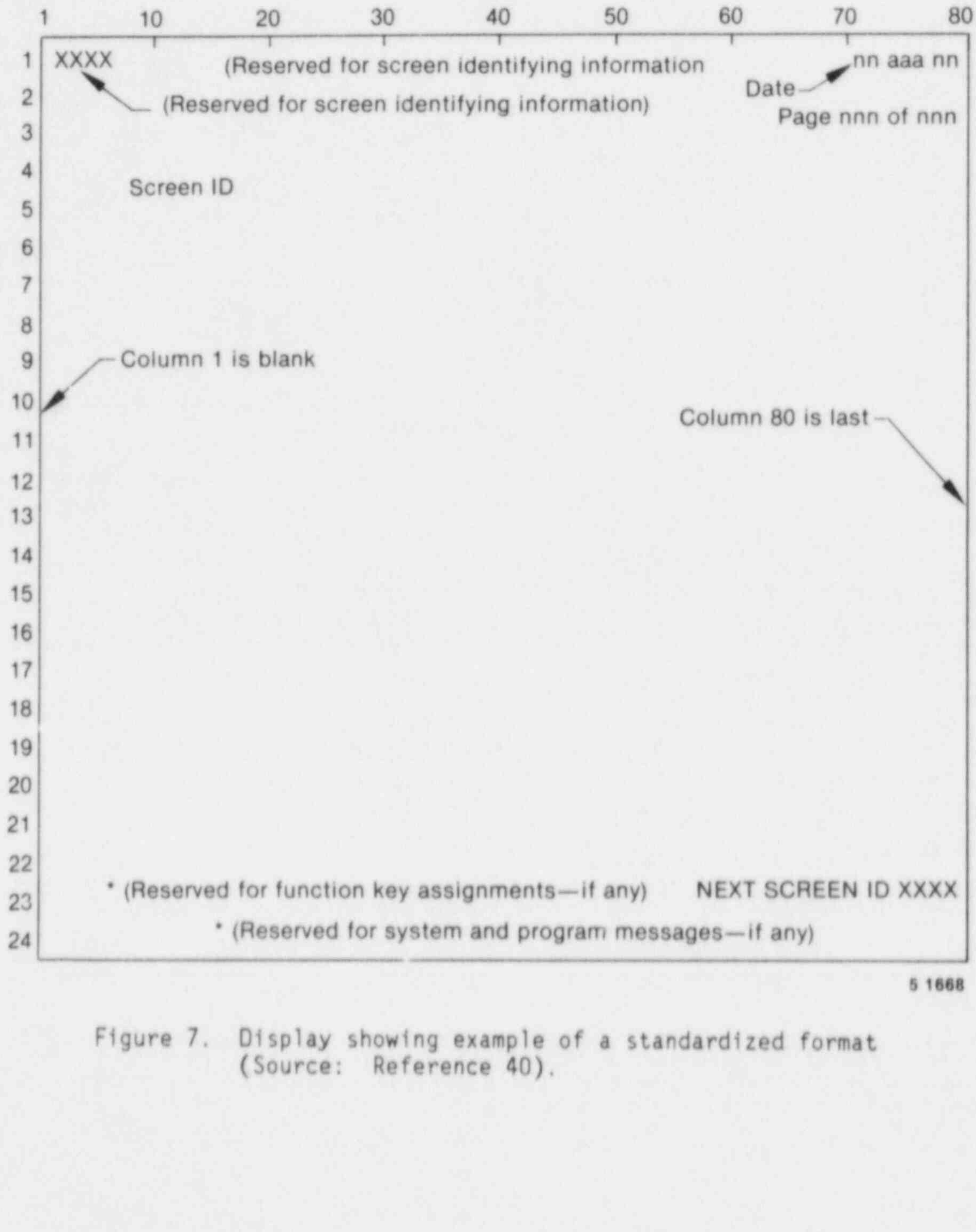


Figure 7. Display showing example of a standardized format (Source: Reference 40).

Interframe Considerations

Definition: The "window to the world", as many CRT screens in process control environments are often called, must be manipulated by the user. Unlike a traditional control board where all the instrumentation is immediately available, a CRT screen is restricted in the amount of information that can be presented at any particular time. As a result, the problem of how information can be accessed is an important issue. This section will address the various techniques for controlling and accessing information flow through the "window". Brown et al.[40] refer to these elements of user control as follows, "One of the most critical determinants of user satisfaction and acceptance of a computer system is the extent to which the user feels in control of an interactive session." Two of the most common techniques for achieving user control are scrolling and hierarchical paging. Another technique is often called windowing. These approaches, their advantages, and applications will be discussed under this variable.

Guidelines.	Research Support	Source
1. Whenever possible, all data relevant to the user's current transaction should be included in one display page (or "frame"). (See Note 1.)	L	6, 14, 34, 36

Example:[36]

	GPSS	GPSS-Transfer
Pick One:	Pick One:	Pick One:
FORTRAN	ADVANCE	Fractional
PL/I	TRANSFER	Pick
GPSS	UNLINK	Unconditional

	Research Support	Source
2. When the requested data exceed the capacity of a single display frame, the user should be provided easy means to move back and forth among relevant displays either by paging or scrolling. (See Note 2.)	L	22, 34

Example: Dedicated function keys might be provided for paging/scrolling forward and back.

	Research Support	Source
3. When a list of numbered items exceeds one display page and must be paged/scrolled for its continuation, items should be numbered continuously in relation to the first item in the first display[14,34] and should indicate the present maximum location.[14,36]	L	14, 34, 36

USE: Line 63 of 157

DON'T USE: Page 3, Line 8[14]

	Research Support	Source
4. When lists or tables are of variable length and may extend beyond the limits of a single display page, their continuation and ending should be explicitly noted on the display. (See Note 3.)	L	34

	Research Support	Source

Example: Incomplete lists might be marked "continued on next page," or simply "continued." Concluding lists might add a note "end of list."

	Research Support	Source
5. When display output contains more than one page, the notation "page x of y" should appear on each display. (See Note 4.)	L	6, 34
6. When scrolling is used, a consistent orientation should be adopted in user-system interface (USI) design as to whether the data are conceived to move behind a fixed display window (commonly called "scrolling") or the display window is conceived to move over a fixed array of data (here called "windowing"). (See Note 5.)	L	34
7. In applications where a cursor is moved freely within a page of displayed data, "windowing" should be selected rather than "scrolling" as the conceptual basis of display movement. (See Note 6.)	L	34
8. The parameters of roll/scroll functions should refer to the data being reviewed, NOT to the window. (See Note 7.)	L	34, 36, 40

	Research Support	Source
Example: "Roll up 5 lines" should mean 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.		
9. When the user may be exposed to different systems adopting different usage, any reference to scroll functions should consistently use functional terms such as "forward" and "back" (or "next" and "previous") to refer to movement within a displayed data set rather than words implying spatial orientation (e.g., "up" and "down"). (See Note 8.)	L	34
10. When using a menu system, the user at all times should be provided access to the main menu. (See Note 9.)	L	40
11. Displays should indicate how to continue. (See Note 10.)	L	40

	Research Support	Source

Data Base Status

USE: Data are current through March 1981 Press PF11 to continue

Data Base Status

DON'T USE: Data are current through March 1981

	Research Support	Source
12. User-terminal interaction tasks that are repetitive, time consuming, or complex should be assigned dedicated functions. (See Note 11.)	L	40
13. Required or frequently used data elements should be included on the earliest screens in the application transaction.	L	37
14. Page design and content planning should minimize requirements for operator memory.	L	6, 14

	Research Support	Source
15. When pages are organized in a hierarchical fashion containing a number of different paths through the series, a visual audit trail of the choices should be available upon operator request.	L	6, 14
16. Sectional coordinates should be used when large schematics must be panned or magnified.	L	6
17. The operator should have some capability for controlling the amount, format, and complexity of information (e.g., core dumps, program outputs, error messages) being displayed by the system.	L	6, 36
18. If the message is a variable option list, common elements should maintain their physical relationship to other recurring elements.	L	6
19. 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.	L	14

USE: Incorrect entry.
Chose one of the following:
Order
Sell
Change

	Research Support	Source
DON'T USE: Incorrect Entry		
20. The system should be designed to minimize the number of display levels required.	L	16
21. When the operator must step through multiple display levels, priority access should be provided to the more critical display levlels.	L	16
22. When the operator must step through multiple display levels, he or she should be provided with information identifying the current position within the sequence of levels.	L	16
23. A similar display format should be used at each level of a multiple-level display.	L	16
24. When the operator is required to accurately comprehend previously learned items appearing with a new list, the list should be kept small (about four to six items).	L	36
25. Frequently appearing/disappearing commands/subcommands should be placed in the same place on the screen. (See Note 12.)	L	36

NOTE 1: Do not rely on the user to remember data accurately from one display to the next.[34]

NOTE 2: Paging/scrolling is acceptable when the user is looking for a specific data item, but not when the user must discern some relationship among separately displayed sets of data.[34]

In certain types of VDT tasks, the convenience with which the operator can recall and refer to parts of the stored text is an important consideration. In applications such as these, adequate display storage capacity and a scrolling facility should be provided. In some applications, however, the convenience of being able to recall parts of the text by scrolling may be less critical or important to the operator than the time it takes. In cases such as these, a short response time to enable the writing up of the next screenfull of information may be more useful than a relatively slower scrolling time.[22]

NOTE 3: Short lists whose conclusion is evident from the display format need not be annotated in this way.[34]

NOTE 4: A recommended format is to put this note immediately to the right of the display title. With such a consistent location, the page note might be displayed in dimmer characters. Leading zeros should not be used in the display of page numbers.[34]

NOTE 5: A user can adapt to either concept, if it is maintained consistently. "Windowing" is the more natural concept for inexperienced users, causing fewer errors, and hence is the preferred option when other considerations are equal.[34]

NOTE 6: Since displayed data will be perceived as fixed during cursor movement, considerations of joint compatibility suggest that displayed data remain conceptually fixed during window "movement". Indeed, it may be possible to use the same arrow-labeled keys to control both cursor movement and "windowing".[36]

NOTE 7: Reference 34 also states that, when a "windowing" orientation is maintained consistently, the wording of scroll functions should refer 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.

NOTE 8: In that event, control of scroll functions should be implemented by keys marked with arrows, avoiding verbal labels altogether.[34]

NOTE 9: 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 (PF 11), a light pen or touch field, or a cursor entry field to display MAIN MENU.[40]

NOTE 10: Indicate on each screen the user response that is necessary to continue the interaction sequence. Do not leave the user viewing a screen with no indication of how to continue.[40]

NOTE 11: User-terminal interaction tasks that are repetitive, time consuming, or complex can be simplified by assigning dedicated functions (usually one user action) in system design. These actions should be accomplished by dedicated program function keys, dedicated light pen or touch fields, etc.

Summary of Function Key Standards

- o PAGE AHEAD
- o PAGE BACK
- o HELP
- o PRIOR LEVEL
- o MAIN MENU
- o HARDCOPY[40]

NOTE 12: Do not compress lists when a work is left out; keep list the same physical length so that the user can depend on finding the work in the same spatial location. This refers primarily to the area of the screen reserved for screen control, modal commands, etc.[36]

Comment. The above guidelines tend to reflect a single underlying theme.

1. When the operator must be working with several frames, attention should be devoted to reduce memory load and recall of information on previous screens

2. Some methods of providing a roadmap should by employed in order to allow the operator to know where he is in the series.

The merits of superiority between paging and scrolling have been given considerable attention in the literature. However, the issue of scrolling versus paging are, to some extent, task dependent.

Method for Assessment: Inspect and evaluate the interframe functions provided on the system being examined. Ensure that these functional capabilities are in compliance with the applicable guidelines for the mode (paging, scrolling) being implemented.

Visual Coding

Visual coding of information, when applied effectively, can be a useful method for aiding operator performance. In many cases, coded information can ensure brevity and also conserve space without compromising interpretational quality (i.e., pack information into a smaller space). On the other hand, poorly designed codes can degrade performance. All coding designs should adhere to the principles of legibility, clarity, and consistency. Ambiguity and confusion should be minimized prior to implementing the code in the field. The following coding variables will be discussed in this subsection:

These dimensions were identified as having the greatest relevance to CRT-generated displays. This section only addresses visual coding techniques confined to graphical and alphanumeric codes. Information highlighting, which is another specialized form of visual and auditory coding, will be examined in a later subcategory ("Enhancement Coding").

A set of general design guidelines, which are applicable to all visual coding dimensions, is provided in Table 3. This top-level table should supplement the guidelines and criteria presented for each of the following specific variables. It is recommended that Table 3 be reviewed prior to investigating the specific variables.

TABLE 3. GENERAL GUIDELINES FOR VISUAL CODING OF INFORMATION

- If a graphic display contains a high density of display elements, particularly overlapping and continuously updated features, then segregate the information using a coding or sequencing technique.[a]

- Double coding dramatically increases user performance in information extraction. A redundant code should augment symbolic information, rather than add new symbols.[a]

- Color is an extremely powerful coding technique for segregating information, but use it to assist the user at the primary or first level of interest. If a display is to be used for multiple tasks, or if the system designer does not know what information is of prime importance to the user, color coding should be placed under user control.[a]

- Techniques for reducing symbol density by segmenting displayed information should be standard functions on automated systems. Topographic information can be displayed sequentially, and an overlap between views facilitates user integration of information.[a]

- Selective Call-up seems to be an attractive solution to high-density, cluttered displays. However, penalties are incurred in the amount of time required to "build" a particular information display. Research is needed to examine means of effectively using this option.[a]

- In selecting a code, consider the following:

  - Compatibility of the code with the kind of information that is to be coded.

  - Space required to use the code.

  - Association value of the code symbols.

  - Ease and accuracy with which the operator can understand the code.

  - Likelihood that the code will distract the operator or interference with other codes.

  - Amount of information that needs to be coded and the amount that can be coded with each method.[b]

- If combination codes are used, the respective meanings should be decodeable separately without confusion. Two codes maximum combination are recommended.[c]

TABLE 3. (continued)

- Codes should be easy to learn and retain.[c]
- Redundant cues (i.e., those which associate a symbol with a particular size) increase coding efficiency.[c]
- The principles of standardization and consistency of language and coding apply not only within a displayed screen, but also within a module, an application program, and an entire information processing system. For a large corporation's information processing system, conventions for wording, coding, definitions, and procedures should be standardized at the company level. When users are forced to adapt to different conventions for each of several application programs they use, accuracy and efficiency suffer.[d]
- Information coding should be used to discriminate among different classes of items presented simultaneously on the display screen.[e]
- Meaningful codes should be used when possible. Codes should be clear and consistent with the user's expectations.[d]
- If the type of information coding selected reduces legibility, is not distinct, or increases transmission time, it should not be used.[f]
- Coding techniques shall be used to facilitate:
  - Discrimination between individual displays
  - Identification of functionally related displays
  - Indication of relationships between displays
  - Identification of critical information within a display.[g]
- Graphic code consistency--Graphic codes, used separately or in combination--should have the same meaning in all applications.[h]

---

a. See Reference 59.
b. See Reference 60.
c. See Reference 20.
d. See Reference 40.
e. See Reference 37.
f. See Reference 61.
g. See Reference 16.
h. See Reference 6.

Color

Definition. The use of color as a coding dimension can increase an operator's information gathering and processing capabilities. Specific colors can be used to distinguish between simultaneous events, to organize information into logical groups, or to call attention to important data. The use of color in display design is probably one of the most researched dimensions of all the coding techniques available. The bulk of this research indicates color to be an extremely effective dimension for search and identification tasks.[62] Christ noted that, compared to other coding dimensions (geometric shapes, size, etc.), color was superior.[62] Other research efforts have been related to determining the number of distinct colors that persons with normal color visions can differentiate on an absolute basis.[63,64,65]

The actual perception of color is determined by the wavelength along the visible spectrum. In general, this visible spectrum ranges from 380 to 700 nm. The reds and oranges are derived from the higher wavelengths, while violets and blues are at the lower end of the spectrum. Within these boundaries of electromagnetic radiation, color is further defined as a function of hue, saturation, lightness, and brightness. Hue can be considered the determinate of color, or in a more perceptual context, the experience of color. For example, when one is talking about whether a color is red, green, or blue, the question might also be appropriately said by interchanging the word color with hue. Along the visible spectrum, hue can also be interpreted as the perceived color having dominant wavelength components (e.g., the color is "red" because the dominant wavelength is approximately 700 nm). Saturation refers to the purity of perceived color. The more white light is mixed with a pure "saturated" hue, the more desaturated the resulting color experience. Lightness is often analogous to saturation. This characteristic includes the gamut of achromatic colors ranging from white through gray to black. No trace of hue is present. The combination of various hues and achromatic colors produce a desaturated hue, with the level of saturation depending upon the relative amounts of each component. Brightness is the dimension of perceptual experience

corresponding roughly to light intensity. It is sometimes synonymous with surface luminance of light source intensity. Alterations in brightness can significantly alter perception of a given hue. For example, increases in brightness levels cause hue to increase in saturation. Eventually, at upper limits of brightness, hues can appear washed out and approach luminescent white.

All perceived colors on the visible spectrum are also produced by mixing the three primary colors for light: red (R), green (G), and blue (B). All colorgraphic CRTs have a color gun for each of these primary colors. By specifying the relative amounts of each primary mixed together, any spectral color (C) can be indicated by an appropriate equation:

$$C = xR + yG + zB$$

where:

x, y, z = proportions of each wavelength.

The following guidelines address various criteria for assessing the effectiveness of color as it is implemented in the coding of CRT displays, even though a sizable portion of these guidelines was developed from surface colors. In addition, specific recommendations for candidate color sets are provided.

Guidelines.	Research Support	Source
1. Color should be used as a formatting aid to assist in structuring a screen and as a code to categorize information or data. (See Note 1.)	L	4, 34, 37, 40, 57, 60

	Research Support	Source
2. Categories for color coding should be chosen based on how the coded information is used.	L	37

Example:

a. If different sets of data are attended to separately, color code the sets to help selective attention to each in turn.

b. If decisions are made based on the status of certain data, color code the types of status the data may possess.

c. If display searching is performed to locate data possessing a particular status or quality, color code such data to contrast with the rest of the data.

d. If certain data are not used frequently, display those data in an unobtrusive color.

e. If the sequence of using data is constrained, use color to identify the sequence.

	Research Support	Source
3. The use of color should be minimized. (See Note 2.)	L	34, 37, 40

	Research Support	Source
4. The color coding scheme should be relevant and known.	L	37
5. Color coding should not create unplanned or obvious new patterns on the screen. (See Note 3.)	L	4
6. The unit should, as a minimum, be provided with the following controls:	L	4
a. A foreground intensity control separate from the background intensity control.		
b. A capability for making grid lines half as intense as the rest of the display.		
c. Intensity control variable enough to accommodate very low ambient illumination and the higher levels normally found in office work areas (5 to 150 fc).		
7. Color coding should be applied as an additional aid to the user on displays that have already been formatted as effectively as possible on a single color. (See Note 4.)	L	34, 40
8. When color coding is used, it should be redundant with some other feature in data display, such as symbology. (See Note 5.)	L	4, 14, 34

	Research Support	Source
9. Color codes should conform to color meanings that already exist in the user's job. (See Note 6 and Table 4.)	L	16, 37, 57
10. Color meanings should be consistent with traditional color expectancies. (See Note 7.)	Y	6, 34, 37
11. Color coding should be consistent within a frame, from frame to frame, and with other color-coded systems in the control room. (See Note 8.)	Y	6, 14, 37, 40
12. Color selections should be compatible with the capabilities of the terminal.	Y	37
13. Specific color selections should conform to the general guidelines of Table 5 and to the following specific recommendations: (See Note 9.)		
a. The most generally used colors should be red, green, yellow, and blue. Other acceptable colors are orange, yellow-green, blue-green, and violet.	L	37
b. When blue headings, numbers, or alphabetic characters are used, the background should be black.	Y	4
c. Yellow should not be used on a white background because of the very low contrast.	Y	4

	Research Support	Source
d. Yellow should not be used on a green background due to a "vibrating" effect to the eye.	Y	4
e. White should be used for very important information. (See Note 10.)	L	4
f. The selected colors should yield satisfactory color contrast for color-deficient users.		57
g. The user should be able to discriminate the selected color on an absolute basis. (See Note 11 and Table 6.)		19, 57
h. Selected colors should be usable in all control room applications (e.g., panel surfaces, labels, CRTs, indicator light bulbs or filters, console surfaces).		57
i. Blue should be used only for background features in a display, <u>not</u> for critical data.	L	34
j. Whenever possible, red and green should not be used in combination. Use of red symbols/characters on a green background especially should be avoided.	L	6
14. For emphasis and separation, contrasting colors should be used, such as:	L	37

- o Red and green
- o Blue and yellow

	Research Support	Source
o Red, green, and blue o Red, green, blue, and white		
15. To convey a similarity, similar colors should be used, such as: o Orange and yellow o Blue and violet	L	37
16. Bright colors should be used to emphasize data, and colors lacking brightness should be used to deemphasize data. (See Note 12.)	L	37
17. If a pattern of color is intended to display a function, the selected colors should indicate the state of the system.	L	4
18. Muted colors should be used for filling in symbols and unit markers on scales.	L	4
19. Colors with high contrast should be selected for parameters and features that must "catch" the operator's attention.	L	4
20. In general, backgrounds should not be brighter than foregrounds.		4
21. Extreme color contrasts should be avoided. (See Note 13.)	Y	4
22. Colors should be specified as a precise wavelength rather than a hue (red, green, violet, etc.). (See Table 6.)	L	4

	Research Support	Source
23. If difference in brightness (intensity) is used as a coding mechanism, perceived brightness should be used rather than absolute brightness. (See Note 14.)	L	4, 40
24. If graduations in hue are used as a coding mechanism, perceived hue should be used rather than absolute hue. (See Note 15.)	Y	4
25. To provide less chance of confusion, color meaning should be broadly defined.	L	37
26. Each color should represent only <u>one</u> category of displayed data. (See Note 16.)	L	6, 34, 40, 57
27. When color is used for special coding, the meaning of the code colors should be shown at the bottom of the data display area. (See Note 17.)	L	40
28. If color discrimination is required, do not use more than eight colors. Alphanumeric screens should display no more than four colors at one time. (See Note 18.)	L	34, 37
29. The use of color should not be distracting to the user. (See Note 19.)	L	37
30. Colored ambient lighting should not be used in conjunction with color-coded CRTs.	L	4
31. If ambient illumination cannot be controlled, hoods should be provided that block out light and glare.	L	4

	Research Support	Source
32. High-pressure sodium should not be used as an ambient-light medium for CRT viewing.	L	4
33. Color displays should be periodically adjusted to maintain proper registration of images. (See Note 20.)	L	40

NOTE 1: Reference 37 recommends that color be used as a formatting aid to:

- o Relate or tie fields into groupings
- o Differentiate groupings of fields from one another
- o Relate fields that are spatially separated
- o Emphasize or call attention to important fields
- o Assist reading of long lines of text or data.

Reference 37 recommends that color be used as a visual code to identify:

- o Kinds of data
- o Sources of data
- o Status of data
- o Order of operations.

Reference 4 recommends that color be used to indicate current status.

Reference 57 states, "Identify potential applications of color in mimic designs. Mimics can incorporate color to differentiate process flow paths. 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. However, where color is used to distinguish flow paths, ensure that colors selected for plant piping system codes are reconciled with colors used in the mimics to establish consistency of association."

Reference 34 states, "Color coding should be considered for applications where the user must distinguish rapidly among several categories of data, particularly when data items are dispersed on the display. [For example] different colors might be used effectively in a position display to distinguish friendly, unknown and hostile aircraft tracks, or alternatively to distinguish among aircraft in different altitude zones.

"Color is a good auxiliary code, where a multicolor display capability is available. A color code can be overlaid directly on alphanumerics and other symbols without significantly obscuring them. Color coding permits rapid scanning and perception of patterns and relationships among dispersed data items."

Reference 40 states, "Variations in color contract considerable attention. For this reason, color is extremely effective for highlighting related data which are spread around on a display, such as data of a particular status or category. Color may effectively aid in the location of headings, out-of-tolerance data, newly entered data, data requiring attention, etc. Search for data on a display is facilitated by color coding if the color of the data sought is known."

Reference 40 recommends color coding be used:

- o To reduce confusion and minimize control search time
- o To reinforce other identification habits, such as location
- o To supplement or provide necessary redundancy to other coding methods
- o To identify emergency controls
- o When the use of existing color stereotypes will foster immediate recognition of the meaning or function of a control.

Reference 4 notes that color is beneficial if:

- o The display is unformatted
- o Symbol density is high
- o Target position is unknown but the color of the target is known
- o Symbol legibility is degraded
- o Color is logically related to the operator's task.

Reference 4 states, "A monochromatic format can be used if the flash is twice as intense as the rest of the display. This will draw the operator's attention as effectively as if color had been added. Fewer colors can be used if they can be adjusted for intensity.

"If elements in a display overlap each other, color as an encoding variable improves search performance. Compared with achromatic encoding variables, the gain in performance by using color can be at least 26% better than shapes, 30% better than a combination of shapes and brightness, and 40% better than a combination of shapes and flashing rates."

NOTE 2: Reference 37 states, "Indiscriminate or poor use of color on one display may interfere with color's attention-getting power on another display.

"Do not overuse color. Use of too many colors may make a screen confusing or unpleasant to look at.

"As the number of colors in a display increases, the following will also increase:

- o The time required to respond to a specific color
- o The probability of confusion among colors
- o The demands on hardware for reliably reproducing each color."

Reference 34 states, "Color coding should be used conservatively, with relatively few colors to designate critical categories of displayed data. Arbitrary use of many colors may cause displays to appear "busy" or cluttered, and may reduce the likelihood that relevant color coding on other displays will be interpreted appropriately and quickly by the user."

Reference 40 states, "Color capability must be used conservatively in the design of display screens. Arbitrary use of multiple colors may cause the screen to appear busy or cluttered, and it may reduce the likelihood that the information in color codes on that screen or on other screens will be interpreted appropriately and quickly. In general, color should be added to the base color display only if it will help the user in performing a task."

NOTE 3: Patterns of color on the CRT face can either impede or enhance operator performance. Test each format for distracting visual noise before finalizing the color-code assignments.[4]

NOTE 4: Reference 34 states, "Do <u>not</u> use color coding in an attempt to compensate for poor display format; redesign the display instead.

"Displayed data should provide necessary information even when viewed at a monochromatic display terminal, or hardcopy printout, or when viewed by a user with defective color vision."

Reference 40 states, "In designing a screen, color is applied as an additional aid to the user, though generally the format should be such that it is effective when displayed in a single color."

NOTE 5: Reference 40 states, "Information must not be conveyed solely by color change if the information may be accessed from monochromatic as well as color terminals and when color may be lost in printed (hardcopy) versions. Where both kinds of terminals may be in use, color must be limited to assisting the user of the color terminal by highlighting, aiding in categorization, or clarifying the relatedness of data, without sacrificing important information to the user of the monochromatic display. Attention should also be addressed to the sometimes misleading appearance of color in photographs of display screens which may be intended for oral presentations. Printed output will not show color or flashing and probably will not indicate highlighting unless a color printer is used.

"Approximately 8% of the males in a user group may be expected to have weak or abnormal color perception. The proportion of female users having color perception abnormalities may be expected to be smaller. Variations in color may not be noticed by these persons, so information presented by color code alone will be missed. In some cases, certain colors are dimmer for color-weak persons and some may not even be perceptible to them. Red is most likely to be affected in this way in displays."

Reference 14 states, "Keep in mind when using color coding in displays that some colors are not discriminative by some users. Some users will have defective color vision."

NOTE 6: Reference 37 states, "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 meansings will be much more difficult to use."

Reference 57 states, "Determine appropriate associations for the selected colors." Table 4 indicates some associations and related characteristics for colors typically used in a variety of nuclear power plant applications.

Rerference 37 further states, "Where previous associations differ among personnel due to differences in experiences (e.g., personnel with Navy versus fossil fuel plant experience), select colors that are not in conflict with prior associations, and recommend that adequate opportunities be provided for practicing the selected color associations."

Reference 16 recommends the following color meanings:

Color	State	Result
Flashing Red	Emergency	Immediate user action
Red	Alert	Corrective/override action must be taken
Yellow	Advise	Caution; recheck is necessary
Green	Proceed	Condition satisfactory
White	Normal Transitory function	No "right" or "wrong" indication

NOTE 7: Reference 37 states, "Color meanings consistent with traditional color expectancies will also be easier to use (for example, red equals danger). They are well ingrained in human behavior and difficult to unlearn."

Reference 34 states, "Color coding should be consistent with conventional associations with particular colors.

"In a display of accounting data, negative numbers might be shown as red, corresponding to the customary use of red ink for that purpose.

"Red is associated with danger (in our society), and is an appropriate color for alarm 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 highlighting."

Reference 6 states, "The many hues (colors) and saturations should, where applicable, equate with the commonly understood meaning of those colors. The following specific meanings for selected colors should apply when these colors are used in CRT displays:

1. Red--Unsafe condition, danger, immediate operator action required, or critical parameter value out of tolerance.

2. Green--Safe condition, no operator action required, or parameter value is within tolerance.

3. Yellow/Amber--Hazard, potentially unsafe, caution, attention required, marginal parameter value exists."

NOTE 8: Reference 14 states, "To illustrate the extent of today's use of inconsistent color coding schemes, a study of color-coding of displays in nuclear power plant control rooms found that red denoted 'on' or 'flow' and green denoted 'off' or 'no flow' (Parsons, Eckert and Seminara, 1978). In addition, the investigators found that this use of red-green coding had been mingled with military and other color-coding schemes to the point where almost every designer used their own preferred scheme. To avoid this kind of confusion, designers should rely on standard color coding schemes."

Reference 57 states, "Do not use one color to delineate all instruments in a mimic for one system and another color for instruments in a separate system mimic. Such misuse of color serves as a distraction rather than to provide meaningful clarification of interrelationships."

Reference 40 states, "Color coding must be as consistent as possible from screen to screen. For example, if data related to technology contracts are displayed in white on one screen, they should be displayed in white on all screens on which such data appear. If technology contracts data are arbitrarily white on some screens and other colors on other screens, the user's task of display interpretation will be more difficult. Not only are the potential advantages of color coding lost, but the display will be more difficult to interpret than a similar monochromatic display."

Reference 4 cautions that reserving a specific color for grid lines will limit the graphics capability of the display.

NOTE 9: Reference 37 makes the following observations with regard to color hues:

- Red provides good visibility under high ambient lighting, but poor visibility at low symbol luminance

- Green provides good general visibility over a broad range of intermediate luminances

- Yellow provides good general visibility over a broad range of luminances

- Blue provides good visibility at low symbol luminance, but provides the poorest visual acuity.

NOTE 10: Use the white color for very important information so that if one of the color guns fails, the information will not be lost from the scree (white uses all three color guns in the CRT).[4]

NOTE 11: Reference 19 observes that the number of easily identifiable spectral colors depends on luminance, size (in visual angle), and color of the lights. The ten spectral colors in Table 6 can be identified with a 2% error after a relatively short training period when the lights have a luminance of 1 mL or more. The angular substance of the color source should not be less then 15 min of arc for highly accurate color recognition.

NOTE 12: Reference 37 orders the brightness of colors, from most to least, as:

- o white
- o yellow
- o green
- o blue
- o red

NOTE 13: Extreme color contrasts can form complementary afterimages due to rod receptor fatigue and should be avoided. For example, after staring at a yellow target for more than 10 s on a black background, when the eye is suddenly averted, a green afterimage will be perceived.[4]

NOTE 14: Reference 40 states, "The human eye is not equally sensitive to all colors, nor are its optics color-corrected. The eye is very much more sensitive to colors near the center of the visible color spectrum (orange, yellow, and green) than it is to colors at the extremes of the spectrum, such as red or blue. This variation in sensitivity causes colors at the center of the spectrum to appear much brighter than colors having equal energy at the extremes of the spectrum.

"Because the optics of the eye are not color-corrected, focusing is more exact for colors toward the center of the spectrum than for blues or reds."

Reference 4 states, "If blue is used on both a black and white background, the white background will cause the blue target to appear more saturated relative to the background."

NOTE 15: In general, apparent relative target hue depends on the hue and saturation of the background. Also, high ambient illumination can wash out colors.[4]

NOTE 16: Reference 34 states, "Color will prove the dominant coding dimension on a display. If several different types of data are displayed in red, say, they will have an unwanted visual coherence that may hinder proper assimilation of information by the user."

Reference 6 states, "Once colors are assigned a specific use or meaning, no other color should be used for the same purpose."

Reference 40 states, "A color should be used for only one meaning on a screen. For example, if white is used to indicate data related to technology contracts, white should not be used for highlighting on the same screen."

However, Reference 57 states, "The meaning associated with a color may change as the context changes--provided that the number of contexts is kept to a minimum and each is mutually exclusive and easily distinguishable from all others. For example, yellow or amber may be used to denote marginal conditions represented in displayed information as well as to code oil lines on mimics."

NOTE 17: Reference 40 states, "Definition of the code color must appear in the defined color. For example, if red data indicate 'overdue' and yellow data indicate 'pending', the bottom line of the data display area should contain 'red: overdue' in red, and 'yellow: pending' in yellow.

NOTE 18: Reference 34 states, "Perhaps as many as 11 different colors might be reliably distinguished, or even more for trained observers; but as a practical matter it will prove safer to use no more than five or six."

NOTE 19: Reference 37 states, "Color's high attention-getting quality may be distracting, causing a person to:

- o Notice differences in color, regardless of whether they have task-related meaning.

- Visually group items of the same color in a way that is unrelated to the task, or in conflict with another task-related group of items."

NOTE 20: Reference 40 states, "Color displays require periodic adjustment to maintain proper registration of images. When out of adjustment, characters formed by a combination of primary colors (pink, yellow, turquoise, and white), may appear as characters in each of the component primary colors. Pink characters, for example, may appear as red characters with blue shadows or echoes on a display which is out of adjustment. Novice users should be made aware of this and the adjustment procedure early in their training. Problems of registration are more common near the corners and edges of displays. Hence, use of mixed colors should be minimized in these areas. The problems of registration do not apply to characters displayed in a single primary color."

Comment. For purposes of evaluating process CRT displays, the guidelines presented in References 4, 6, and 57 are perhaps the most relevant. Some controversy between the meanings of particular color codes was discussed by Reference 57. The authors suggest that adherence to Reference 16 and general population stereotypes should take precedence over alternative conventions.

However, as with most coding methods, some mode of standardization and consistency should be observed throughout the control room. If a previous standard is already in place and consistent, then recommendations for altering existing color meanings could be devastating. If the color meanings are already standardized, the screen should be examined for number of codes implemented and whether or not they can be easily discriminated by the operators.

Method for Assessment. The reviewer should observe the screens which utilize a color coding methodology under normal operating conditions and the full range of ambient lighting conditions. First, ensure that the proposed colors are standard and consistent throughout the control room. Second, examine the number of colors used and validate their uses with the

color strategies identified in the guidelines. Also ensure that the number of colors selected does not exceed eight. Although this is not a hard-and-fast number, it should certainly NOT be significantly higher than this value. Third, verify that the colors are readily discriminative from each other. Fourth, obtain a key outlining the meanings of the color set and ensure that a representative group of operators can identify the meanings of all color codes used on the display. Fifth, follow through the remaining guidelines described above to ensure that compliance with the color coding schemes has been established.

TABLE 4. ASSOCIATIONS AND RELATED CHARACTERISTICS FOR COLORS TYPICALLY USED IN PANEL DESIGN AND RELATED APPLICATIONS IN NUCLEAR POWER PLANTS (Source: Reference 57)

Color	Associated Meanings	Attention-Getting Value	Contrasts Well with
Red	unsafe danger alarm state open/flowing closed/stopped	good	white
Yellow	hazard caution abnormal state oil	good	black dark blue
Green	safe satisfactory normal state open/flowing closed/stopped	poor	white
Light blue (cyan)	advisory aereated water cool	poor	black
Dark blue	advisory untreated water	poor	white
Magenta	alarm state	good	white
White	advisory steam	poor	green black red dark blue magenta
Black	background	poor	white light blue yellow

a. Meanings associated with red and green colors differ, depending on past experience. Personnel with previous fossil fuel plant experience typically associate an open/flowing state with red and a closed/stop state with green, but reverse associations typically exist for personnel with previous Navy experience.

TABLE 5. GENERAL GUIDELINES FOR COLOR SELECTION (Source: Reference 6)

Red--Good attention-getting color. Associated with danger.

Yellow (amber)--Good attention-getting color. Associated with caution.

Green--A nonattention-getting color. Associated with satisfactory conditions.

Black--Normally used as the background color, i.e., the color of blank character spaces. Also used as the action character when reverse field coding is employed.

White--A nonattention-getting color. It should be used for standard alphanumeric text or tables where the information is contained in the characters and not the color. Might also be used for labels, coordinate axes, dividing lines, demarcation brackets, etc.

Cyan (light blue) - (Same as white)--Might be used in conjunction with white to provide some amount of noncritical discrimination (e.g., use cyan for tabular column headings and demarcation lines; use white for alphanumeric data).

Blue (dark)--Poor contrast with dark background. Not recommended for attention-getting purposes or for information-bearing data. Use for labels and other advisory type messages.

Magenta--A harsh color to the eye. Should be used sparingly, and for attention-getting purposes.

Orange--Good attention-getting color. Care must be taken that hue is selected to be readily differentiable from red, yellow, and white.

TABLE 6. SPECTRAL COLORS IDENTIFIED ACCURATELY WITH LITTLE TRAINING (Source: Reference 19)

Wavelength	Label
642 nm	Red
610 nm	Orange
596 nm	Orange-yellow
582 nm	Yellow
556 nm	Yellow-green
515 nm	Green
504 nm	Green-blue
494 nm	Blue-green
476 nm	Blue
430 nm	Violet

Geometric/Shape

Definition. Dreyfus[68] considered graphic symbols to be one of three types: (a) representational--accurate simplified pictures of objects, e.g., skull and crossbones; (b) abstract--graphic symbols retaining only a faint resemblance to the original concept, e.g., sign of zodiac; and (3) arbitrary--symbols that have been invented and need to be learned, e.g., inverted triangle indicating "yield". In actual practice, many of these graphical codes may not be solely confined into any one category. For example, a roadway sign in the shape of a pentagon (arbitrary portion), may have a silhouette of two children walking (representational portion) to indicate a school crossing.

This section will be devoted primarily to the arbitrary category of graphical symbols. This includes the geometric forms and shapes which do not have a direct reference to the real world and also require some level of formal training before they can be learned and implemented. Pictorial graphical coding (often referred to as iconic coding) will be addressed in another section.

Guidelines.	Research Support	Source
1. "Alphabets" of geometric shapes should be limited to a maximum of 15 different symbols. (See Note 1.)	Y	17, 19, 34, 56, 69
2. When geometric shape (symbol) coding is used, the basic symbols should vary widely in shape. (See Note 2.)	Y	6, 70, 74
3. Symbols should subtend a minimum of 20 minutes of arc. If the viewing distance is longer than the normal 28 inches, it should form a visual angle of about 22 minutes of arc. (See Note 3.)	Y	72

	Research Support	Source
4. The stroke width-to-height ratio should be 1:8 or 1:10 for symbols of 0.4 inches or larger viewed up to a distance of 7 feet.	Y	72
5. Simple geometric symbols should be used if high accuracy and low search time are required and the center viewing (10 degrees) can be used.	Y	45
6. If the right and left viewing angle must be used (but angles are not greater than 45 degrees from center), simple geometric and/or pictorial-perimeter-type forms should be used (the latter being preferred).	Y	45
7. When efficiency of decoding is important, redundant cues (such as size difference) should be used. (See Note 4.)	Y	74
8. When rate of comprehension and detection is important, graphical coding should be used rather than word messages. (See Note 5.)	Y	75
9. Geometric shapes should be considered for discriminating different categories of data on graphic displays.	L	34
10. The assignment of shape codes should be consistent for all displays and should be based upon an established standard. (See Note 6.)	Y	34

	Research Support	Source
11. Internal and external modifiers should not be used. (See Note 7.)	Y	74

NOTE 1: A group of 15 shapes can be differentiated nearly 100% of the time if (a) their maximum dimension subtends a visual angle of 12 min of arc and (b) their outline of shape is sharp and contrast high.[69]

If [an] "alphabet" [of 15 symbols] is too small, it may be possible to use component shapes in combination, as in some military symbol codes.[34]

The number of identifiable shapes in letter and number form is unlimited. For shapes in geometric form, however, learning and retention are limited to around 15 unless special training and continued practice are undertaken.[19]

For geometric shapes, the maximum number of code steps is 15 with five recommended. The maximum number assumes a high training and use level of the code. Also a 5% error in decoding must be expected. The recommended numbers assume operational conditions and a need for high accuracy.[56]

Sleight[69] found 15 geometric shapes that are highly discriminative if their apparent size is at least 12 min of visual angle and there is high contrast with the background. These included common shapes such as the triangle, circle, star, square, and pentagon. These shapes may be used in coding, but their meaning must be taught. Other shapes among the 15 such as the swastika, heart, half-moon, or aircraft silhouette have certain conventional meanings that could detract from their usage in other applications.[17]

NOTE 2: Reference 70 states that search time and errors increase when highly similar shapes are used. Reference 74 states that variations of a single form such as an ellipse are not desirable.

References 45 and 71 find that the "triangle" is the most discriminative geometric shape when compared with other forms (e.g., star, rectangle, circle, square, parallelogram).

Reference 73 reports the following findings:

- o Combinations of symbols using outlined diamonds are poor in discrimination and are often confused with other symbols.

- o Outlined squares and circles are safisfactory in discrimination with other combinations.

- o Outlined triangles are more discriminative than outlined diamonds but poorer than outlined squares and circles.

- o Square and circle combinations have best search time ranking when compared with triangle or diamond combinations.

NOTE 3: The size of any symbol can be measured 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.[30]

The angle which any object subtends can be calculated by the equation

$$B = \frac{S \times 360 \times 60}{2\pi D} \qquad (1)$$

where

S = size of the image on the screen

π = 3.14

D = distance to the screen (same units as S)

B = arc which the object subtends (minutes)

For the designer, it is probably more useful to rearrange this equation into the form

$$S = \frac{2\pi DB}{360 \times 60} \qquad (2)$$

For alphanumeric characters (letters and numbers) it is suggested that all symbols subtend an angle of 20 min for black and white displays or 30 min for color displays. Minimum acceptable angles would be 16 and 21 min for black-and-white and color, respectively. For nonalphanumeric symbols the angle should be at least 40 min because they are less easily recognized.[30]

Symbol size is considered to be an important parameter. If a high resolution display is used, the capability of using small symbols may tempt the designer to get more information on the screen. This is not advised. The design team should determine the minimum acceptable character size using Equation (2) and the proposed viewing distance.[30]

NOTE 4: Size differences on the CRT must be exaggerated because of size irregularities resulting from tube curvature.[74]

Reference 76 states that, under normal viewing conditions, such as white light and daylight, people use area and jaggedness most frequently to describe shapes.

Reference 77 states that, under poor viewing conditions such as subdued light, glare, or fading, area and the largest dimensions are used to distinguish different shapes.

NOTE 5: In general, symbolic/pictographic signs are more quickly detected and comprehended than word messages.

NOTE 6: 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 by the display designer.

NOTE 7: Internal and external modifiers lose distinctive characteristics as contour definition and contrast are reduced by activation of the phosphor layers.[74]

Comment. Research evidence indicates a superiority of pictographics over geometric or shape coding.[75] Van Cott and Kinkade[19] stated, "Pictorial shapes depicting the real-world objects they represent, such as aircraft, ship, and missile silhouettes, can be easily learned, remembered, and used." This observation is supported by Smith and Thomas,[7] who found that pictorial shapes of military objects are superior to highly discriminative geometric forms. However, pictorial shapes must not be similar in form. Otherwise search time and errors increase.

As indicated by the above guidelines, the 15 discriminative shapes identified by Sleight[68] (shown in Figure 8) are most often recommended if a geometric coding methodology is implemented. With minor modification, such as removal of those shapes with conventional meanings (swastika, airplane, heart, etc.), a limited coding set could be derived for process control application. The earlier evidence also supports the use of the triangle as being the most discriminative. Therefore, it should be included as a prime candidate symbol for the limited set. If these shapes (identified by Sleight) are to be used for indicators of warning, the following data from traffic safety signs might be applicable. In that study, Riley et al.[78] evaluated various sign shapes to determine those that were preferred indicators of warning. Stimuli consisted of nine standard shapes and an additional 10 shapes based upon their similarity to the standards.

Subjects were asked to select the shape that was the most preferred indicator of warning. The analysis resulted in a ranking of the most preferred shapes (illustrated in Figure 9). Based on that study, Riley established the following conclusions:

1. Shapes that appear unstable tend to be more preferred as warnings.

2. Since shapes of signs and labels do have a relationship to warning indication, the shape hierarchy determined from this study should be considered in guiding the design of warning indicators.

In addition, care should be taken to ensure that the selected shapes are of sufficient size to be easily identified from a predetermined viewing distance. Symbol size can be quantitatively determined using the equation described in Note 3 above.[30]

Method for Assessment. View the screen and determine the number and type of shapes which comprise the coding alphabet. Access to a hard copy of these shapes would be beneficial. First, qualitatively examine the set to verify whether or not they can all be discriminated from each other (i.e., are the shapes unique and displayed with sufficient resolution to avoid confusion). Second, check the size of each symbol for conformance to criteria at the specified viewing distance. Third, test a few members of the user population to ensure that they can immediately identify the intended meanings of each code. If there is confusion or discrepancy between the shapes tested, then recommendations should be provided to:

(a) either reject the coding scheme for a pictographic coding strategy, or

(b) recommend a modified version of shapes, based on the set developed by Sleight.

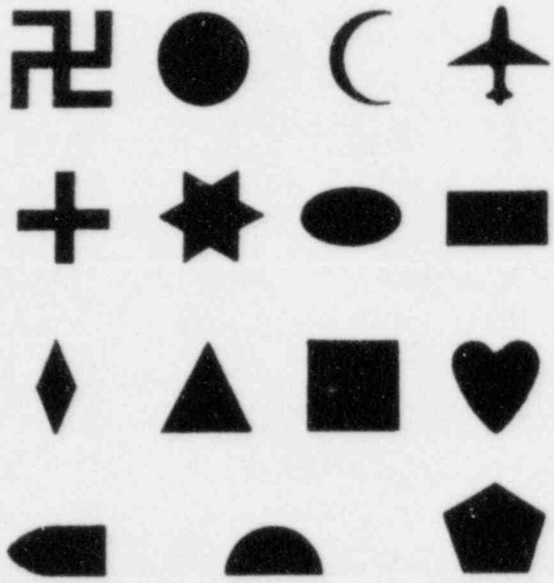


Figure 8. Fifteen highly discriminable shapes identified by Sleight (1952) (Source: Reference 19).

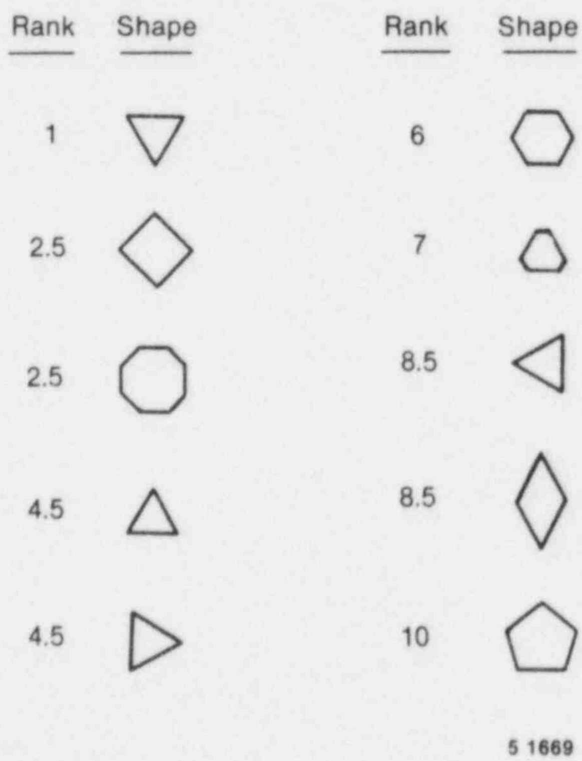


Figure 9. Rankings of preferred shapes (Source: Reference 78).

Pictorial

Definition. This coding strategy contrasts sharply with simple geometric or shape coding. Pictorial codes are essentially "pictorial" representations of the objects and events they reproduce by various laws of projection. According to Dryfus,[68] geometric or shape coding would be categorized as arbitrary symbols. Pictorial coding comprises the category of representational symbols and, in some cases, abstract symbols as defined by Dreyfus. A more detailed definition of pictorial coding has been defined by Schiff,[79] "A drawn, painted, etched, or projected structure, usually representing a scene or object. It varies from photographic realistic pictures to representational paintings or drawings to nonrepresentational sketches, line drawings, or abstract designs." In the literature, pictorial coding is often referred to as iconic coding. In general, less training is needed for identification of referents through pictorial coding. If it is well designed in accordance with expectations of the user population, the users already know the relationships. This section will be devoted to the use of pictures as a coding method with particular application to their usefulness to CRT displays and mimics used in process control.

Guidelines.	Research Support	Source
1. Pictographs should have obvious meanings. (See Note 1.)	Y	17, 57, 80
2. Symbols should be consistently applied. (See Note 2.)	L	57
3. For search and identification tasks or whenever there is any doubt as to whether some observers will be able to understand the pictorial, both pictorial and word labels should be used. (See Note 3.)	Y	20, 55, 57

	Research Support	Source
4. Words and symbols should not be used alternately. (See Note 4.)	Y	20, 57
5. 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.	L	57
6. Numeric data should be readily associated with the respective symbol and should not be confused with alphanumeric designators.	L	57
7. Symbols used to represent equipment components vary widely in shape and should be similar to those used in piping and instrumentation drawings.	L	57
8. About six different symbols, with 20 being an upper limit, should be used. (See Note 5.)	Y	56, 57
9. To provide the illusion of continuity, graphic lines should contain a minimum of 50 resolution elements per inch.	L	57
10. When iconic symbols are used, solid forms without unnecessary detail are preferred. (See Note 6.)	Y	18, 80
11. The amount of feature similarity among different members of a symbol set should be minimized.[80]	Y	80

	Research Support	Source
12. The visual saliency of those features that must remain redundant across members of a symbol set should be minimized.	Y	80
13. The discriminability of those graphic features used to code important tactical information should be maximized.	Y	80

Example: Horizontal and vertical lines should be more salient than those with oblique orientation.

---

14. When letters are used, perhaps to annotate geometric display symbols, lower-case letters should be used to improve discriminability.	Y	80
15. Given that a sufficient number of dimensions are available to portray required information parameters, multidimensional display codes should be used.	Y	80
16. The use of salient horizontal and vertical lines in the display background should be minimized.	Y	80
17. To minimize distortion (especially under degraded viewing conditions), well-learned or unitized symbol designs should be used.	Y	80
18. Figure-to-ground articulation should be clear and stable.	Y	18

	Research Support	Source
19. A closed figure enhances the perceptual process and should be used unless there is reason for the outline to be discontinuous.	Y	18
20. The symbols should be as simple as possible, consistent with the inclusion of features that are necessary. (See Note 7.)	Y	18, 20
21. Symbols should be as unified as possible.	Y	18

Example: When solid and outline figures occur together, the solid figure should be within the outline figure.

	Research Support	Source
22. The pictorial pattern should be identifiable from the maximum viewing distance and/or under minimal ambient lighting conditions. (See Note 8.)	Y	20
23. Pictorial symbols should always be oriented "upright". (See Note 9.)	Y	20

NOTE 1: Reference 17 states that pictorial silhouettes or pictographs are intended to have obvious meanings and hence would not need to be learned. Whether or not the intended meaning is, in fact, apparent to nearly all viewers should be tested. Examples of military pictographs are aircraft, ships, missiles, and antiaircraft guns. Pictographs such as these are located more quickly and with fewer errors than geometric shapes because they are very distinctive. However, pictographs take longer to locate and with more errors than geometric shapes if they are very similar, such as a variety of aircraft models.[70]

Reference 80 recommends that the designer take advantage of the user group's prior learning and conditioning to select symbol design features (e.g., iconicity, color) which enhance association formation. For example, if the color "red" is culturally identified with the concept of danger, it might be utilized in the portrayal of enemy threat.

NOTE 2: Establish a set of symbols for consistent application in all labeling. Symbols may be used to conserve space or facilitate associations. Conserving space by such means may permit use of larger characters, thereby increasing the distance from which labels can be reliably read--a consideration that is especially important for annunciator tile legends. Whatever symbols are used, it should be demonstrated that the meaning of a symbol is obvious or easily learned as is compatible with previously acquired associations of personnel.[57]

NOTE 3: There is more freedom for use of symbols to designate information in designing CRT displays than in labeling instruments. For example, symbols may depict equipment (e.g., pumps, valves), thereby reducing reliance on words for identification. However, the use of symbols in CRT displays should be coordinated with the use of words in labeling related panel instruments.[57]

Text and shape coding should be used for search and identification tasks. The successful completion of these tasks results in focusing the operator's attention on a specific portion of the CRT--they do not involve processing the information located there. A pump symbol, with perhaps amplifying text, would allow the operator to easily find the correct pump on the display.[55]

NOTE 4: Alternate use of symbols and words could cause confusion and retard task performance.[57]

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.[20]

NOTE 5: For pictorial shapes, Reference 56 recommends that the maximum number of code steps be 30 with 10 recommended. The maximum number assumes a high training and use level of the code. Also, a 5% error in decoding must be expected. The recommended number assumes operational conditions and a need for high accuracy.

NOTE 6: Reference 30 recommends, as a method of indicating equipment status, using a hollow (outline) element to indicate the element is off, closed, or showing no flow and using a solid element to indicate that it is on, open, or showing flow.

Reference 20 recommends that some type of border should always be used around a pictorial; otherwise, it may blend with background images.

NOTE 7: In creating a pictorial to represent some actual visual element, provide just enough detail to make the symbol recognizable, and no more. Fine detail often cannot be seen under certain distance and lighting conditions and may serve only to distort the impression the symbol creates. On the other hand, be extremely careful not to overstylize pictorial symbols just to create an artistic rendition. Such stylization often makes all symbols begin to look alike.[20]

NOTE 8: 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 and/or atmospheric conditions are not good.[20]

NOTE 9: Do not place pictorials on components that may be reoriented, i.e., turned or moved so that the pictorial may not appear right side up. Although the observer might figure out what the pictorial is after considerable study, a prime purpose of the single pictorial is to elicit a quick response with a single symbol, as opposed to several words in a label.[20]

Comment. The majority of the research data on pictorial coding schemes was conducted specifically for military or roadway environment applications. Very little information is available for specific process control systems. The most pervasive guidelines in this area have been adapted primarily from the engineering and drafting disciplines. The basic source for these guidelines is documented in ANSI Y32.11 (Graphic Symbols for Process Flow Diagrams).[81] These ANSI voluntary standards are often seen in Piping and Instrumentation Diagrams (P&IDs). The meanings of some of these forms are shown in Figure 10. The Instrument Society of America (ISA)[82] is currently preparing a standard for graphic displays which will be used for process control displays in a variety of industrial applications. These standards are loosely based on ANSI Y32.11. A word of caution is advisable before acceptance of these P&ID conventions to process control environments. Experimental data are limited and problems may arise when generalizing these standards without modification to plant operators. True, the ANSI standards are useful building blocks, but further research and development are needed before specific recommendations can be addressed.

The above guidelines can best be summarized by adherence to the following general recommendations:

1. The apparent meanings of all candidate pictorial codes should be tested for a sample of the user population.

2. The coding symbols selected should be consistent for all applications. For example, the use of symbols in CRT displays should be coordinated with those used on all panels throughout the control room.

3. Alternate use of symbols and word labels should be avoided.

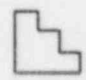
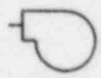
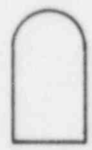
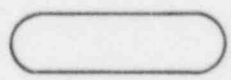
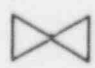
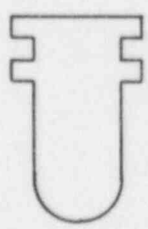
4. The implementations of P&ID (ANSI) graphic symbols should not be accepted at face value. The population should be tested regardless of the standards adapted.

5. Use letters when necessary to annotate pictorial codes which are not readily obvious.

6. All graphical codes should be closed, unitized, simple, produce a high contrast with the background, and of sufficient size to be interpreted at a predetermined viewing distance (apply the technique for calculating symbol size in the section for shape coding if this dimension is questionable).

7. When it becomes available, a copy of the ISA standard "Graphic Symbols for Process Displays"[82] should be a useful supplement for further recommendations and guidelines.

Method for Assessment. View the screen and determine the number and type of pictographs which comprise the coding alphabet. (Access to a hard copy of those pictographs would be beneficial.) First, examine the pictographs for conformance to the general guidelines discussed in the above "Comment" section. Review the above detailed guidelines if further specific information is desired. Second, test a few members of the user population to ensure that they can immediately identify the intended meanings of these codes. If there is specific confusion or discrepancy between the pictographs tested, recommendations should be provided to implement a new pictographic coding alphabet based on the above guidelines.

Meaning	Graphic Form
Positive-displacement pump	
Centrifugal pump	
Steam generator	
Tank	
Valve	
Reactor vessel	

5 1670

Figure 10. Pictographic codes which conform to conventional piping and instrumentation diagrams (P&IDs).

Magnitude

There are occasions when it might be feasible to select a common geometric shape (circle, square, triangle, etc.) and create an alphabet by varying some of its characteristics (e.g., changing the height to width ratio of a rectangle). Techniques such as these generally fall into the domain of magnitude coding. Magnitude coding can also include dimensions such as brightness and flash rate. This section is limited to coding techniques applicable to area and length. Alternative magnitude coding dimensions are discussed under the subcategory "Enhancement Coding." Experimentally derived symbol alphabets, general guidelines, and techniques for developing these alphabets will be discussed in this section.

Guidelines.	Research Support	Source
1. When symbol size is used for coding, the intermediate symbols should be spaced logarithmically between the two extremes (largest and smallest). (See Note 1.)	Y	19
2. 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. (See Note 2.)	Y	85
3. For AREA coding, the maximum number of code steps should be six with three recommended. (See Note 3.)	Y	34, 56, 84
4. For LENGTH coding, the maximum number of code steps should be six with three recommended. (See Note 4.)	Y	19, 34, 56

	Research Support	Source
5. Line length coding should be used for applications involving spatial categorization in a single dimension.	Y	34

Example: The length of a displayed vector might be used to indicate distance or speed.

---

6. Size coding should be used only when displays are not crowded.	Y	34, 56
7. When size coding is used, a larger symbol should be at least 1.5 times the height of the next smaller symbol.	Y	34
8. In tactical graphic symbology, a desirable design feature is to include a "size is strength" concept so that if a unit is powerful, it is visually shown as bigger and/or brighter.	L	80

NOTE 1: Two groups of ellipses have been identified which can be absolutely recognized with ratios varying from 0.0 (a line) to 1.00 (a circle). The groups are shown in Figure 11. The symbols and axis ratios are presented for an eight and five symbol alphabet. The orientation of the ellipses is not an important factor influencing recognition and the major axis should have a visual angle greater than 30 min.[83]

Three-, four-, and five-symbol alphabets of circles have also been developed. The 3-, 4-, and 5-symbol alphabets result in less than 1-, 2-, and 5-percent errors, respectively. The intermediate symbols were scaled logarithmically. These alphabets are shown in Figure 12. The accuracy of these alphabets is valid, provided:

- o The ratio of smallest to largest area is at least six
- o The smallest area subtends a visual angle of at least 5 min of arc
- o For normal viewing distances (30 in.), these particular symbols range in diameter from 0.05 to 0.30 in.[83]

Data on accuracy in reading symbols that are coded with various numbers of area steps are presented in Figure 13. This figure illustrates how accurate a size code can be when the code has different numbers or symbols. The symbols used in this experiment were isosceles triangles in which the base was 3/5 of the altitude. The size of the smallest triangle was 10 min by 16 min, and the size of the largest triangle was 28 min by 80 min. The intermediate size triangles were spaced logarithmically between these two extremes. It is evident that if more than five sizes are used, errors in identifying any particular size become excessive.[84]

The data in Figure 13 are generally applicable to codes using line length. The line lengths should be equally spaced on a logarithmic scale to provide near maximum decoding accuracy.[19]

NOTE 2: The sizes of graduated circles are generally scaled with the areas of the circles made proportional to the data values to be represented. If diameters are used for scaling the information, serious graphic problems arise.[85]

Research evidence indicates if the areas of the circles are made proportional to the data values, differences in the sizes will be underestimated. These findings are not restricted to circles. It also applies to squares, triangles, and a multitude of other two-dimensional

symbols. In summary, graphic symbols are NOT effective when scaled in a strict mathematical relationship to a set of data. However, the use of training and user access to an accurate detailed legend on the display may minimize the error involved in reading these types of symbols.[85]

NOTE 3: The maximum numbers assume a high training and use level of the code. Also, 5% error in decoding must be expected. The recommended number assumes operational conditions and a need for high accuracy.[56]

References 34 and 84 recommend five as the maximum number of symbols.

NOTE 4: The maximum number assumes a high training and use level of the code. Also, 5% error in decoding must be expected. The recommended number assumes operational conditions and a need for high accuracy.[56]

Reference 34 recommends a maximum of four steps for reliable decoding. Reference 19 recommends a maximum of five steps.

Comment. Van Cott and Kinkade[19] stated, "This type of coding actually combines variations of shape, area, or size and would be particularly suitable for CRT display where dynamic variation in shape and area can be used as combined codes." The utility of an area/length coding method by systematically varying some parameter of a basic geometric form has merit if it adheres to the following restrictions:

1. Values for a selected alphabet must be equally spaced on a logarithmic scale. Direct quantitative correlations of symbol size with a parameter value are not effective.

2. The symbol alphabet must be small (usually less than five) to ensure accuracy.

3. Large symbol space is required.

In addition, care should be taken to ensure that the CRT screen and upper and lower boundaries are sufficient for maximum discrimination at the prescribed viewing distances and resolution.

The factor for size coding of 1.5 times the height of the next smaller symbol was originally referenced in MIL-STD 1472C[16] and cited by Smith and Aucella[34] in the above guidelines. In the author's opinion, this may be a reasonable hard and fast rule of thumb. However, a more precise logarithmic scaling approach (as prescribed by VanCott and Kinkade[19]) on a case by case basis is recommended.

Method for Assessment. View the screen and determine the number and type of area/length codes which comprise the coding alphabet. Access to a hard copy of these codes would be beneficial. First, examine the code alphabet to ensure it can be readily discriminated on an absolute basis and is not in conflict with other geometric or shape coding methods which may be employed. Second, verify that the coding alphabet parameters (area, length) are equally spaced on a logrithmic scale. This can be verified by using the following method.

To space or scale the steps to get the same amount of accuracy all along the scale, apply the following general rule:

1. Identify the upper and lower limits of the scale.

2. Identify the number of steps.

3. To obtain the required order of magnitude between each step, apply the following formula:

$$R^{(S-1)} = \frac{A_{max}}{A_{min}}$$

where

R = required order of magnitude

S = number of steps

A_{max} = upper limit of the scale

A_{min} = lower limit of the scale

For example, suppose an area coding alphabet of five circles is desired. Given:

$A_{max} = 1.0\ iu^2$

$A_{min} = 0.01\ iu^2$

$S = 5$

Then using the equation

$$R^{(S-1)} = \frac{A_{max}}{A_{min}}$$

$$R^{(S-1)} = \frac{1.0\ iu^2}{0.01\ iu^2}$$

$$R^4 = 100$$

$$R = 100^{1/4} = 100^{0.25}$$

$$R^2 = 3.2$$

The required areas for a symbol alphabet of S circles would be 0.01, 0.032, 0.10, 0.32, and 1.0 iu^2, with each area being 3.2 times the next smaller one.[19]

Third, examine the alphabet for conformance to the remaining general guidelines discussed in the above "Comment" section. Review the above detailed guidelines if further specific information is desired. Fourth, test a few members of the user population to ensure that they can immediately identify the intended meanings of these codes. If there is specific confusion or discrepancy between the magnitude coding scheme tested, recommendations should be provided to implement an alternative technique or to modify the existing scheme so that user accuracy will be maximized.

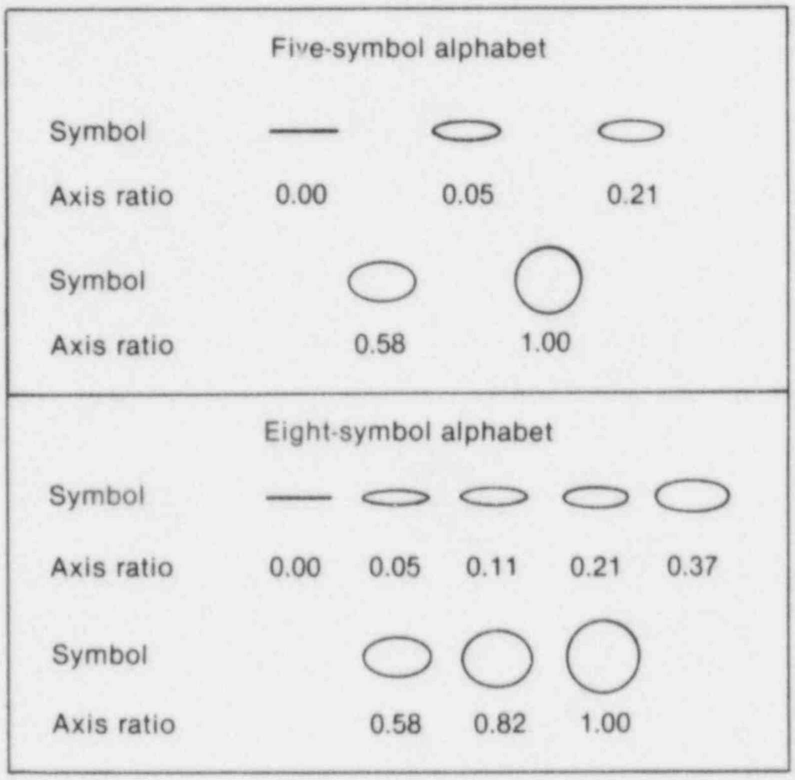


Figure 11. Symbol alphabets designed for maximum discriminability. (Source: Reference 83, as presented in Reference 19).

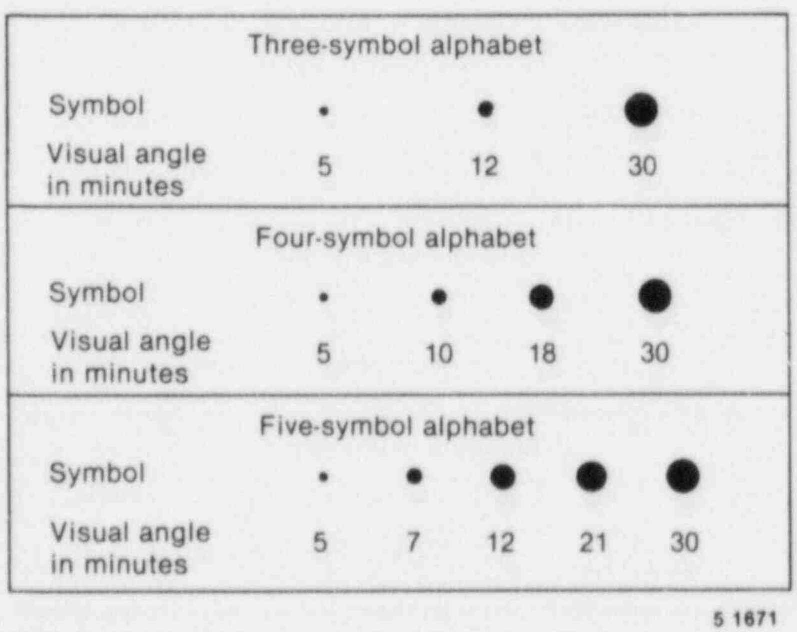


Figure 12. Three maximally discriminable area codes for alphabet sizes of 3, 4, and 5. (Source: Reference 83, as presented in Reference 19.)

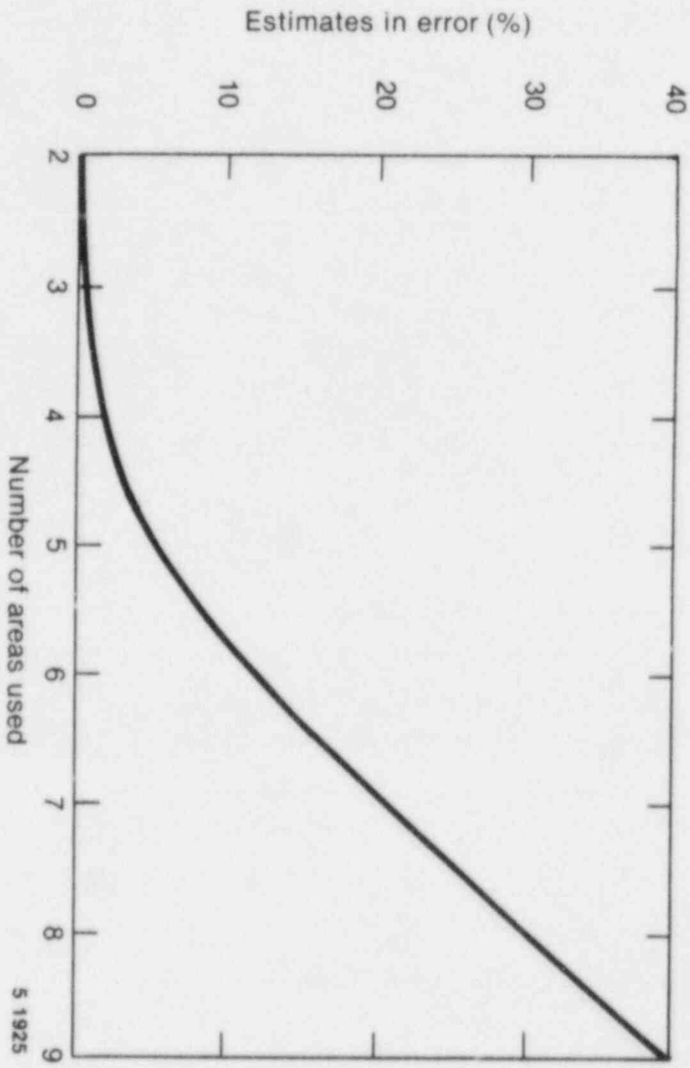


Figure 13. Accuracy of absolute identification of area magnitude as a function of the number of areas used. For each alphabet size, equal ratio scaling of areas was used (Source: Reference 84, as presented in Reference 19.)

Visual Number

Definition. Various parameters can be coded by number of dots. For example, one dot might be used to indicate a quantity of one to five, two dots six to ten, etc.

Guidelines.	Research Support	Source
1. For visual number coding, the maximum number of code steps is six with four recommended. (See Note 1.)	Y	17, 19, 56
2. A large symbol space should be provided in the display.	Y	56

NOTE 1: Errors are negligible for identification of signals coded by five dots or less. Errors rise rapidly when this value exceeds six.[86] Figure 14 shows how accurately people can estimate the number of dots when the dots are exposed for only 0.1 s. These accuracies are for immediate identification of the number of dots. If more time were allowed for observation, the accuracy would be greater, but the time required for identification is usually critical. If immediate identification is required, as many as five or six coding steps could be used to code signals. The data are for dots in random positions. Arrangements in familiar patterns (such as on playing cards or dominoes) improves accuracy even more. This patterning of dots is actually a form of shape coding.[17,19]

Reference 56 notes that the maximum number assumes a high training and use level of the code. Also, a 5% error in decoding must be expected. The recommended number assumes operational conditions and a need for high accuracy.

Comment. If the visual number of dots is used as a coding dimension, it is advised that:

- o The alphabet be small (usually less than four)
- o Large symbol space is available
- o The dots be arranged in familiar patterns.

The author is in agreement with Sinaiko and Barmack[56] that this type of coding dimension has limited application and may not be suitable for process control applications.

Method for Assessment. First, view the screen and determine the size of the visual number coding alphabet. Access to a hard copy of these codes would be beneficial. Ensure that the alphabet is less than or equal to four. Next, test a few members of the user population to ensure that they can immediately identify the intended meanings of these codes. If there is specific confusion or discrepancy in the coding scheme tested, recommendations should be provided to implement an alternative technique (e.g., geometric shapes, pictographs, text labels, etc.).

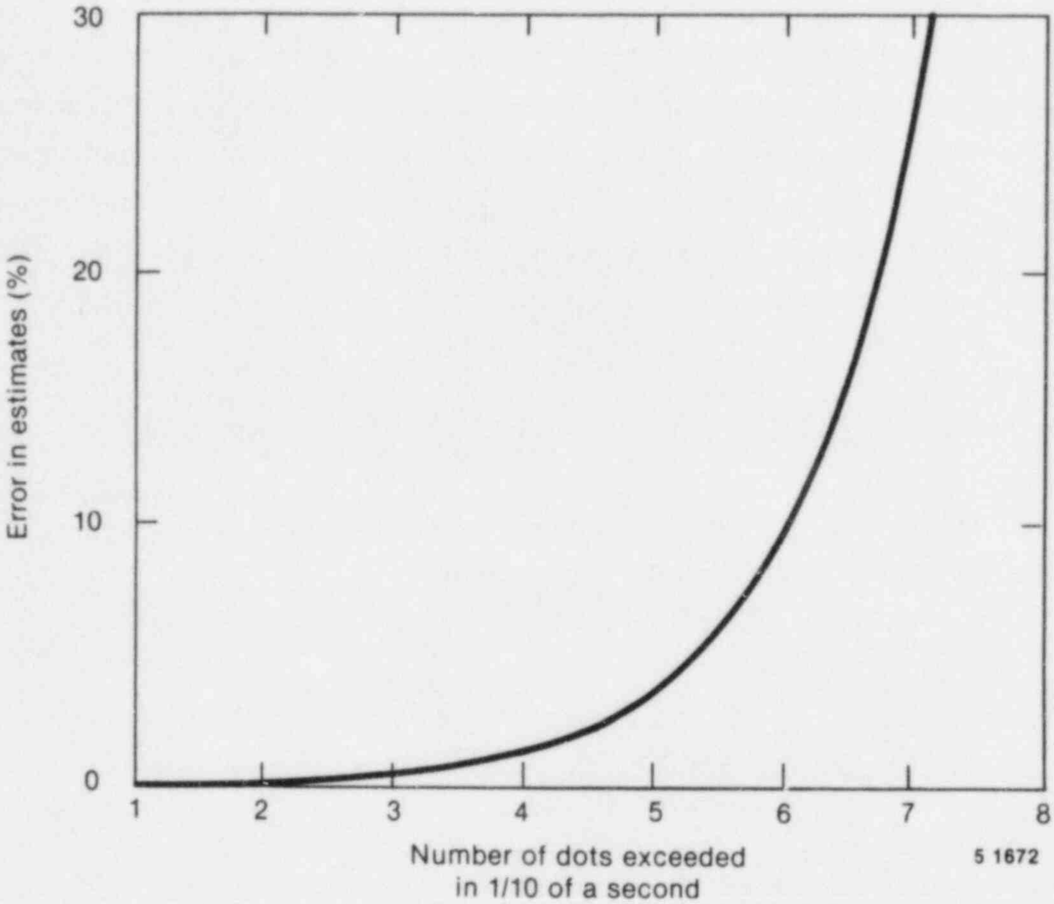


Figure 14. Accuracy of estimating the number of random dots seen as a function of the number of dots exposed. The viewer has only a fraction of a second to see the dots. (Source: Reference 86, as presented in Reference 19.)

Inclination

Definition. The orientation or angle of a line can often be used as a coding dimension. Inclination coding, as it is used in military applications, can often be coupled with length coding. For example, on CRT screens the length of a line might be used to code the speed of a target, while inclination of a line might indicate course (direction of movement). In process control systems, inclination coding techniques are most commonly observed in moving-pointer, fixed-scale dials. Additional guidelines with specific reference to the design of pointer/dial displays are discussed in a separate section.

Guidelines.	Research Support	Source
1. For inclination coding, the maximum number of code steps is 24 with 12 recommended. (See Note 1.)	Y	17, 19, 56, 87
2. The minimum length of lines used for inclination coding should be 0.1 inch. (See Note 2.)	Y	17, 19
3. Inclination coding combined with size coding should be considered for applications involving spatial categorization in two dimensions.	Y	34

Example: The angle of a displayed vector might be used to indicate direction, i.e., heading or bearing.

---

4. When check reading is required, a group of dials should be aligned so that all pointers are in the same (angular) position for the normal conditions.	Y	21

NOTE 1: The length of line as a coding technique has been researched in conjunction with another coding method, angle-of-line inclination. We have developed skills in judging inclination angles by reading watches and other circular dials. Alluisi[87] found that 24 angles of inclination could be identified by trained subjects with less than 5% error. (See Figure 15.) However, only 12 angles, as illustrated by the hours on a clock, are recommended for coding.[17]

Reference 56 notes that the recommended number of steps assumes operational conditions and a need for high accuracy, and recommends that inclination be used only as a quantitative code.

Reference 88 states that users can make fairly accurate estimates of angles for lines displayed at 10-degree intervals.

Reference 19 states that using a large inclination alphabet does little to increase the coded information because observers make more errors. However, if two lines of different lengths are used, such as the hour and minute hands on a standard clock, larger alphabet codes can be read accurately.

NOTE 2: Lines could be as short as 0.1 in., but better performance is achieved with longer lines. No more than three different lengths are recommended for coding. Symbolic information, such as target speed on a CRT, sometimes employs line length while target course is shown by inclination angle.[17]

<u>Comment</u>. Alluisi's[87] studies contain the most widely quoted and relevant research support which specifically addresses inclination coding. The majority of guidelines identified by the author overwhelmingly reference Alluisi. The fact that there are a maximum of 24 discriminative angles is useful, but not directly relevant to process control systems. In the majority of cases, pointer/dial displays which incorporate an inclination technique would be supplemented with some form of scale or zone. As a result, the need for discrimination by inclination or

orientation alone would not likely be encountered in a process control environment. The most relevant findings from these guidelines are:

- o Ensure that the lines are greater than 0.1 in.

- o If more than one inclination angle is used on a single display (e.g., multiple meters), ensure that they are all aligned uniformly so that they are in the same position for the normal condition.

Method for Assessment. If an inclination coding scheme is encountered, verify that the two conditions are satisfied as discussed in the above Comments section. Next, it is not recommended that these codes be applied to a process control application without the addition of some supplementary scaling, or zones. Therefore, consideration to provide redundant cues to an inclination coding scheme should be recommended.

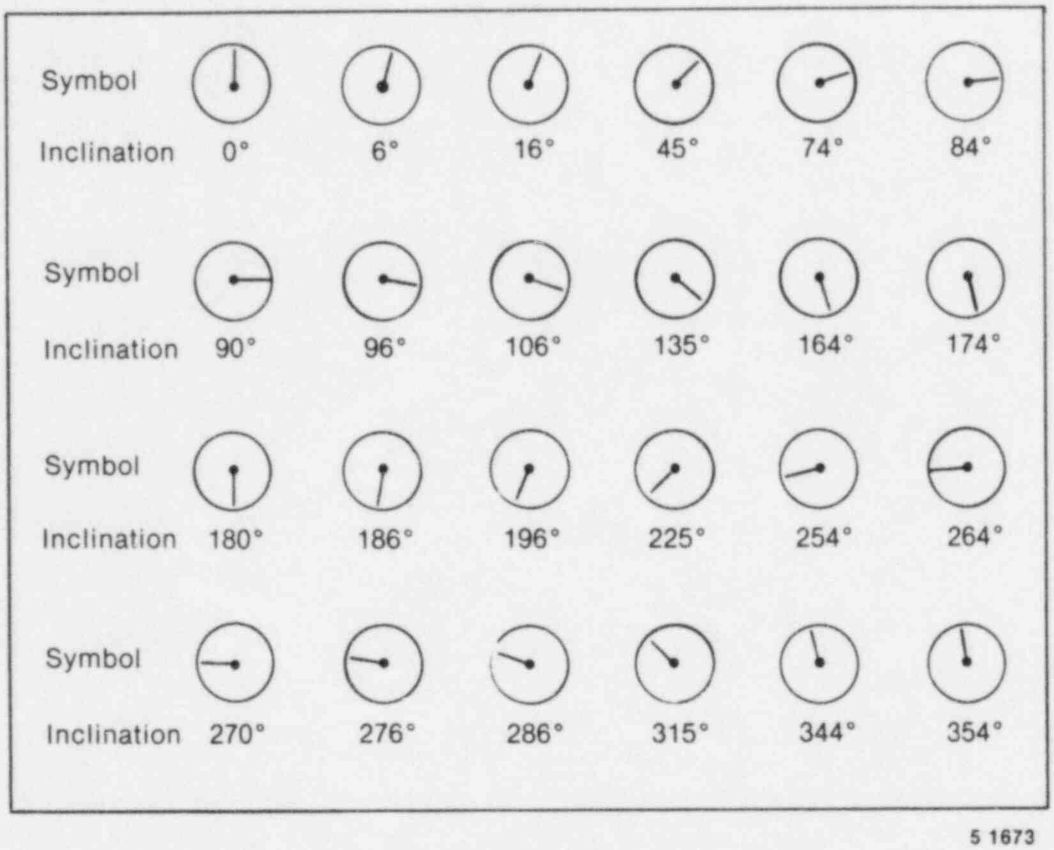


Figure 15. A 24-symbol alphabet of line inclination. The values used are equally discriminative (Reference 87).

Enhancement Coding Dimensions

The previous category ("Visual Coding Dimensions") examined alternative methods for presentation of information to the operator using a variety of coding dimensions. The category "Enhancement Coding" continues review of coding dimensions with a more specialized function.

Highlighting or enhancement coding techniques rely on several coding dimensions. This subsection examines those variables having the most relevance to applications in process control systems:

This category reviews those variables for coding CRT displays that accent critical information to the viewer. Alternatively, effective enhancement coding techniques will make the information more prominent to help attract the attention of the operator to specific items of information in the display. On a more general level, enhancement coding aids the operator to visually distinguish between classes or categories of information. Cakir et al.[22] reported, "The provision of one or more enhancement coding dimensions is usually an essential attribute of the VDTs (Video Display Terminals) in an interactive system in which the information on the display screen is to be searched and manipulated." The majority of the guidelines reviewed often refers to enhancement coding as "Highlighting". For example, Engel and Granda[36] define "Highlighting" as "the art of emphasizing something (e.g., data, field, title, or message) on the display screen." Whereas Cakir et al.[22] define enhancement coding as, "the use

of graphical techniques, . . . to enhance the visual appearance of selected parts of the information on the display screen." Even though there may be subtle differences, these terms are considered synonymous (and are often used interchangeably) by the author throughout the discussion of this document.

A set of general guidelines, which are applicable to all enhancement coding dimensions, is shown in Table 7. This top level table should supplement the guidelines and criteria presented for each specific dimension which follows. Those guidelines should be used as supporting information with each of the specific variables. It is recommended that those guidelines be reviewed prior to investigating the specific variables.

TABLE 7. GENERAL GUIDELINES FOR ENHANCEMENT CODING OF INFORMATION

- Highlighting methods which have information value beyond their attention-getting quality should have the same meaning in all applications.[a]
- Recommend methods of highlighting should be used to attract attention to any displayed data that require rapid response.[b]
- Highlighting methods associated with emergency conditions should not also be used in association with normal conditions.[a]
- Highlighting can be a means of providing feedback to the user. For example, when a user selects an object on a screen, the system should highlight that item so that the user knows that the system has accepted his input, and knows how the system has interpreted his input. The latter information is very important when the screen is cluttered and/or the choice is critical for successful subsequent operations.[c]
- Important but infrequent events, such as error messages, may need some enhancement or highlighting to be recognized. Place such messages in the user's central field of view.[d]
- Labels should be highlighted for ease of identification.[d]
- Labels should be highlighted or otherwise accentuated to facilitate operator scanning and recognition.[a]
- The technique used to highlight labels should be easily distinguished from that used to highlight emergency or critical messages.[a]
- Whatever the specific technique, the main purpose of highlighting is to attract attention.[d]
- Highlighting can be used to provide feedback to the user. For example, when a user is presented with a menu containing a list of mutually exclusive options, and one option on the list is selected, those remaining in the list could be dimmed. This is particularly important when the screen is cluttered. Another common use of highlighting is to help the user detect an item of information. If a user is to perform an operation on some item on a display, highlight that item so that the user is rapidly directed to it.[d]

TABLE 7. (continued)

- o A movable cursor with distinctive visual features (shape, blink, etc.) should be used to designate position on a CRT screen. If the position designation involves only selection among displayed alternatives, some form of highlighting might be used instead.[d]

- o For critical instruction color could be used to highlight specific ideas or objects.[d]

- o Important but infrequent events need enhancement by stimuli involving high attention-getting factors. Place such symbols/messages in the user's central field of view, relative to the display or window.[e]

- o Refrain from overusing highlighting.[e]

a. See Reference 6.

b. See Reference 57.

c. See Reference 36.

d. See Reference 14.

e. See Reference 37.

Brightness

Definition. Brightness (or contrast) enhancement is a useful technique for providing visual distinction between different classes of information. The method simply involves the display of items at different luminance levels. This technique is most often used in the display of alphanumeric information.

Guidelines.	Research Support	Source
1. No more than three levels of brightness coding should be used, with two levels preferred. (See Note 1.)	Y	6, 19, 22, 34, 36, 37, 56, 57, 60, 61

Example: A data form might combine bright data items with dim labels to facilitate display scanning.[34]

---

2. Maximum contrast should be provided between an item and its background.	L	37
3. Brightness coding should be employed only to differentiate between an item of information and adjacent information.		16
4. High brightness levels should be used to signify information of primary importance and lower levels to signify information of secondary interest.	L	57
5. Brightness coding should not be used in conjunction with shape or size coding. (See Note 2.)	L	57

	Research Support	Source
6. When an operation is to be performed on a single item on a display, the item should be highlighted.	Y	36
7. On crowded displays, codes such as dim labels and bright data should be used to distinguish the labels.	Y	89
8. In a list, the option(s) selected by the user should be highlighted.	Y	36
9. If brightness has been assigned another meaning, such as depth in a multilayer circuit board, then some other coding technique should be used to indicate the selected item.	Y	90
10. No more than 10% of the display should be highlighted at one time.	Y	61
11. Maximum contrast should be provided between those items highlighted and those not. (See Note 3.)	Y	36
12. When graphical items are close together on the screen, successive brightening of graphical items and user selection by button activation should be considered.	Y	91

NOTE 1: Reference 22 recommends that no more than two brightness levels be used, corresponding to normal and bold appearance; if the application requires additional levels of coding, that should be provided by introducing an additional coding dimension.

References 19, 34, 56, and 60 state that, under optimal conditions, as many as four brightness levels could be used; however, those references also recommend that only two brightness levels be used if accuracy of decoding is a criterion. References 19, 56, 57, and 60 caution that brightness codes can be inefficient because the sorting of different brightness can be distracting and fatiguing; in addition, brighter characters often obscure or mask dimmer characters. Reference 19 further notes that changes in ambient lighting decrease decoding accuracy. Reference 56 qualifies the maximum of four levels by assuming the user is highly trained and frequently uses the code; even with those assumptions, a 5% error in decoding must be expected.

NOTE 2: Shape or size coding influences the apparent brightness of the coded information.

NOTE 3: For text, maximum contrast seems to be best achieved by reversing the image (dark on a light background, for example) of the item specified.[36]

Comment. All of the above sources tend to be in general agreement concerning the number of coding steps. Two steps are most often recommended. Even though up to four are cited, it is often considered risky to exceed two. If more than two coding levels are needed, Cakir et al.[22] suggest introducing additional coding dimensions. Potential weaknesses in the use of this coding dimension were also noted in the source documents:

- Brighter characters often mask dimmer characters, thus reducing legibility.

- Brightness coding, used in conjunction with shape and size coding, may influence the brightness of the coded information. That is probably the foundation for limiting brightness coding to a constant symbolic dimension such as alphanumeric characters.

- Variations in ambient lighting may hinder the utility of brightness coding.

In addition, too much visual contrast may cause a dazzling effect to the viewer.[30]

Therefore, it is the opinion of the author that alternative coding dimensions should be considered prior to implementing a brightness coding technique. However, if brightness coding is implemented, due caution should be exercised not to exceed two coding steps.

Method for Assessment. Inspect the visual display(s) that employ a brightness coding technique. The actual VDU display should be examined under typical ambient lighting conditions used in the control room. Ensure that no more than two coding steps are exceeded. Check the coding dimension for deficiencies as identified in the above "Comments" section. Interview a group of operators to determine whether or not the coding dimension detracts from or enhances its intended function. If this technique does not provide its intended function, provide recommendations to implement an alternative highlighting dimension.

Blink

Definition. Blink coding attracts the attention of the operator to particular items of information by "blinking" the specific character, label, or field representing the relevant data. This term is also often referred to in the literature as flash rate or intermittency coding. The use and frequency of the blink rate are the most significant parameters associated with defining guidelines for this dimension. Indiscriminate use of blink coding may be an annoyance to the operator. In determining blink rate, one that is too low may not be immediately recognized by the operator. When blink rates are too high, it may be imperceptible by the operator. Therefore, much of the research in this area is devoted to development of optimum blink rates. Guidelines for the use of and determination of effective blink rates are discussed in this section.

Guidelines.	Research Support	Source
1. The blink rate should lie in the range of 0.1 to 5 Hz, with 2 to 3 Hz preferred. (See Note 1.)	Y	6, 16, 22, 34, 36, 57, 93, 94
2. If difference in blink rate is used as a coding method, no more than two steps should be used. (See Note 2.)	Y	6, 19, 22, 34, 36, 56, 60, 92, 94
3. Blink coding should be limited to small fields. (See Note 3.)	Y	22
4. A means should be provided for suppressing the blink action once the coded data have been located.	Y	16, 22, 37, 61
5. When two blink rates are used, the fast blink rate should approximate four per second and the slow rate should be one blink per second.	Y	6, 57

	Research Support	Source
6. When two blink rates are used, the higher rate should apply to the most critical information.	Y	6, 57
7. When two blink rates are used, the "on-off" ratio should approximate 50%.	Y	6, 57
8. An "off" condition should never be used to attract attention to a message.	Y	57
9. Blinking should be reserved for emergency conditions or similar situations requiring immediate operator action.	Y	6, 16, 34, 36, 37, 57, 61
10. The minimum "on" time should be 50 ms. (See Note 4.)	Y	6, 36, 94
11. When blink coding is used to mark a data item that must be read, an extra symbol (such as an asterisk) should be added as a blinking marker, rather than blinking the item itself. (See Note 5.)	Y	34
12. Blink coding should be used for target detection tasks, particularly with high-density displays.	Y	61
13. Blink coding should not be used with long-persistence phosphor displays.	Y	94
14. To avoid interference with reading performance, the blink rate should be such that the user can match his scan rate to the blink rate.	Y	94

NOTE 1: Many display designers like to use blinking to provide an attention-getting feature for alarms or other conditions. The human eye responds differently to various blink rates, producing symptoms ranging from nausea to urgency. A blink rate between 0.5 and 2 Hz (once every two seconds to twice per second) is the most attention-getting rate and generates a sense of urgency. Frequencies of 25 to 34 Hz produce symptoms of nausea and can be very annoying. Blink rates below 0.1 Hz (once every 10 s) are basically indistinguishable unless the operator happens to watch the character as it changes.[93]

NOTE 2: Reference 22 states that it is technically possible to employ more than one blink rate in order to increase the number of coding levels but this is of questionable value. First, the frequency range within which blink coding is most effective is a narrow one, and it is doubtful if the provision of more than two blink rates would help to reduce search time. Second, and perhaps of more practical significance, the simultaneous blinking of different parts of the display at different rates, particularly if several small fields are involved, may confuse the appearance of the display and hinder, rather than aid, the interpretation of the coded data.

Reference 60 states that there are little data on this method of coding, but available information seems to indicate that not more than four identifiable flash rates can be used, even under ideal conditions. Limit this kind of coding to only one or two items on a display because a field of flickering lights is irritating to the observer.[60]

Cohen and Dinnerstein[92] trained subjects to identify flash rates varying from one flash every four seconds to 12 flashes every second. Trained subjects were able to use only four rates with reasonably high accuracy. It was found that the maximally efficient frequencies should be equally spaced on a log scale. Because flashing codes are annoying, their application to displays should be limited.[19]

Reference 56 notes that for Frequency Coding (Blink Coding), the maximum number of code steps is four with two recommended. The maximum number

assumes a high training and use level of the code. Also, 5% error in decoding must be expected. The recommended number assumes operational conditions and a need for high accuracy.

NOTE 3: A disadvantage with blink coding is that the blink action may be a source of annoyance to the operator. For this reason, blink coding is more appropriate for small fields and means should be provided for suppressing the blink action once the coded data has been located and is being attended.

NOTE 4: Reference 94 recommends a minimum "on" time of 80 ms. References 16 and 34 recommend equal "on" and "off" times. Reference 34 further states that an effective code can probably be provided even when the "off" interval is considerably shorter than the "on" interval.

NOTE 5: This practice will draw attention to an item without detracting from its legibility.[34]

Comment. The following general conclusions can be drawn from the above guidelines:

- Blink rate should be between the range of 0.1 to 5 Hz with 2 to 3 Hz preferred.

- Blink coding should be reserved for unique attention getting purposes (e.g., emergency alarms) and not overused.

- A maximum of four coding steps are identified, but no more than two are recommended. Code steps beyond this value are risky.

- The operator should be provided with the capability to turn off the blinking after he or she has responded.

In reference to the on/off times for blink coding, a variation among the guidelines was noted. Regardless of the values selected, the following general rule of thumb should apply in all cases: for a blinking display,

the cycle should be such that the "on" mode should be substantially longer than the "off" mode. This is in contrast to design guidelines that suggest an "off," "on" mode of equal intervals (50% on and 50% off) as acceptable.[97]

Variations in the use of blink coding have also been examined. Rather than blinking a displayed message, label, or specific item to attract an operator's attention, it seems preferable to present the message in a steady form and indicate its importance by juxtaposing a separate blinking symbol (e.g., flashing arrow).[98]

Method for Assessment. Inspect the visual display(s) which employ a blink coding technique. Ensure that no more than two coding steps are exceeded. Check the coding dimension to ensure compliance with the general guidelines cited in the above "Comment" section. (NOTE: a rough approximation of the blink rate can be accomplished using a stop watch.) Conduct further investigation as needed to verify that the code satisfies the specific guidelines presented above. Interview a group of operators and verify whether or not the coding dimension is satisfactory with its intended function and does not detract from or degrade the operator's task. If deficiencies are noted, provide recommendations to mitigate these problems based on the guidelines presented above.

Image Reversal

Definition. Image Reversal or Reverse Video coding is a technique made possible by reversing the polarity of the electron beam so that the beam is "on" which would normally be "off" and vice versa. For example, suppose normal or uncoded data remain displayed as light characters on a dark background (negative polarity). Coded data are presented as dark characters on a light background (positive polarity). Examples of negative and positive image polarity are shown in Figure 16. For many applications, it is assumed that "normal" data are light characters on a dark background and image reversal coding makes use of the reverse of these parameters (characters and background). However, there are no conclusive guidelines which state whether normal data presentation should be positive or negative polarity. Arguments in favor of positive polarity (dark characters against a light background) indicate compatibility between the VDU screen and the source document (normally black ink on white background). This premise assumes a high frequency of looking back and forth between screen and source document such as in a word processing task. The superiority of negative polarity (light characters against a dark background) is supported by the argument that the overall luminance reduction produces less eye strain. Trade-offs between negative and positive polarity warrant further investigation. The basic point being established in this section is that given a screen of data, whether it is positive or negative, the "reversal" of desired fields can be an effective coding dimension. However, it will be noted that many of the following guidelines are based on the assumption that negative polarity is normal and regarded as the standard format and that reverse video coding is achieved with positive polarity.

Guidelines.	Research Support	Source
1. Image reversal (e.g., dark characters on a light background) should be used primarily for highlighting in dense data fields. (See Note 1.)	L	6, 22, 57

	Research Support	Source
Example: A word or phrase in a paragraph of text or a set of characters in a table of data.		
2. Image reversal can be used to code annunciator information that requires immediate response. (See Note 2.)	L	34, 57
3. Maximum contrast should be provided between highlighted and nonhighlighted items. (See Note 3.)	L	36

NOTE 1: Where a large area of the screen is displayed in reverse video, flicker is more likely to be perceived.[22]

NOTE 2: Ensure that operating sequence codes used in CRT displays are compatible with codes used for annunciator tiles.[57]

NOTE 3: Provide maximum contrast of a highlighted item with a nonhighlighted item. This seems best done with text by reversing the image (dark on a light background, for example) of the items specified.

Comment. Supporting research for all of these guidelines is extremely scarce. The feasibility of this technique appears to be most appropriate for the highlighting of information in dense fields (e.g., such as words in paragraphs).[6] The use of image reversal has also been identified in a variety of personal microcomputer software. In that case,

image reversal seems to provide more of an aesthetic rather than a highlighting function. In addition to its merits, it should be cautioned that this technique may reduce legibility. Cakir et al.[22] also pointed out that flicker is more likely to be perceived when large areas of the screen are displayed in reverse video.

Method for Assessment. Inspect the visual display(s) which employ this coding technique. Examine the coded information to ensure that legibility is not hindered and that there is no perceptible flicker. Next, interview a group of operators to ensure that the use is satisfactory with its intended function (e.g., what does this indicate to you? Is the information legible? etc.). If deficiencies are identified, modify the technique according to the above guidelines or provide recommendations to implement an alternative enhancement coding technique.

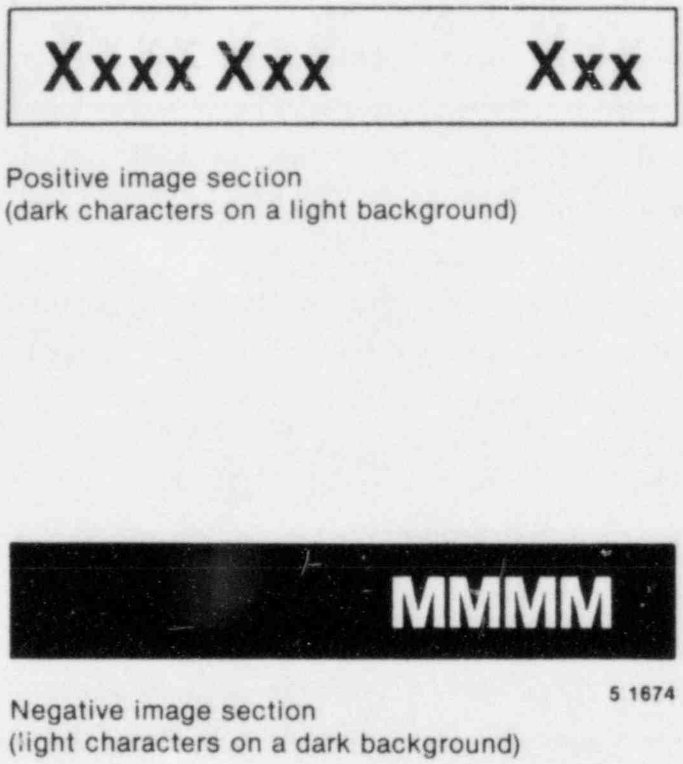


Figure 16. (a) Positive image polarity--dark characters on a light background.
(b) Negative image polarity--light characters on a dark background.

Auditory

Definition. The perception of auditory signals, based on factors such as intensity, frequency, duration, and direction are especially effective in a variety of applications. There are roughly three types of human functions involved in the reception of auditory signals: (a) detection (determining if a given signal is or is not present, such as a warning signal) (b) relative discrimination (differentiating between two or more signals when presented close together) and (c) absolute identification (identifying a particular signal of some class, when only the one is presented). Relative discrimination and absolute identification can be made on the basis of any of several stimulus dimensions, such as intensity, frequency, duration, and direction (the difference in intensity of signals transmitted to the two ears).[18]

The auditory coding dimension is unique in comparison to the coding techniques examined in this category. All other Enhancement Coding Dimensions require stimulus input to the operator through the visual system. In contrast, this particular dimension relies on the auditory senses for detection and interpretation of the stimulus. The use of auditory presentation of information to the operator can often be preferable to visual displays. Some circumstances when auditory coding can be advantageous to visual coding are given below:

- When the origin of the signal is itself a sound
- When the message is simple and short
- When the message will not be referred to later
- When the message deals with events in time
- When sending warnings or when the message calls for immediate action

- When presenting continuously changing information of some type, such as aircraft, radio range, or flight-path information

- When the visual system is overburdened

- When speech channels are fully employed (in which case auditory signals such as tones should be clearly detectable from the speech)

- When illumination limits use of vision

- When the receiver moves from one place to another.[18]

McCormick[18] cautions that these guidelines should be tempered with judgment rather than being rigidly followed.

Certain characteristics of auditory coding are sometimes misunderstood. The use of auditory coding techniques is NOT restricted to alarms and warning devices. Even though auditory signals satisfy many of the guidelines for alarms, their utility should not necessarily be limited to emergency response conditions. This section addresses auditory coding guidelines in a more generic sense. A detailed discussion concerning the use of alarm/warning functions is reported in a separate section. Obviously, this latter section includes auditory coding in addition to a multitude of visual coding parameters which comprise the total alarm/warning system.

Relevant auditory coding guidelines with particular reference to their suitability in VDU process control applications are presented below.

Guidelines.	Research Support	Source
1. Audio displays should be provided when:		
o The information to be processed is short, simple, and transitory, requiring immediate or time-based response.	Y	16
o The common mode of visual display is restricted by overburdening; ambient light variability or limitation; operator mobility; degradation of vision by vibration, high g-forces, hypoxia, or other environmental considerations; or anticipated operator inattention.	Y	16
o The criticality of transmission response makes supplementary or redundant transmission desirable.	Y	16
o It is desirable to warn, alert, or cue the operator to subsequent additional response.	Y	16
o Custom or usage has created anticipation of an audio display.	Y	16
o Voice communication is necessary or desirable.	Y	16
2. The design of audio display devices and circuits should preclude false alarms.	Y	16

	Research Support	Source
3. 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.	Y	16
4. Audio displays should be equipped with circuit test devices or other means of operability testing.	Y	16
5. The use of one audio signal in conjunction with several visual displays should be limited to applications where immediate discrimination is not critical to personnel safety or system performance.	Y	16
6. Audio displays should be compatible with the ambient conditions in which they are used. (See Note 1.)	Y	20
7. 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. (See Note 2.)	Y	20
8. Once a particular auditory signal code is established for a given operating situation, the same signal should not be designated for some other display.	Y	20, 38
9. The frequency of an audio signal should be within the range of 200 to 5000 Hz, and preferably between 500 and 3000 Hz. (See Note 3.)	Y	38

	Research Support	Source
10. When small changes in signal intensity must be detected, the signal frequency should be from 1000 to 4000 Hz.	Y	17
11. When an audio signal must travel over 1000 ft, its frequency should be less than 1000 Hz.	Y	38
12. When an audio signal must "bend around" major obstacles or pass through partitions, its frequency should be less than 500 Hz.	Y	38
13. When the noise environment is unknown or suspected of being difficult to penetrate, the audio signal should have a shifting frequency that passes through the entire noise spectrum and/or be combined with a visual signal.	Y	20
14. When the tonal signal information is to be quantifiable, a reference tone (a base-line loudness or pitch) should be provided against which the primary signal can be compared.	Y	20
15. 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.	Y	20

	Research Support	Source
16. When the signal must indicate which operator (of a group of operators) is to respond, a simple repetition code should be used.	Y	20
17. Audio signals should not startle listeners, add to overall noise levels, or interfere with local speech activity. (See Note 4.)	Y	20
18. Earphones should be used in areas with high ambient noise level.	Y	20
19. Auditory signals should be easily discernible from any ongoing audio input (be it either meaningful input or noise). (See Note 5.)	Y	38
20. The intensity of audio signals should be at least 60 dB above the absolute threshold.	Y	17, 38
21. When several signals come in two or more channels at approximately the same time, there should be a separate operator for each channel. (See Note 6.)	L	17
22. Where feasible, audio signals should exploit learned or natural relationships of the user.	Y	38

Example: Use high frequencies for "up," use wailing signals for emergencies.

	Research Support	Source
23. When complex information is to be presented, two-stage signals should be used. (See Note 7.)	Y	38
24. If a person is to listen concurrently to two or more channels, the frequency of the channels should be different.	Y	38
25. Audio signals should provide only that information which is necessary for the user.	Y	38
26. Extremes of auditory dimensions should be avoided.	Y	38
27. Where feasible, interrupted or variable signals should be used rather than steady-state signals. (See Note 8.)	Y	38
28. Audio signals should be tested prior to using them. (See Note 9.)	Y	38
29. When equipment is modified or added to an existing system, any new audio signals should be compatible with existing audio signals. (See Note 10.)	Y	38
30. When an audio signal is installed to replace another type of signal, a changeover period should be allowed during which both the new and the old signal are in effect.	Y	38
31. Auditory signal frequencies should differ from those that dominate any background noise.	Y	38

	Research Support	Source
32. High-intensity, sudden-onset signals should be used to alert the receiver. (See Note 11.)	Y	38
33. Where feasible, a separate communication system (such as loudspeakers, horns, or devices not used for other purposes) should be used for warnings.	Y	34, 38

NOTE 1: The effectiveness of any auditory display depends on proper consideration of the sound equipment within which the display must operate (i.e., a spoken message is easily obscured by other spoken messages, a particular tone signal is easily masked by other similar tone signals, and any auditory signal or message be masked by frequent, extremely loud noise such as would occur during a battlefield bombardment or the noise of a jet aircraft afterburner).[20]

E 2: Certain types of signals (sirens, bells, klaxons, etc.) are recognized and associated with certain activities, such as those of fire fighters and the police. Such characteristic signals should not be used for other purposes when the situation is such that the more common convention is in use. Other natural relationships, such as high frequencies being associated with "up" and low frequencies being associated with "down," should be taken into account when considering the use of pitch as an auditory code.[20]

NOTE 3: 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.[20]

NOTE 4: Most auditory warning signals are too loud. Most warning signals are designed on the principle that if you want to capture a person's attention, you must hit him over the head with a crowbar.[99]

Most auditory warning signals are too abrupt. While abrupt signals capture attention, they may also induce startle reactions.[99]

Most auditory warning signals are "on" too long. There are three important consequences: (a) no more than one warning signal can be heard at any one time, (b) communications are often blocked out in the presence of a continuous "on" signal, and (c) when manual override is available, operators often disable warning signals.[99]

NOTE 5: There are often too many different warning signals. This leads to identification errors, especially in times of stress and emergency.[99]

Most auditory warning signals have the same temporal pattern, either regularly interrupted or continuous. This leads to errors of identification of warning signals.[99]

Emergency auditory warning signals are not differentiated from other signals. Typically, however, a range of operational urgencies must be communicated.[99]

NOTE 6: Nonurgent messages should be taped, stored, and played back on demand when time permits. This assures greater accuracy than direct listening.

NOTE 7: These stages to consist of:

1. Attention-demanding signal: to attract attention and identify a general category of information.

2. Designation signal: to follow the attention-demanding signal and designate the precise information within the general class indicated above.

NOTE 8: Use a modulated signal (1 to 8 beeps/s or warbling sounds varying from 1 to 3 times/s), since it is different enough from normal sounds to demand attention.

NOTE 9: Such tests should be made with a representative sample of the potential user population, to be sure the signals can be detected by them.

NOTE 10: Any newly installed signals should not be contradictory in meaning to any somewhat similar signals used in existing or earlier systems.

NOTE 11: Where earphones are used, consider dichotic presentation (altering signal from one ear to the other).

Comment. The above guidelines have identified auditory coding criteria for the following concerns: (a) when auditory coding should be implemented (i.e., its merits and limitations) and (b) a general methodology for designing auditory displays. These criteria should provide sufficient background for assessing the suitability of auditory codes in process display environments.

In addition to the guidelines and criteria, Huchingson[17] noted that it is important to actually field test the auditory codes for detectability and ensure that operators are indeed trained as to their meanings.

Method for Assessment. Examine the auditory codes under the normal environmental conditions of the control room. Ensure that: (a) The code is detectable. Can it be heard? Are there background noises which mask its perceptibility? (b) The code is absolutely discriminative from the auditory coding alphabet--Do any signals with different meanings sound identical? (c) The code is recognizable--Is the intended meaning clear and immediately understood by the operator without ambiguity? If the coding dimension does not satisfy these characteristics, then provide recommendations to resolve these issues, based on the above guidelines.

Note that a more objective analysis to verify the recognition of a set of signals could be accomplished with the use of a confusion matrix. This method will aid in determining the identification of potential confusers. This process consists of the following steps:

1. Draw up a matrix with the auditory signals to be examined down the left hand and top portion

2. Select a group of operators to be tested

3. Select a signal from the top portion of the matrix, activate it, and ask the operators to identify its meaning

4. Record responses in the appropriate columns

5. All diagonal entries will represent correct identifications and the off diagonal entries will represent incorrect identifications.

These data will indicate where frequencies of errors occur and thus provide results for subsequent modifications.

Voice

Definition. Other auditory coding techniques are presently being developed which are not restricted entirely to tonal signals. The technology of voice output provides a remarkable design alternative. This dimension will encompass only those features of voice coding as a substitute for traditional tonal signals, i.e., preprogrammed signals which respond as a function of plant conditions. In other words, the vast domain of research concerned with speech synthesis and voice recognition devices will not be covered. See References 17 and 100 for a good introduction to this topic.

Even though this application is relatively recent in development, there appears to be some potential for its implementation in process control systems. Perhaps the greatest advantage resides in the minimal requirements for learning these codes. On the other hand, immediate problems remain to be resolved in adapting a "voice" that can be readily accepted by the user.

A cursory review of the guidelines in the area of voice coding and its trade-offs with tonal signals is presented below.

Guidelines.	Research Support	Source
1. A tonal signal should be used when:		
o Immediate action is required on the part of the listeners (i.e., when vocal explanations or directions are not necessary for the listeners to know what the signal means and what they should do)	L	20

	Research Support	Source
o A specific point in time (that has no absolute value) is to be indicated (e.g., when the sound of a gong tells the listeners that something has happened or is about to happen, that they should be prepared for a message, etc.)	L	20
o A spoken message would compromise the security of a situation (i.e., when a coded tonal signal would be unrecognizable to persons not privy to the code)	L	20
o Noise conditions are unfavorable for receiving spoken messages	L	20
o Speech channels are overloaded	L	20
o A spoken message could annoy listeners for whom it is not intended or when the spoken message could mask other messages	L	20
o The intended listeners are familiar with the tonal signal implication or the tonal signal code	L	20
o It is desired to use the simplest audio signal.	L	20

	Research Support	Source
2. A spoken message should be used when: (See Note 1.)		
o More message flexibility is needed than a tonal signal can convey	L	20
o It is necessary to identify the source of the information	L	20
o Listeners have not had training in a special tonal signal code	L	20
o There is a need for rapid two-way exchanges of information	L	20
o The intended information deals with a future time and when preparation is required (e.g., preparatory to initiating some operation during a countdown)	L	20
o Use of a tonal signal countdown could result in a miscount	L	20
o Operational stress surrounding the intended listeners could cause them to forget the meaning of a tonal signal code.	L	20
o The message is simple, short, and will not be referred to later.	L	14

	Research Support	Source
o The message calls for immediate action, visual is already overburdened, or the job requires the user to move about continually.	L	14
3. For auditory displays with voice output, different voices should be considered for use in distinguishing different categories of data. (See Note 2.)	L	34
4. Verbal warning signals should consist of:	L	16
(a) An initial alerting signal (nonspeech) to attract attention and to designate the general problem.		
(b) A brief, standardized speech signal (verbal message) which identifies the specific condition and suggests appropriate action.		
5. Verbal alarms for critical functions should be at least 20 dB above the speech interference level at the operating position of the intended receiver.	L	16
6. The voice used in recording verbal warning signals should be distinctive and mature.	L	16
7. Verbal signals should be presented in a formal, impersonal manner.	L	16

	Research Support	Source
8. Verbal warning signals should be conditioned only when necessary to increase or preserve intelligibility. (See Note 3.)	L	16
9. In selecting words to be used in audio warning signals, priority should be given to intelligibility, aptness, and conciseness in that order.	L	16
10. Computer speech outputs should be repeatable at user request.	L	14
11. After each computer speech output, the computer should provide the user the choice of responding with "wait," "go ahead," or "repeat."	L	14
12. The user should be provided with a means of easily returning to the step in the program sequence immediately prior to the computer speech output.	L	14

NOTE 1: Computers and associated electronic equipment can produce signals sounding remarkably like words produced by a human voice. In some situations, it may be preferable to have a voice output rather than a CRT display or printout.

Voice output from the computer may seem more natural than reading from a CRT or from a printout, but it is not always the best way to present information. When used, computer speech should be broken into phrases or sentences in a way that clearly meets the requirements of users. For example, only short user requests and short system answers should be used in inventory control systems.

NOTE 2: At least two voices, male and female, could be readily distinguished, and perhaps more depending upon fidelity of auditory output and listening conditions.[34]

NOTE 3: Such as by increasing the strength of consonant sounds relative to vowel strength. Where a signal must be relatively intense because of high ambient noise, peak-clipping may be used to protect the listener against auditory overload.[16]

Comment. The utility of voice coding as an alternative to tonal coding is slowly evolving into a variety of uses. However, its uses should not be spontaneously implemented without addressing its advantages and disadvantages in systematic trade-off analysis.

Method for Assessment. The method described in "Auditory Coding" should be applicable for this section as well.

Audio-Visual

Definition. As the term implies, audio-visual warning and signal devices are capable of presenting emergency stimulus information to both the auditory and/or the visual systems. This type of information generally takes on the form of a dangerous condition or a signal that something is or is not operating. Warning devices, as a rule, simply represent two value information (e.g., on/off, go/no-go). This concept can also be expanded to include cautionary or intermediate information, but the basic function is intended to alert the operator that an emergency event will, or is about to, take place. In the literature, with minor exception, some confusion arises between the terms "Warning" and "Alarm". The military, as pointed out by Danchak,[101] reserves "alarms" for auditory systems and "warning" for nonauditory. In industrial applications, all components designed to alert or warn the operator of an emergency action are functionally categorized within the annunciator warning system. However, since no standard definition exists in industry, clarity should not be compromised if these terms are considered to be synonymous in this section.

Before guidelines can be examined, it may be beneficial to further define the function of a good warning device. This can be divided into three basic requirements. It should (a) break through and get the attention of a busy or bored operator, (b) tell him what is wrong or what action to take, and (c) allow his or her continued attention to other important duties if this is necessary.[60]

The following set of guidelines was identified to ensure that these three requirements can be met in a process control environment. These guidelines, it should be noted, are only intended to supplement the various enhancement coding techniques previously examined. The emphasis will be toward determining top level human factors guidelines as they apply to the total integrated alarm/warning system. As a result, supporting variables such as blink coding, auditory coding, and color coding are certainly relevant; knowledge of them is essential for assessment of these systems.

The various factors and criteria for design and assessment of alarm/warning systems are extremely broad. Thus, for the sake of being succinct, many of the issues concerned with alarm prioritization, design tradeoffs, and overall alarm philosophies have been either deleted or greatly summarized. See the following documents if further detail concerning design and implementation of alarm/warning systems is desired:

1. Kinkade and Anderson, Human Factors Guide for Nuclear Power Plant Control Room Development[57]

2. Guidelines for Control Room Design Reviews, NUREG-0700[6]

3. M. M. Danchak, Alarms Within Advanced Display Systems: Alternatives and Performance Measures, NUREG/CR-2776[101]

4. W. W. Banks and M. P. Boone, Nuclear Control Room Annunciators: Problems and Recommendations[102]

As an aside, it should also be emphasized that a complete review of the alarm systems for the VDUs must be complementary to, and integrated with, the complete NPP control room reviews as established in NUREG-0700.

Many of the available guidelines unearthed in this area by the author have been developed for design and layout of hardwired panels. Standards and guidelines for VDU-type warning/alarm systems are somewhat scarce. Another limitation of this material is: given a VDU in a control room, no criteria exist for functional allocation of alarms between the CRT displays and hardwired annunciator panels. In spite of these limitations, a reasonable proportion of these data is certainly applicable to VDUs and they will be presented in this section as deemed appropriate. However, due to the unique flexibility and capabilities of VDU systems, the direct transfer of these older guidelines should be placed under scrutiny and caution before consideration for use in assessment.

Guidelines.	Research Support	Source
1. Appropriate trend and status displays for minor upsets should be available to the user. (See Note 1.)	L	93
2. Status displays for minor upsets should include a detailed alarm list that identifies alarms by name and number. (See Note 2.)	L	93
3. Errors with a structured response pattern should be handled within the computer and should not trigger alarms.	Y	21, 103
4. Only those errors that require rapid operator decision making and intervention should activate the redundant alarms.	Y	21
5. Early signs of a system going out of specification should be identified by low-level alarms since response time is not as critical.	Y	21
6. In some operations, it may be desirable to preprogram a hierarchy of alarms that could be altered if changes were made in manufacturing specifications.	Y	21
7. It should be possible to program the computer to display specific information each time one of the major system failures is detected and triggers an alarm. (See Note 3.)	Y	21

	Research Support	Source
8. Information displayed to the operator should include the chronological order of failure.	Y	21
9. Information that will interfere with decision making, such as alarms from systems that are secondarily affected by the initial problem, should not be presented to the operator unless requested.	Y	21
10. Once the operator has responded to an alarm with a controlling action, some feedback should be indicated on the VDU to acknowledge that action has been taken.	Y	21, 104, 105
11. The alarm should cease <u>only</u> after the user responds appropriately.	Y	14
12. Audio signals should be provided, as necessary, to warn personnel of impending danger, alert the 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.	Y	16
13. Audio warning signals should normally consist of two elements: an alerting signal and an identifying or action signal.	Y	16

	Research Support	Source
14. When reaction time is critical and a two-element signal is necessary, an alerting signal of 0.5-s duration should be provided. All information should be transmitted in the first 2.0 s of the identifying or action signals.	Y	16
15. When reaction time is critical and a single element signal is permissible, all essential information should be transmitted in the first 0.5 s.	Y	16
16. Caution signals should be readily distinguishable from warning signals and should be used to indicate conditions requiring awareness but not necessarily immediate action.	Y	16
17. When used in conjunction with visual displays, audio warning devices should be supplementary or supportive. The audio signal should be used to alert and direct operator attention to the appropriate visual display.	Y	16
18. The frequency range of audio warning signals should be between 200 and 5000 Hz and, if possible, between 500 and 3000 Hz.	Y	16
19. If the user will ever be a considerable distance from the equipment in the performance of other tasks, the signal should be loud but low frequency (less than 1000 Hz).	Y	14, 16

	Research Support	Source
20. If the user goes into another room or behind partitions, the signal should be low frequency (below 500 Hz).	Y	14, 16
21. If there is substantial background noise, the signal should be of a readily distinguishable frequency.	Y	14, 16
22. If an auditory signal must attract attention and the above guidelines are inadequate, the signal should be modulated.	Y	14
23. 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.	Y	16
24. The intensity, duration, and source location of audio alarms and signals should be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal areas.	Y	16
25. Audio warning signals should not be of such intensity as to cause discomfort or "ringing" in the ears as an after-effect.	Y	16
26. Controls for operator response to the annunciator system should include silence, acknowledge, reset, and test controls.	Y	6

	Research Support	Source
27. It should be possible to silence an auditory alert signal from any set of annunciator response controls in the primary operating area.	Y	6
28. The acknowledgment control should terminate the flashing of a visual tile and have it continue at steady illumination until the alarm is cleared.	Y	6
29. Acknowledgment should be possible only at the work station where the alarm originated.	Y	6
30. The reset control should silence any audible signal indicating clearance and should extinguish tile illumination.	Y	6
31. The reset control should be effective only at the work station for the annunciator panel where the alarm initiated.	Y	6
32. The test control should actuate the audible signal and flashing illumination of all tiles in a panel.	Y	6
33. Periodic testing of annunciators should be required and controlled by administrative procedure.	Y	6
34. To facilitate "blind" reaching, repetitive groups of annunciator controls should have the same arrangement and relative location at different work stations.	Y	6

NOTE 1: When minor upsets are either noticed or predicted by the operator, he needs to take a closer look at the process area in question. If trend displays are available for the process area, they can be used to show how key variables have been interacting for the past few minutes. A status display is also useful at this point because it will contain detailed information about the process area.[93]

NOTE 2: Alarms can be indicated with reverse video or blinking, and each variable should be represented with a digital value and an analog bar graph.[93]

NOTE 3: Because the operator has to respond quickly to an alarm indicating a major failure in the manufacturing s em, it is important to use the computer to assist in the problem-solvi process. Building information retrieval into the alarm can halve the t e taken to remedy the problematic situation, since most of the response time is spent in gathering relevant information.[21]

Comment. A large portion of recent research and inquiry in the area of alarm/warning systems can best be summarized by Danchak,[106] "Once again . . . the operator's ability to cope with large amounts of information has been overtaxed. Process control literature of the 70's repeatedly decries the fact that existing alarm systems are inadequate." Danchak, in addition to several other researchers, substantiates this inadequacy by referring to the sequence of events at Three Mile Island. Danchak also recognizes the capabilities of CRTs as potential resources to rectify these problems, "Use of the CRT (to display process alarms) has many advantages in this application, but also many serious disadvantages." It is not sufficient to reproduce the annunciators or error-loggers in electronic form. "One needs to return to basics and answer some fundamental questions, the primary of which is the purpose of an alarm display--CRT or otherwise." The need to go back and address these fundamental issues leads to a research effort conducted by Danchak to answer the following question: "What information do nuclear power plant operators need in order to respond to an alarm?" The results of this analysis consisted of a rank ordering of the following information requirements from most important to least important:[106]

1. Point English Language Descriptor--Name of the parameter in the alarm (Pressurizer Pressure, Hot leg Temperature)

2. Current Point Value/State--The actual value of the parameter that went into alarm (Pressurizer Pressure - 2500)

3. Violated Set Point Limit--The limit that has been violated to cause the parameter to go into alarm (Pressurizer Pressure Hi Limit = 2450)

4. Alarm Severity Indicator--A simple designator that specifies which alarm limit set point has been violated (HiHi, Hi, Lo, LoLo)

5. Engineering Units--Units associated with any displayed values (degrees F, gallons/minute, PSI)

6. Priority--An indicator that reflects the importance of the parameter when alarmed (Priority 1, Priority 2)

7. Major System Designator--Name of the major system of which the alarmed parameter is a part (Coolant, LOOP1, CVCS)

8. Alarm Limits--All possible set points which are associated with a given parameter in alarm (trip set points, Hi/Lo set points, etc.)

9. Time of Occurrence--The hours, minutes and seconds at which the parameter went into alarm (10:14:56)

10. Quality Tag--Computer generated indicator that reflects the confidence level of the instrument measuring the alarm (Out of range, Questionable)

11. Reference--An indicator that tells the operator where he can find more information about the alarm (Display page number, Panel containing meter or control)

12. Detector Number--The P&ID identifier of the detector which measures the current value in alarm (PCDAXL03)

13. Point Identification Number--Number used to access the alarmed parameter from the computer (NCP103)

14. Sequential Number--A number that indicates the position of the alarmed parameter in the entire alarm list (No. 25)

15. Date of Occurrence--The month, day and year that the alarm occurred (2/24/78).

The major conclusions of these findings are as follows:

- The operators want a simple indication of what the alarm is and as much help as possible in determining the seriousness of the alarm.

- The Point English Language Descriptor satisfies the first criterion while fields such as Current Point Value/State, Violated Set Point Limit, Alarm Severity Indicator, and perhaps Priority satisfy the second.

- Items such as time of occurrence, point identification number, and sequence number are of questionable value.

- Date of occurrence is obviously something that the operator does not need.[106]

Danchak's finding, in conjunction with the criteria identified in the Guidelines section and those guidelines for the supporting variables, should provide a relatively comprehensive source of information for determining a thorough assessment strategy.

Method for Assessment. Examine the alarm/warning features which have been incorporated into the VDU being assessed: (a) verify that the coding dimensions for the VDU(s) are consistent and standardized for the coding strategies employed throughout the control room, (b) compare the information requirements for process alarms identified by Danchak[106] in the above comments section with those in use on the VDU. If any of those requirements listed in the top six are not present in the VDU, then recommendations should be provided to implement them into the alarm/warning system, and (c) further assessment can be accomplished using the criteria from the above guidelines section. If human engineering discrepancies are identified, then recommendations for compliance should be provided.

Other Techniques

Definition. A variety of other methods is available which might be useful as enhancement coding techniques. These techniques range from the simple intuitive techniques with widespread applications to more exotic and unique approaches. A list of such methods includes but is not necessarily limited to: motion, focus, distortion, graphics (boxes, underlining, etc.), and texture. Many of these techniques are feasible and could be easily implemented into process control applications. Yet, the implementation of others is highly questionable. A cursory examination of guidelines for these alternative techniques not previously mentioned is presented below.

Guidelines.	Research Support	Source
1. Graphic coding methods should be used to present standardized qualitative information to the operator or to draw the operator's attention to a particular portion of the display. (See Note 1.)	L	6
2. Extra spacing, horizontal and vertical lines of differing widths, and perhaps color should be used to set off and highlight data.	L	14
3. Special symbols (e.g., bullets or arrows) should be used to indicate position and to direct attention. (See Note 2.)	L	14, 34
4. Other methods of coding which should be considered for graphic displays and computer generated drawings include motion, focus, distortion, and line orientation on the display surface. (See Note 3.)	L	22

	Research Support	Source
5. A border should be used to improve the readability of a single block of numbers or letters. (See Note 4.)	L	21, 37
6. If several labels or messages are clustered in the same area, distinctive borders should be placed around the critical ones only. (See Note 5.)	L	21
7. When a special symbol is used to mark a word, it should be separated from the beginning of the word by a space. (See Note 6.)	L	34
8. Auxiliary methods of line coding should be considered for graphics applications, including variation in line type (solid, dashed, dotted) and width ("boldness"). (See Note 7.)	L	34
9. When a line is added simply to mark or emphasize a displayed item, it should be placed under the designated item.	L	34, 37
10. Visual dimensions that should be considered for special display coding applications include variation in texture, focus, and motion. (See Note 9.)	L	34
11. Related data which are distributed about the screen and data to be updated, etc. should be highlighted in white. (See Note 10.)		40

NOTE 1: Reference 14 recommends emphasizing objects such as labels, data items, titles, or messages by:

- o Underlining the object
- o Presenting it in a different style or size font (if the object consists of alphanumeric characters)
- o Pointing it out with a noticeably large flashing object (such as an arrow)
- o Making a shaded box around the item
- o Putting graphics (such as a rectangle composed of a string of asterisks) around or near the object.

Reference 14 further states that cartoons can be used to highlight points that call for special attention--such as warnings. They should, however, contain the idea to be communicated and not serve merely as decoration where they might detract from the main intent of a set of instructions.

NOTE 2: Symbols chosen for such an "alerting" purpose should not be used for other purposes in the display.[34]

NOTE 3: In several applications involving the representation of three dimensional bodies, the use of lines to represent the three axes and their orientation can provide a useful depth cue.[22]

NOTE 4: If space is limited and the character size is critical, it is preferable to fill most of the space within the border. If space is not critical, a larger surrounding border contributes to even better readability.[21]

NOTE 5: Keep the embellishments to a minimum, since each one reduces the effectiveness of display of the others.[21]

NOTE 6: A symbol immediately adjacent to the beginning of a word will impair legibility.[34]

NOTE 7: Perhaps 3 to 4 line types might be readily distinguished, and 2 to 3 line widths.[34]

NOTE 8: A consistent convention is needed to prevent ambiguity in the coding of vertically arrayed items; underlining is customary and does not detract from word legibility. For words from the Roman alphabet, underlining probably detracts from legibility less than overlining.[34]

NOTE 9: Texture can be useful for area coding in graphic displays. Only two levels of focus are feasible, clear and blurred, with the risk that blurred items will be illegible. Perhaps 2 to 10 degrees of motion might be distinguished in display applications where motion is an appropriate and feasible means of coding.[34]

Barmack and Sinaiko[56] suggest other methods of coding that may also be considered:

1. Motion (2 to 10 coding levels)

2. Focus on distortion (2 levels)

3. Line type, dashed, solid (3 to 4 levels)

4. Line length (2 to 4 levels)

5. Line width, baldness (2 to 3 levels)

6. Orientation, location on the display surface (4 to 8 levels).

Methods 3 to 6 would be very appropriate to computer generated graphics. For more detail, the papers by Barmack and Sinaiko[56] and by Foley and Wallace[107] are recommended.[36]

NOTE 10: White is used for highlighting related data which are distributed about the screen and for updates, etc., which are worthy of particular attention. If the grouping conveyed by white highlighting is critical, the grouping information must be conveyed in another fashion as well as to support users at monochromatic terminals. Double brightness is often used in this case.

Comment. The utility of this variety of techniques is task specific and dependent upon the particular application. Experimental research is also limited toward their effectiveness and appropriateness for a given situation. Examples of some of these techniques most appropriate for VDU applications are shown in Figure 17. Some of the more unfamiliar techniques such as focus, motion, and stereodepth appear to possess limited use for VDU applications. In summary, the uses of these various coding dimensions are left up to the discretion of the designer on a case by case basis. Without detailed guidelines and supportive research, the greatest misuse of such techniques resides in overuse. For example, if underlining were overused, the following deficiencies could result: (a) its original function as an enhancement technique could be greatly diminished and (b) legibility of the elements would be reduced and the subsequent cluttering effect may actually degrade performance.

Unfortunately, no data are available to determine how much represents "overuse".

Therefore, each screen must be subjectively evaluated on a case by case basis to ensure that whatever technique is employed, it is used parsimoniously.

Method for Assessment. Inspect the screens for the other coding dimensions not previously examined. Subjectively examine each dimension to ensure: (Criterion 1) that legibility of the item being highlighted is not hindered with the technique being used and (Criterion 2) that it truly assists the operator as a prompt to discriminate enhancement coded items

from other information. If discrepancies are noted, poll a group of operators for their opinions. If definite discrepancies are identified: For Criterion 1--provide alternative techniques based on the above guidelines. For Criterion 2--reduce the number of coded items as needed based on a scheme of prioritization.

9.0 DIRECT THE SECONDARY OPERATOR SHUTDOWN SECONDARY PLANT EQUIPMENT USING APPENDIX D AS TIME PERMITS.

NOTE:
RCS cooldown must commence no later than one hour after the LOCA occurred. If cooldown must commence immediately go directly to Step 13.0 if this procedure. The following Steps 10.0, 11.0 and 12.0 may be completed as time permits under those circumstances.

10. EVALUATE, RESET AND RESTORE SAFETY SYSTEMS AS FOLLOWS:

> CAUTION
>
> SIA MUST BE REINITIATED WHENEVER THE RCS IS NOT AT LEAST 20°F SUBCOOLED.

> CAUTION
>
> IF RCS ACTIVITIES ARE EXCESSIVELY HIGH, DO NOT RESTORE LETDOWN.

5 1675

Figure 17. Formats that highlight cautions, warnings, and notes using boxes, underlines and different margins.

Dynamic Display

Many CRT displays are dynamic in nature. That is, they are continuously driven by various data inputs to update the condition of the displayed parameters. The determination of the rate of these changes before overload or loss of comprehension is an area that needs further research.[4]

In this subsection, the following variables will be examined:

Display Motion

Definition. Display motion refers to the degree of movement or animation present in a given display, e.g., water moving through a pipe that is dynamically and graphically presented, control rods moving up or down, or a valve changing position from open to closed. All of these examples indicate some dynamic movement or change that could be presented graphically to operators.

One of the important questions associated with animated display motion is how fast or slow should the apparent motion of the graphic representation be projected to the operator. The display motion should clearly be of sufficient magnitude to be easily detected and recognized by operators. If the rate of pixal excitation is too great, a progressive incremental movement perception will not be readily apparent to the operator, but instead a "zip effect" will be produced. If one were to prescribe an animated fluid flow rate linearly in terms of pixals per second, such a definition would be unsatisfactory because pixal size and dimension are not standardized within the computer industry. A better definition, one which would enable the easy establishment of guidelines and the applicability to virtually all types of CRTs, would be to state rate in terms of millimeters per second.

Unfortunately, there are no specific guidelines available for determining these rates. However, some basic building blocks toward developing such guidelines have been examined. These developments are the product of both observational analysis and formal experimentation. The results of these studies, in addition to relevant top level design criteria, will be summarized in the guidelines sections below. The reader is referred to the following references for further information:

J. W. Kling and L. A. Riggs (ed.), Woodworth and Schlosberg's Experimental Psychology, 3rd ed., Volume 1: "Sensation and Perception.[108]

R. Sekuler and P. D. Tynan, Sourcebook of Temporal Factors Affecting Information Transfer from Visual Displays.[109]

Guidelines.	Research Support	Source
1. The speed of a graphic showing fluid flow in a pipe should be greater than 7.28 mm/s (0.29 in./s) but less than 295 mm/s (11.8 in./s). (See Note 1.)	L	4
2. Changing values which the operator uses to identify rate of change or to read gross values should not be updated faster than 5 per second nor slower than 2 per second when the display is to be considered as real time. (See Note 2.)	L	16
3. A display freeze mode should be provided to allow close scrutiny of any selected frame. (See Note 3.)	L	16
4. Display formats should be designed to optimize information transfer to the operator by means of information coding, grouping, and appropriate information density.	L	16
5. Rate of motion should not exceed 60 degrees per second of visual angle change with 20 degrees per second preferred. (See Note 4.)	Y	19, 79

NOTE 1: In informal unpublished studies, conducted at the LOFT facility in 1980 by Banks, some rough guidelines were generated that were not rigorously tested. To display fluids moving through a piping vessel, a value of 7.28 mm/s (0.29 in./s) continuous flow was found to be the approximate slowest rate of apparent motion to be comfortably detected by several LOFT operators (with operator's viewing distance ~24 in. from screen). When values exceeded 295 mm/s (11.8 in./s), operators reported that the fluids "moved too fast".[4]

NOTE 2: Graphic displays requiring operator visual integration of rapidly changing patterns are an exception and should be updated at the maximum refresh rate of the display device consistent with the operator's information handling rates.[16]

NOTE 3: An option should be provided to allow resumption at either the point of stoppage or at the current, real-time point. The operator shall be warned if an important event occurs while the display is frozen. An appropriate feedback label should be provided to remind the operator when the display is in the freeze mode.[16]

NOTE 4: "Dynamic Visual Acuity" (DVA) is generally defined in terms of the smallest detail that can be detected when the target is moving. Angular movement of the target decreases the threshold of visual acuity;[19,79] DVA also varies with age.[79]

Loss of DVA increases rapidly as the rate of motion exceeds 60 degrees per second. Such thresholds could be considerably higher with a shorter viewing time or target travel distance.[110,111] At rates of 20 degrees/s, our ability to resolve detail is almost as good as with motionless targets.[79]

Comment. With the exception of some general findings cited in Van Cott and Kinkade,[19] formal laboratory experimentation directly applicable to minimal safety-related standards or guidelines are limited. The findings of Bank's represent the only known relevant guidelines for this variable in process control systems. It should, however, be cautioned

that these data are only observational and not supported with formal research. There is an obvious need to perform research in this area to anchor any suggested guideline to laboratory validation and minimize reliance on intuition and casual observation.

The general design guidelines stated in MIL-STD-1472C[16] are also vague, but should provide the assessor with some usable benchmark criteria. A display freeze mode as recommended in that standard seems to be a beneficial resource to the operator.

Method for Assessment. Observe the screen to be examined in a dynamic mode. Subjectively determine the display(s) adequacy to ensure (a) that the apparent dynamic features can be comfortably detected and (b) that the dynamic features do not hinder legibility of critical information and that a "zip effect" is not created.

Query a group of operators to verify whether or not problems are encountered with the dynamic features of the display.

Apply the upper and lower values established by Banks if further quantitative clarification is desired. (This could be accomplished using a stop watch to track the position of a predetermined target between two reference points.)

Check the VDU for display freeze and playback options.

If discrepancies are noted, i.e., moves too fast to be legible or too slow to be interpreted, provide recommendations to resolve of these problems based on each particular case.

Digital Counters

Definitions. Another aspect of dynamic characteristics involves the display of quantitative, and often real time, information through a digital counter type format. Though this mode of information presentation is often more accurate than scales, it is also subject to gross reading errors. A possible contributing factor to these reading inaccuracies are attributed to the counter's rate of change. An overview of the general guidelines associated with establishing these values are discussed below.

Guidelines.	Research Support	Source
1. Numerals should not follow each other faster than two per second when the operator is expected to read the numerals consecutively.	L	6
2. Changing digital values which the operator must reliably read should not be updated faster than one per second, with a 2-second minimum time preferred.	L	6, 16

Comment. In contrast to MIL-STD-1472C,[16] a more conservative update rate is set forth in NUREG-0700.[6] A 2-second minimum value is recommended due to the induced safety margin established with a longer reading time. In addition, for digital counters, the following features should also be incorporated into the overall design criteria:
(a) multidigital counters should be oriented to read horizontally from left to right, (b) "simple" character fonts should be used, and (c) where more than four digits are required to display numerical values, the digits should be separated into groups and the groups separated by commas, a decimal point, or additional space.

Method for Assessment. Inspect the digital counters used on the screen(s) being assessed. Using a stopwatch or other suitable timing device, ensure that the values do not change at a rate faster than 2 seconds. Also inspect the general layout of the digital counter for compliance with the guidelines presented in the above Comment section. If discrepancies are noted, provide recommendations accordingly.

blank page

Information Formats

The flexibility of a VDU as an operator interface provides the display designer with a multitude of formats to select from. Historically, feasibility and development costs precluded all but the most conventional display types. This section investigates both traditional displays and a range of effective graphical techniques currently being proposed for use in VDU technology.

The variables discussed in this section are:

The particular advantages, uses and restrictions of each variable are discussed in this subcategory. Summary tables for each of these information formats are shown in Appendix B.

The massive number of these display patterns can be overwhelming to the designer who is tasked with the mission of selecting the most optimal design. Danchak[112] surveyed the literature concerning the available techniques for display of multivariate data and uncovered over 60 methods of graphical representation. Fortunately, the methods for selecting a suitable format are not entirely subjective. A man/machine systems engineering approach provides the basic elements for determining the fundamental requirements for the designer to base his or her decision.

Even though a complete systems analysis is the most effective strategy, the concepts can still be entertained on a more informal scale. Before selecting a display, the designer must possess or have access to the following information requirements:

1. What is the operator's task, i.e., what objectives are to be accomplished with the use of this display and how will the operator benefit from it?

2. How many dimensions of plant state does this task depend on (temperature, pressure, flow, etc.)?

3. How many variables does this task depend on?

4. How many samples are needed for this task?

5. What is the primary function of the information?

6. How quickly will this information respond to control actions?

7. Does this information come directly from measured data or is it derived using a formula or model?

8. Does this task require quantitative or qualitative information?

9. What is the range of this variable?

10. What is the required level of accuracy for using this information?

11. What is the signal-to-noise ratio of the incoming data?

12. Is this information to be used in an absolute or a relative manner?

In short, before selecting a particular display type, the designer should consider both the type of data and the intended use of the

display.[57] Once these basic information requirements are fulfilled, the designer can proceed with selection of the specific format or display pattern. It might also be added that the implementation of this strategy is germane to design of displays. A post hoc assessment evaluation of current displays could also be conducted by applying these same principles based on the current guidelines.

As mentioned previously, the number of available display patterns is enormous. However, a great deal of preliminary analysis has already been conducted (based on Danchak's findings) to determine a useful subset of candidate displays.[8,30] This candidate group was founded on the determination of the most feasible (and, in some cases, not feasible) types proposed for implementation in nuclear power plant (NPP) control rooms. One list of display options was generated by EPRI.[30] A second list identified by the author is located in NUREG-0835.[8] The results of those lists were summarized and collated to produce the display categories presented herein.

A set of general guidelines, which are applicable to all Information Formats, is shown in Table 8. This top level table should supplement the guidelines and criteria presented for each following specific format. These guidelines should be used as supporting information with each of the specific variables. It is recommended that these guidelines be reviewed prior to investigating the specific variables.

TABLE 8. GENERAL GUIDELINES FOR INFORMATION FORMATS

- o Chernoff face representations and Linear Fourier Plots are NOT acceptable display patterns for a SPDS in NPP process control applications.
- o Recommend that a limited variety of graphic display techniques be used, so that personnel may become sufficiently familiar with each to extract information rapidly from the display.
- o Consider whether special training will be necessary to facilitate interpretation of unfamiliar graphic display techniques, such as the Chernoff face representation.
- o Content. The information displayed to an operator shall be limited to that which is necessary to perform specific actions or to make decisions.
- o Precision. Information shall be displayed only within the limits and precision required for specific operator actions or decisions.
- o Format. Information shall be presented to the operator in a directly usable form.
- o Redundancy. Redundancy in the display of information to a single operator shall be avoided unless it is required to achieve specified reliability.
- o Combining Operator/Maintainer Information. Operator and maintainer information shall not be combined in a single display unless the information content and format are well suited to, and time compatible for, both users.
- o Display Failure Clarity. Failure of a display or its circuit shall be immediately apparent to the operator.
- o Demand Information Versus Status Information--Demand information shows that equipment has been commanded (by control settings or otherwise) to a particular state or level. It shows only what is demanded--not what is actually being realized. Status information shows the state or level actually in effect.

    (1) To prevent operator confusion, it is essential that displays be identified as to whether they reflect demand or actual status.

(2) Video display of actual system/equipment status should be displayed for all important parameters.

o General Principles

1. Use the simplest display concept commensurate with the information transfer needs of the operator or observer. The more complex the display, the more time it takes to read and interpret the information provided by the display, and the more apt the observer or operator is to misinterpret the information or fail to use it correctly.

2. Use the least precise display format that is commensurate with the readout accuracy actually required and/or the true accuracy that can be generated by the display-generating equipment. Requiring operators to be more precise than necessary only increases their response time, adds to their fatigue or mental stress, and ultimately causes them to make unnecessary errors.

3. Use the most natural or expected display format commensurate with the type of information or interpretive response requirements. Unfamiliar formats require additional time to become accustomed to them, and they encourage errors in reading and interpretation as a result of unfamiliarity and interference with habit patterns. When new and unusual formats seem to be needed, consider experimental tests to determine whether such formats are compatible with basic operator capabilities and limitations and/or whether the new format does in fact result in the required performance level.

4. Use the most effective display technique for the expected viewing environment and operator viewing conditions (lighting, acceleration, vibration, operator position, mobility restrictions, etc.). Match the display technique to the operator's constraints; do not make the operator match the display.

5. Optimize the following display features:

   a. Visibility: Viewing distance in relation to size, viewing angle, absence of parallax and visual occlusion, visual contrast, minimal interference from glare, and adequate illumination.

b. Conspicuousness: Ability to attract attention and distinguishability from background interference and distraction.

c. Legibility: Pattern discrimination, color and brightness contrast, size, shape, distortion, and illusory aspects.

d. Interpretability: Meaningfulness to the intended observer within the viewing environment; requirements for interpretation, extrapolation, special learning, and training; and general reliability in terms of retention of meaning.

- o Illustrations, line drawings, and animation should be used to supplement the explanations in the text. Graphics are especially useful for spatial visualization problems or where the problem to be solved has multiple interacting dimensions. Graphical dialogues are intrinsically motivating, at least for the novice user.

- o The axes of graphs should always be labeled.[h]

- o Labels for graphs should describe what is being displayed, not the name of the display.

- o The axes of graphs should be subdivided approximately with divisions of 1, 2, 5, or 10, not with 3, 7, or other numbers obtained arbitrarily through division.

- o The number of graduation marks between numbered scale points should be greater than 9.

- o Scales should be numbered starting at zero.

- o Increases in magnitude on scales should be clockwise, left to right, or bottom to top.

- o Maximum contrast should be maintained between scale markings and the value displayed.

- o The size of the letters used to label scales should be independent of the scales on the displays on which they appear. If a user contracts a graphic display, labels must not be contracted to the point where they cannot be read.

TABLE 8. (continued)

- o If trend lines are to be compared, multiple lines should be used on a single graph.
- o Symbols should be designed with consideration of the graphic conventions to which the user may be accustomed, while at the same time being as economical as possible in the use of screen space and image complexity.
- o Unnecessary ornamentation, unwanted graphic patterns and illusions, and flaws in alignment should be avoided in graphic displays.
- o In graphic displays, the center of rotation should be the center of the object.

---

a. See Reference 8.

b. See Reference 57.

c. See Reference 16.

d. See Reference 6.

e. See Reference 20.

f. See Reference 36.

g. See Reference 94.

h. See Reference 113.

i. See Reference 56.

j. See Reference 114.

k. See Reference 90.

l. See Reference 91.

Analog

Definition. This type of information format is best characterized by a meter configuration (the most common being a moving pointer/fixed circular scale) but can also take the form of curved (arc), horizontal (straight), and vertical (straight) arrangement of either fixed pointer/moving scale or vice versa. Regardless of arrangement, values are indicated to the observer by a pointer position to scale relationship. Examples of moving-pointer and moving-scale indicators are shown in Figure 18.

The traditional uses of this format originate from hardwired instrumentation, but "software generated meters" which rely on these previous conventions and guidelines are certainly plausible for VDU applications.

General guidelines related to design and assessment of this information format are presented below. For the interested reader who desires further information concerning these formats beyond the guidelines discussed herein, NUREG-0700,[6] MIL-STD-1472C,[16] and Van Cott and Kinkade[19] are recommended.

Guidelines.	Research Support	Source
1. Analog displays should not be used when quick, accurate readings are a criterion. (See Note 1.)	Y	30
2. Numbers should increase clockwise, left to right, or bottom to top, depending on the display design and orientation.	Y	17

	Research Support	Source
3. 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.	Y	17
4. When check-reading positive and negative values, the zero or null position should be at 12 o'clock or 9 o'clock. (See Note 2.)	Y	17
5. All numbers should be oriented upright.	Y	17
6. Numbers should be outside the graduation (tick) marks unless doing so would constrict the scale. (See Note 3.)	Y	17
7. Numbers on moving scales should progress in magnitude like fixed scales (the numbers should increase in value by counterclockwise dial movement).	Y	17
8. For moving scales, numbers should be read at 12 o'clock for right-left directional information and at 9 o'clock for up-down information.	Y	17
9. On moving scales, the window should be large enough to permit seeing one numbered graduation on each side of the indexed number whenever the display is used to set in values. For tracking, the whole dial face should be exposed.	Y	17

	Research Support	Source
10. The pointer on fixed scales should extend from the right of vertical scales and from the bottom of horizontal scales.	Y	17
11. The pointer on fixed scales should extend to but not obscure the shortest graduation marks.	Y	17
12. 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.	Y	17
13. Nine should be the maximum number of tick marks between numbers.	Y	17
14. Tick marks should be separated by at least 0.07 inches for a viewing distance of 28 inches (710 mm) under low illumination (0.03-1.0 fL).	Y	17
15. Dials should not be cluttered with more marks than necessary for precision.	Y	17
16. Zones should be color-coded by edge lines or wedges. Red, yellow, and green should be used. (See Note 4.)	Y	17
17. Shape coding or striping should be used when red lighting or blackout station conditions prevail.	Y	17
18. Information should be in a directly usable form (for example, percent RPM).	Y	17

	Research Support	Source
19. Fixed-scale, moving-pointer displays should be used rather than moving-scale, fixed-pointer displays.		6

NOTE 1: Each analog display generally shows one discrete value of one variable in one dimension, which is the main reason why conventional display panels are so large. Because the user must estimate where the pointer is on the scale, these displays are most suitable for supplying approximate values. Although analog displays may be read accurately, it may take two to three times longer than reading a digital display accurately.[30]

NOTE 2: 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 multirevolution dials.[17]

NOTE 3: While this is desirable for preventing pointer head obstruction of numbers, the crowding of markings on small dials has resulted in most numbers being inside the marks.[17]

NOTE 4: Zones indicate operating ranges, dangerous levels, and so on.[17]

Comment. Conventional analog displays are exceptional for specific applications. The general pointer orientation gives a quick cue to scale-pointer relationship, rate of change, and reference to scale limits.[20] This technique is also suitable for qualitative information, check reading, for setting in numbers, and for tracking.[17] The disadvantage is requirement for large panel space. It can be argued that this technique does not fully exploit the full graphic capability of VDU technology. However, such a display arrangement is readily familiar to the operators,[30] thus minimizing training and potential for confusion.

Method for Assessment Inspect the screen(s) which utilizes this information format for assessment. Ensure that all markings and indications are clearly visible from the normal viewing distance. Next, verify that the display characteristics and usage comply with the above guidelines. If discrepancies are noted, either provide recommendations to enhance the current arrangement or suggest alternative information formats.

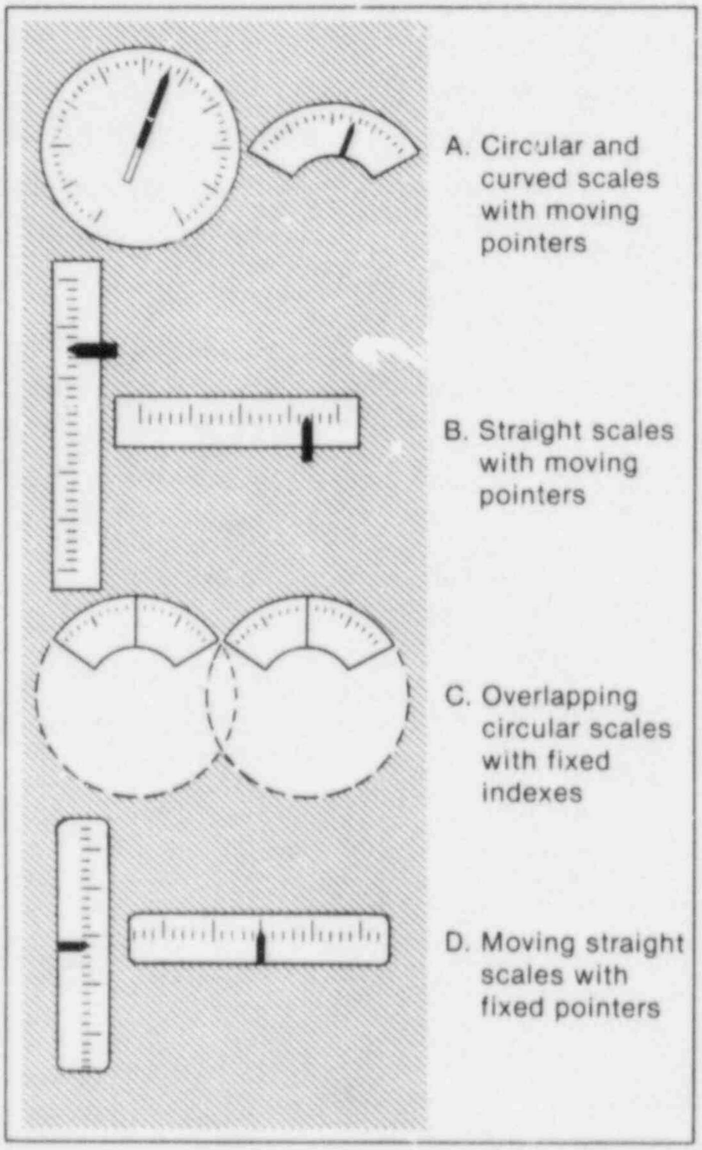


Figure 18. Types of moving-pointers and moving scale indicators (Source: Reference 60).

Digital

Definition. This information format represents the simplest and most frequently implemented display type for process control. Digital displays (counters) are most often recommended when presentation of precise quantitative data (or exact value) is required. They are best suited to one dimension, one variable, and one value, but they may be clustered together to show multiple dimensions or variables.[30] An example of this information format is shown in Figure 19.

An overview of the relevant guidelines pertaining to digital displays is presented below. As with many of the traditional display devices of this type, the majority of such guidelines is for mechanical counters rather than electronic or CRT displays. However, many of the basic principles from these earlier guidelines for mechanical devices are certainly applicable.

Guidelines.	Research Support	Source
1. Each digital display should have a label to identify its meaning. (See Note 1.)	Y	30
2. Digital displays should include the appropriate number of significant figures for the required level of accuracy.	Y	30
3. Digital displays should accommodate the full range of the variable (i.e., highest and lowest values).	Y	30
4. Digital displays should change slowly enough to be readable.	Y	30
5. Digital displays should be provided with arrows to indicate the direction of change (if that is likely to be needed).	Y	30

	Research Support	Source
6. If more than four digits are required, they should be grouped and the groupings separated as appropriate by commas, a decimal point, or additional space.		6
7. The window should be sized to allow no more than one digit per drum to appear in the window at any one time.		6
8. Numbers should change by snap action rather than through continuous movement.		6
9. The counter drums should move upward with increasing values.		6
10. Mulitdigit counters should be oriented to read horizontally from left to right.	Y	6
11. Simple character fonts should be used.	Y	6
12. Horizontal spacing between numerals should be between one-quarter and one-half the numeral width.	Y	6

NOTE 1: Multiple digital values often appear in tables in printed material, but this should be avoided on VDUs. Tables of numbers on VDUs often appear too dense and cluttered, making it easy for the viewer to read the wrong row or column. Placing a straight edge on the screen to follow a row or column is less simple than it is on printed material.[30]

NOTE 2: Styles using variable stroke widths, slanted characters, etc. should be avoided.[6]

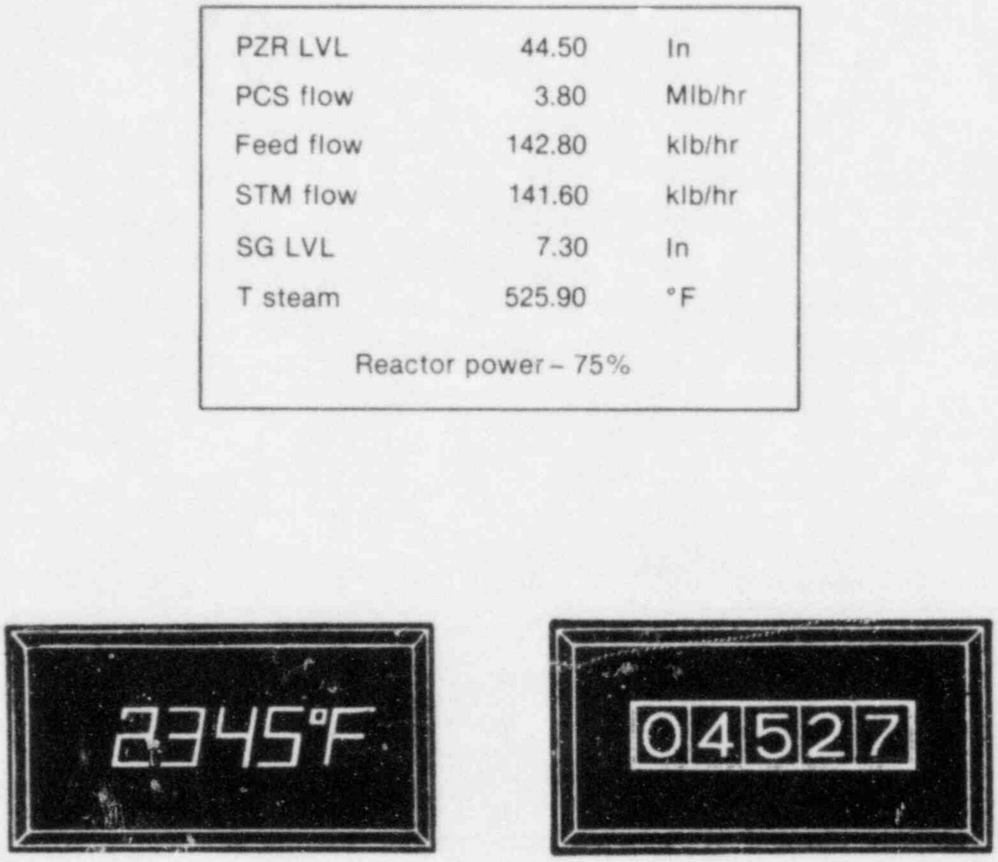
Comment. Many of the above guidelines are echoed throughout the human engineering design literature and appear relatively standardized across references. One exception was noted in the guidelines between MIL-STD-1472C[16] and NUREG-0700.[6] NUREG-0700 recommends, "If more than four digits are required, they should be grouped and the groupings separated as appropriate by commas. . ." MIL-STD-1472 states, "Commas shall not be used." The tradeoffs are not altogether clear, whether pro or con, for commas. Consideration for this guideline is probably dependent on a task specific situation.

In the guidelines concerning digital displays, Bailey[14] also noted some disadvantages to this format: (a) determining the rate of change is difficult, (b) reading rapidly changing display values is difficult, (c) interpolating is difficult when two numbers are partially visible in a window, and (d) gauging distance to a boundary (control limit, danger zone) is difficult.

These constraints should be examined in conjection with the design guidelines to ensure that this format is the most appropriate technique for a given application.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessments. Ensure the characteristics comply with the guidelines presented above. Also determine whether or not this technique is relevant to the specific operator's task and is not in violation of the constraints proposed by Bailey[14] in the Comments section.

If discrepancies are noted, either provide recommendations to enhance this format or suggest an alternative format.



5 1677

Figure 19. Examples of digital/counter type displays.

Binary Indicator

Definition. This technique and the guidelines proposed for it are representative of another information format often used on conventional display panels. It is usually applied to meet those display requirements which require two-valued information (go-no go, start-stop, safe-unsafe, warning-caution, etc.). The most common of these uses is seen in alarm/warning devices. An example of this information format is shown in Figure 20.

A brief overview of this technique is discussed in the guidelines below. Further information with specific reference to this format as an alarm/warning device can be gleaned from the category on "Enhancement Coding."

Guidelines.	Research Support	Source
1. Binary indicators should be clearly labeled and understood. (See Note 1.)	Y	30
2. For quantitative measurements, binary indicators should be used ONLY for check-reading purposes.	Y	18
3. Alerting the operators to unfavorable status should be a function of the annunciator system and not assigned to light indicators.	Y	6
4. Where meaning is not apparent, labeling should be provided close to the light indicator showing the message intended by its glowing.	Y	6
5. The color of the indicator should be clearly identifiable.	Y	6

	Research Support	Source
6. Legends should be legible under ambient illumination with indicator lights "off".	Y	6
7. General legend design should be consistent throughout the control room.	Y	6
8. Symbolic legends should be clear and unambiguous as to their meaning.	Y	6
9. Legend text should be short, concise, and unambiguous.	Y	6
10. Legend messages should contain no more than three lines of texts.	Y	6
11. Legend nomenclature and abbreviations should be standard and consistent with usage throughout the control room and in the procedures.	Y	6
12. Legends should be worded to tell the status indicated by glowing of the light.	Y	6
13. The legends of illuminated indicators should be readily distinguishable from legend push buttons by form, size, or other factors.	Y	6

NOTE 1: It is critical that binary indicators be clearly labeled and understood, as misinterpretation would give the user the opposite of the intended message.[30]

NOTE 2: This criterion has special emphasis to VDUs when touch panels are employed as a control device.

Comments. An assessment of this information format would not be complete without consideration of the assorted coding dimensions associated with this type of format (flash rate, color, intensity, etc.). In addition, as with other alarm/warning techniques, this method should not be overused. Too many indicators will "clutter" the screen or make it appear "busy," thus overloading the operator.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessments. Ensure that the indicators are supplemented with textual labels (or other appropriate coding approach) if the meanings are not obvious. Also, ensure that this format is not overused to the point where the screens appear "busy" to the operator.

If discrepancies are identified, either provide recommendations to enhance this dimension (e.g., alter the enhancement coding dimensions) or suggest an alternative format.

PRIMARY FLOW	COLD LEG TEMPERATURE	DELTA TEMPERATURE	PRIMARY PRESSURE	PRESSURIZER LEVEL
SECONDARY PRESSURE	SECONDARY FEED FLOW	STEAM CONTROL VLV POSITION	STEAM GEN LEVEL	CONDENSER PRESSURE

5 1678

Figure 20. Example of alarm warning device display.

Bar/Column Charts

Definition. The bar/column chart is probably one of the most popular graphical information formats proposed for use in process control. The different arrangements of displays which implement a bar chart approach are almost limitless. For bar charts, "simple" and "deviation" are two techniques most often encountered. A simple bar chart contains horizontally oriented rectangles or bars emanating from a single vertical line. In a deviation bar chart, each item has a bar extending either to the right or left of a common vertical base line to indicate deviations from some "normal" value.[112] Similar configurations exist for column charts with the difference being vertically oriented rectangles.

This technique, as described in NUREG-0835,[8] "synthesizes an array of analog meters." Further definition can be best described by the following attribute germane to all bar/column charts: the length of each bar is generally proportional to the magnitude of the measured parameter it represents.[8] Examples of simple bar, simple column, and deviation bar charts are shown in Figures 21, 22, and 23.

The guidelines in this section are devoted to these major types with the known intent that a multitude of variations can be founded on the basic configurations discussed here.

Guidelines.	Research Support	Source
1. Each bar on the display should have a unique identification label. (See Note 1.)	Y	8
2. Bar charts should contain reference(s) to the normal operating conditions(s). (See Note 2.)	Y	8

	Research Support	Source
3. Column 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. (See Note 3.)	Y	30

NOTE 1: 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.[8]

NOTE 2: With references showing normal parameter operating values, the operators are more likely to notice deviations from normal conditions.[8]

NOTE 3: Column charts are similar to bar charts, except that the columns run vertically instead of horizontally. This seemingly trivial difference leads to subtle differences in how information is perceived. First, because the column heights move vertically, there is a natural compatibility between a rise in the value of a variable and a rise in the column height. Second, because the scale of the variable is on the Y axis, the X axis can be used to denote time. (For a bar chart, time would be on the Y axis, which runs counter to convention.) In the conventional column chart, values increase from bottom to top.[30]

Comment. In addition to the guidelines presented above, the displays should also comply with "good" human factor engineering standards and practices, i.e., are the displays legible, cluttered, inconsistent, labeled, etc. It is also important to emphasize the need for reference points to indicate normal operating status. In other observations of these guidelines, it was noted that they have failed to discuss the advantages or disadvantages between column versus horizontal presentation. The only known guidelines addressing this issue were located in work performed by EPRI,[30] but detailed tradeoff guidance between horizontal and column presentation is limited.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Determine whether or not the overall display complies with "good" human factors standards and practices. Assess the display to ensure that reference points are prominently presented to indicate normal operation. If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format.

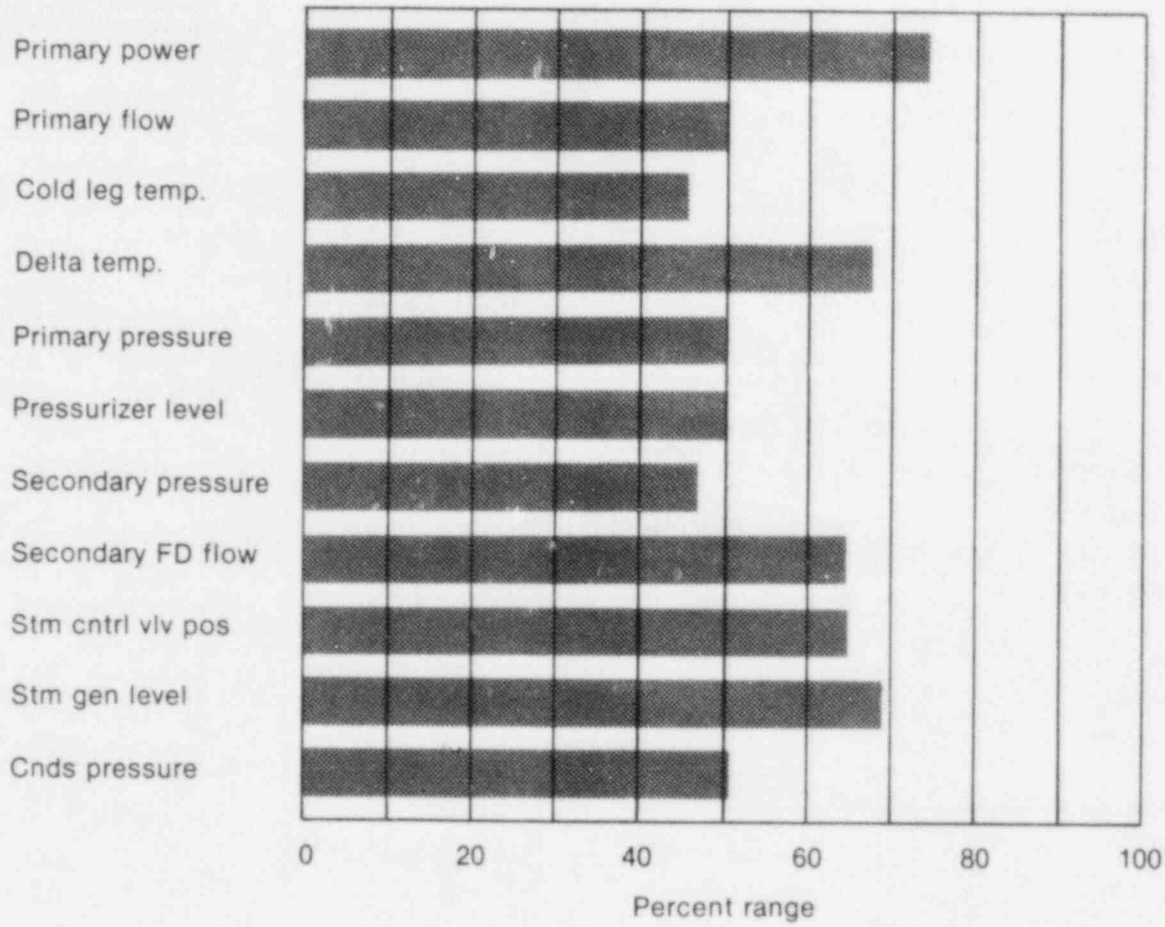


Figure 21. Example of a simple bar chart.

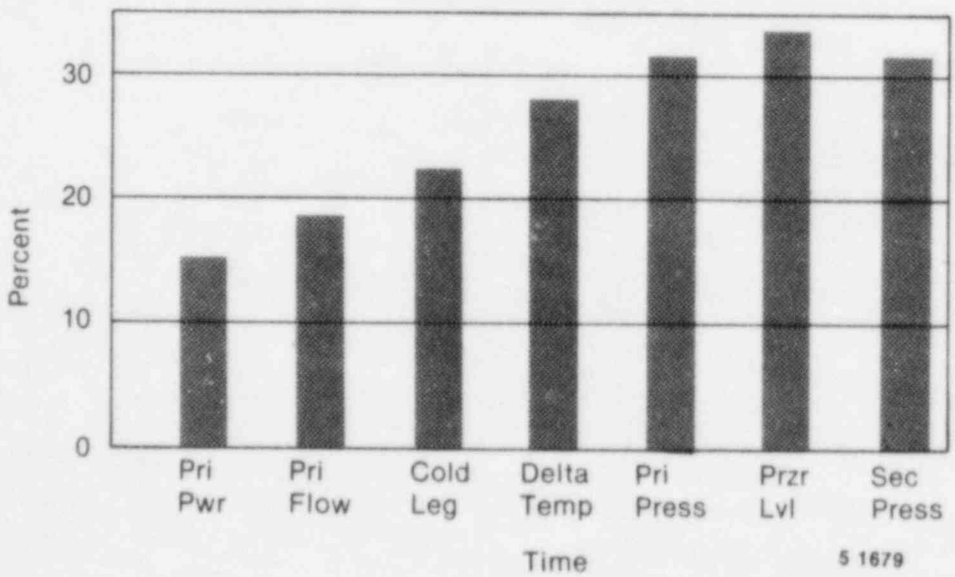


Figure 22. Example of a simple column chart.

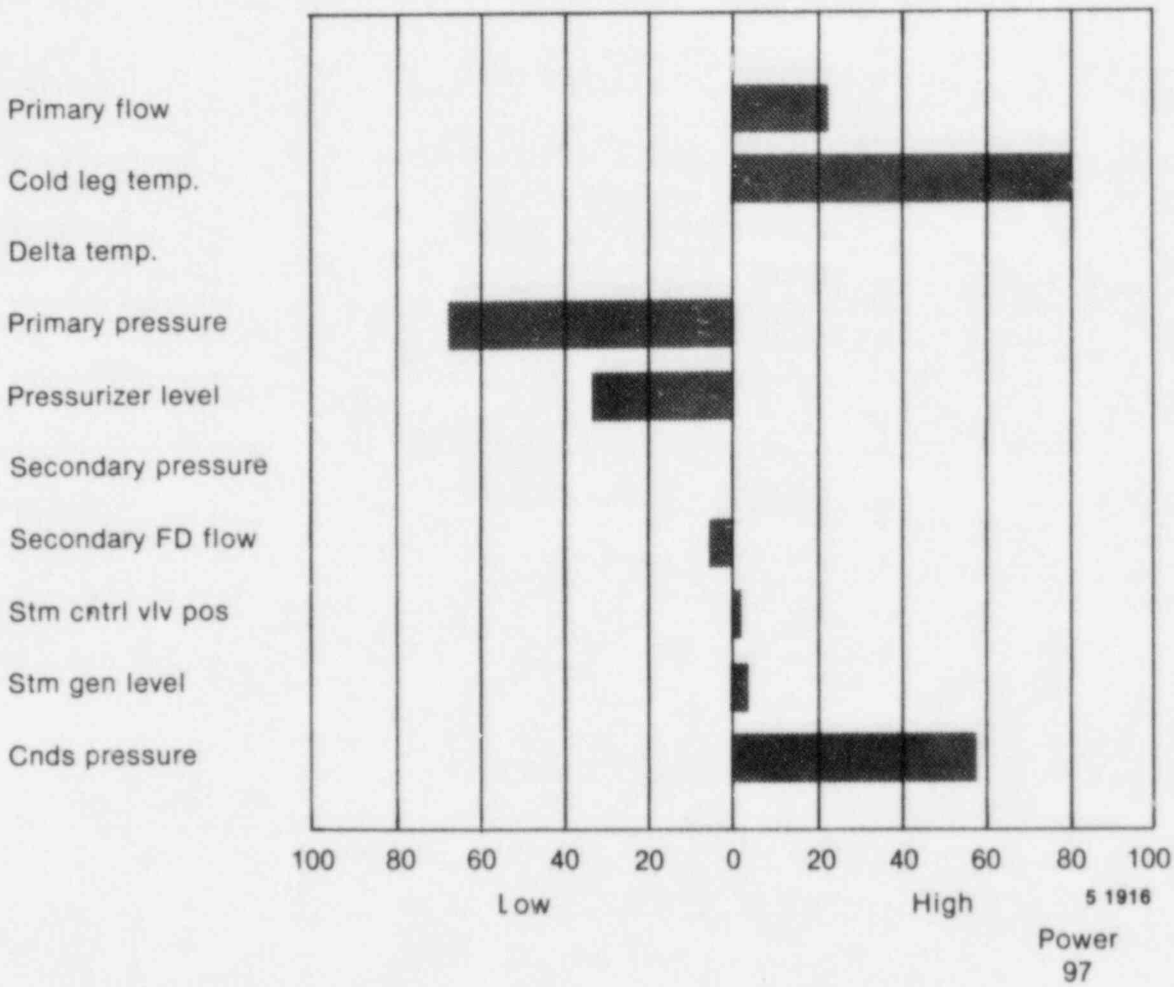


Figure 23. Example of deviation bar chart.

Band Chart

Definition. This type of information format 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.

An example of this type of information format is presented in Figure 24.

Guidelines.	Research Support	Source
1. All items on a band chart should be related to the total. (See Note 1.)		112

NOTE 1: This type of chart (band chart) can be used to show, for example, 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.[30]

Comments. Specific guidelines pertaining to this format are limited. However, this format appears to have useful application provided its implementation does not violate the following constraints identified by Danchak:[112]

- All components must be related to the total.
- Not to be used when changes in the movement of a series are abrupt.
- Not to be used where accurate reading of a component is of paramount importance.

The layout of the display type should also be in compliance with "good" human factors engineering standards and guidelines.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Determine whether or not the overall display is in compliance with "good" human factors standards and practices. Assess the display to ensure its use does not violate the limitations described by Danchak.[112] Also, verify that all components are related to the whole (i.e., avoid attempts at summing up "apples and oranges"). If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format.

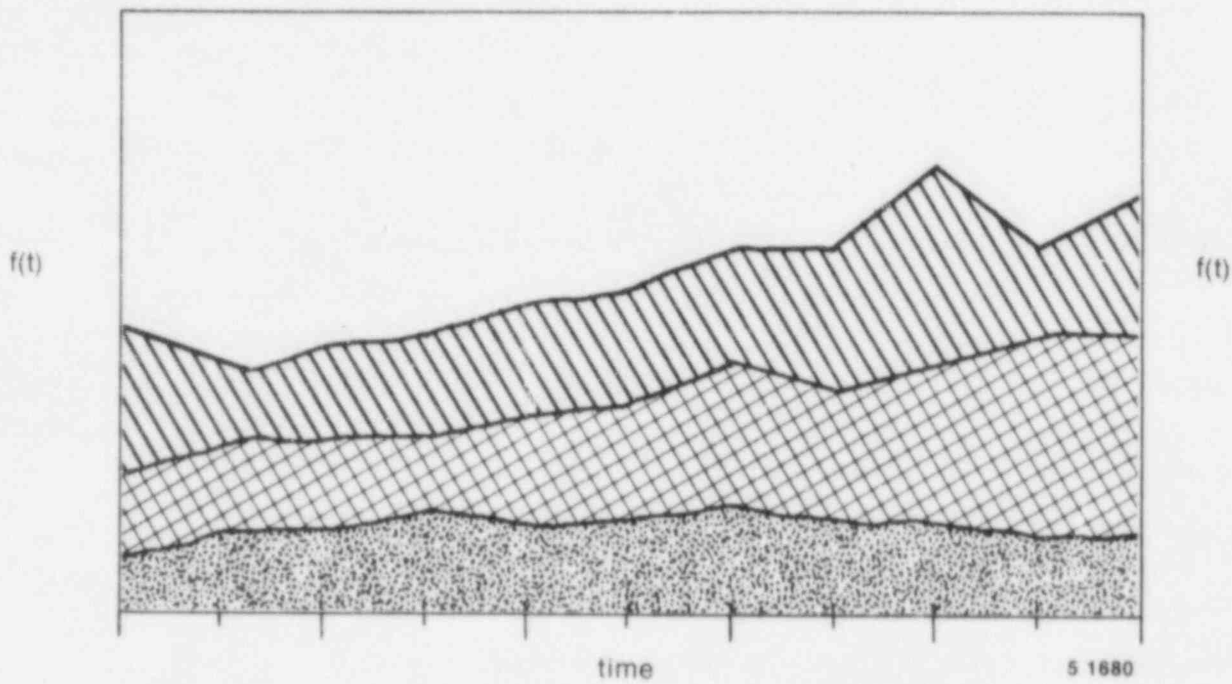


Figure 24. Example of multiple surface/band chart.

Linear Profile

Definition. The linear profile format is analogous to a modified version of a column chart and band chart. The wide bars common to the column chart are replaced by thin lines. The vertical height or magnitude of those lines, all emanating from a base line on the X axis, represent parameter values. The maximum heights of each line are connected by a profile line (analogous to a band chart). This profile line graphically shows the nature of a relationship between variables. For example, an irregular profile would be indicative of abnormal operating conditions.

An example of this type of information format is shown in Figure 25.

Guidelines.	Research Support	Source
1. A horizontal line representing normal operating conditions should be superimposed on the display. (See Note 1.)	Y	8
2. The area below the profile line should be shaded to provide a more distinguishable profile.	Y	8
3. Labels should be provided along the bottom to identify each parameter.	Y	8
4. Linear profile charts should be used in applications where detection of abnormal events is important. (See Note 2.)	Y	112

NOTE 1: Scaling considerations for the linear profile are the same as for the bar chart. A horizontal line, representing normal operating conditions superimposed on the display, is an acceptable enhancement.[8]

NOTE 2: The linear aspect of this display is confusing and makes pattern recognition marginal, but it is considered adequate for determining the problem as well as severity.[112]

Comment. This format provides the operator with a set of pattern recognition cues which would be highly desirable for detection of abnormal events. Though it is not considered as effective as circular profiles in which the patterns generated are deemed more prominent, Danchak[112] also suggests that the simple bar chart design may be superior to linear profiles. As evidenced from the above guidelines, specific data for this format are lacking and more research is needed.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Determine whether or not the display is within compliance with "good" human factors standards and practices. Interview a group of operators and determine: if the display patterns actually enhance the operators detection of abnormal events, i.e., do they understand the meaning of the display patterns? Have they received any training concerning its use? Are the parameters legible and easily discriminative from each other?

If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format (i.e., simple bar chart).

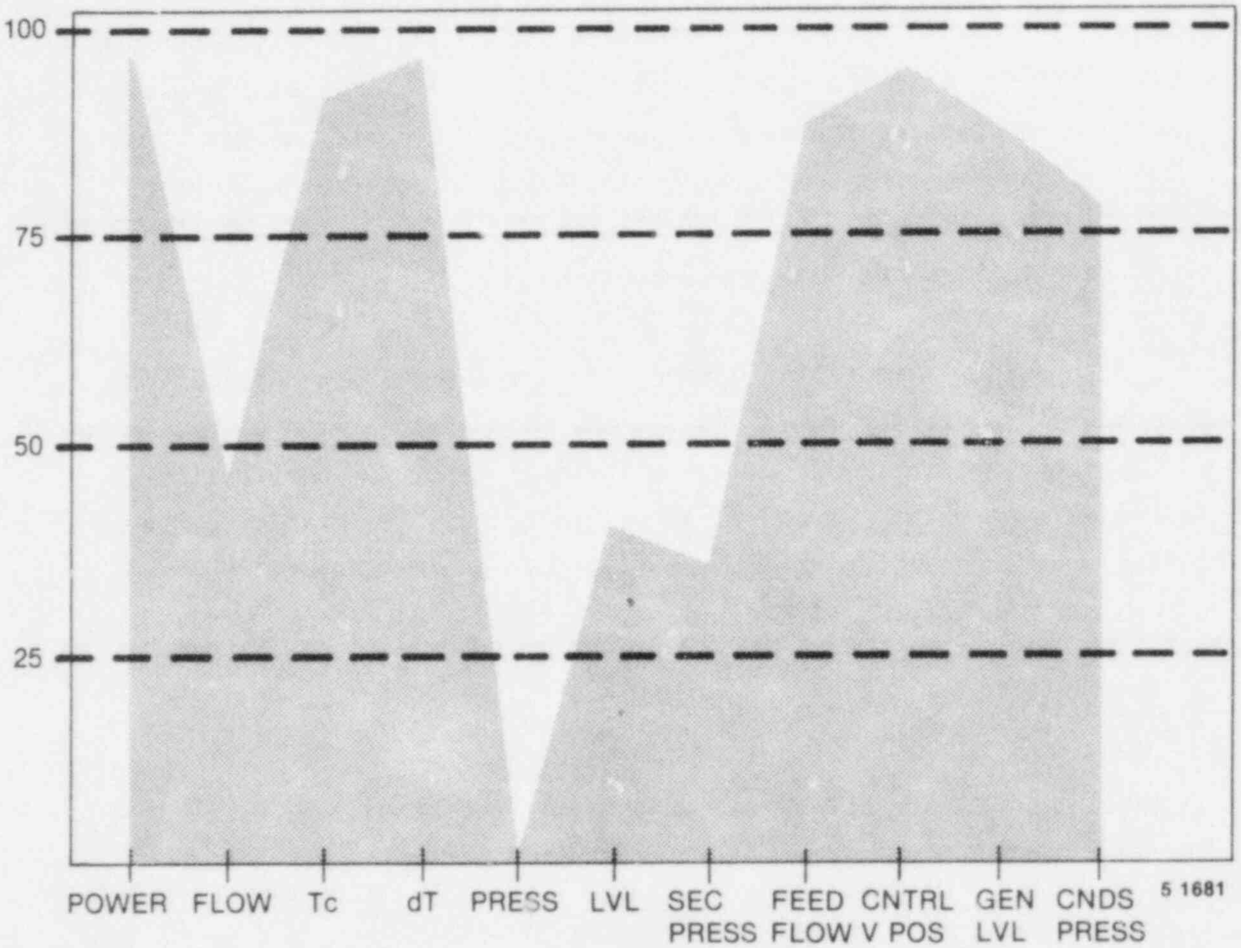


Figure 25. Linear profile display.

Circular Profile

Definition. This format is also often referred to as a star display or n-fold circular display. In a circular profile, the same principles apply as with the linear profile with one distinct difference: the parameter lines of a linear profile, which emanate from a common baseline, are joined at a common origin. In this manner, the parameter lines (or spokes) now radiate from the origin point (center of the "circle") with equal angular spacing relative to each other. As with the linear profile, the distance along each spoke from the center represents the value of the parameter, and the scales are indexed such that the normal value of each of the variables can be connected to form some easily recognizable polygon. For example, under normal operating conditions the profile should be circular. An irregular profile is indicative of an abnormal operating condition.

An example of this information format is shown in Figure 26.

Guidelines.	Research Support	Source
1. The chart should be designed so that it forms recognizable geometric patterns for specific abnormal conditions. (See Note 1.)	L	30
2. Labels should be provided to identify each radial line.	Y	8
3. The area within the profile should be shaded to enhance the operator's perception of plant status.	L	8

NOTE 1: 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. Research with this type of picture element has shown promise but may require more training than is necessary for use of the more familiar picture elements.[30]

Comment. This format is considered an extremely effective mode of providing a set of pattern recognition cues to the operator as an aid for detection of abnormal events. It is also useful for showing the relationship between variables that do not have the same units.

As evidenced from the guidelines, specific data for this format are lacking and more research is needed.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Determine whether or not the display is within compliance with "good" human factors standards and practices. Interview a group of operators and determine: if the display patterns actually enhance the operators detection of abnormal events, i.e., do they understand the meaning of the display patterns? Have they received any training concerning its use? Are the parameters legible and easily discriminative from each other?

If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format.

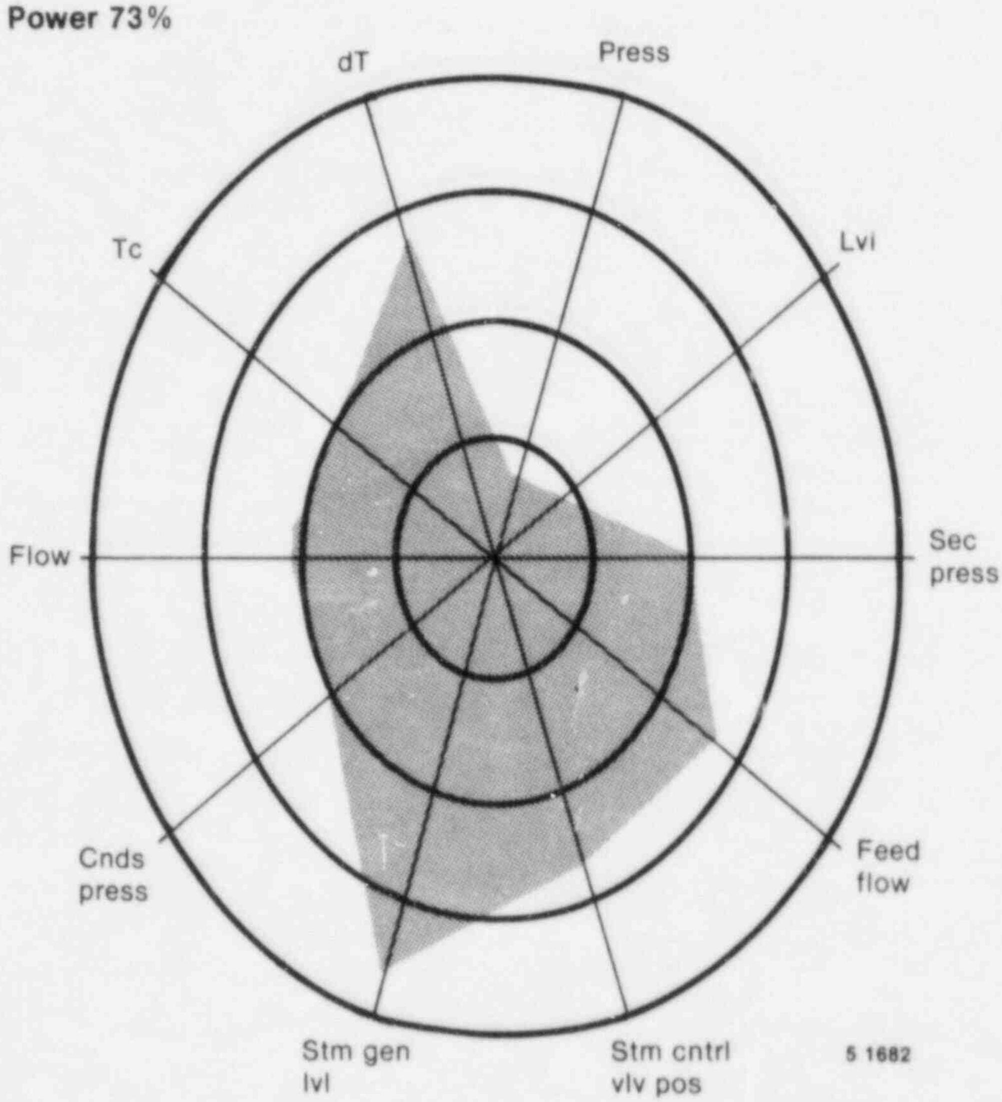


Figure 26. Example of circular profile display.

Single Value Line Chart

Definition. This format is a parameter versus parameter type chart where one dimension is plotted against the other (e.g., pressure versus temperature) on an X-Y axis. This generic pattern is well suited for design of the classical Pressure-Temperature (P-T) map used in the nuclear industry. The P-T map concept is not a recent innovation. The principles of this technique have historically been implemented as an operator information aid in a hard copy format. Such P-T graphs are integrated into the plant operating procedures and technical specifications. The recent innovations in VDU technology have made it possible to display dynamic process information in this form. The basic P-T map has the following features:

- o Parameter values (e.g., hot leg and cold leg temperature and pressure) are plotted as an identifiable cursor on the map.
- o A saturation curve is provided which applies to both primary and secondary water and steam conditions. Above the saturation line is the subcooled water region; below it is the superheated steam region.
- o Each of the cursors is surrounded by a box which represents "normal" operating boundaries. Deviations from those normal operating boundaries are indicated by data points (or trails).

An example of this information format is shown in Figure 27.

Guidelines.	Research Support	Source
1. The target area should be defined. (See Note 1.)	L	30
2. Old data points should be removed after some fixed period of time. (See Note 2.)	L	30

NOTE 1: 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.[30]

NOTE 2: To avoid clutter, the old data points should be removed after some fixed period of time. Ideally, as one new point is plotted the oldest point is removed, thereby maintaining a constant number of displayed points. Hardware limitations may force one to plot an entire series, clear the screen, and begin plotting over again, although this is much less desirable.[30]

Comment. When effectively applied, an information-rich display can be created using a P-T Map concept. The introduction of the data trails also aids the operator in mitigating an abnormal event. Therefore, the P-T map can be used to not only detect and identify an event but to track and follow to mitigation as well. However, caution should be exercised to avoid the display of "too much" information. Otherwise, clutter is induced and operator performance may actually be degraded. Other potential problems may reside in the training requirements needed to effectively utilize this information resource. In other words, operators cannot be expected to do well if training is either cursory or inadequate.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Determine whether or not the display is within compliance with "good" human factors standards and practices. Interview a group of operators and determine: if the display patterns actually enhance the operators detection of abnormal events, i.e., do they understand the meaning of the display patterns? Have they received any training concerning its use? Are the parameters legible and easily discriminative from each other?

If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format.

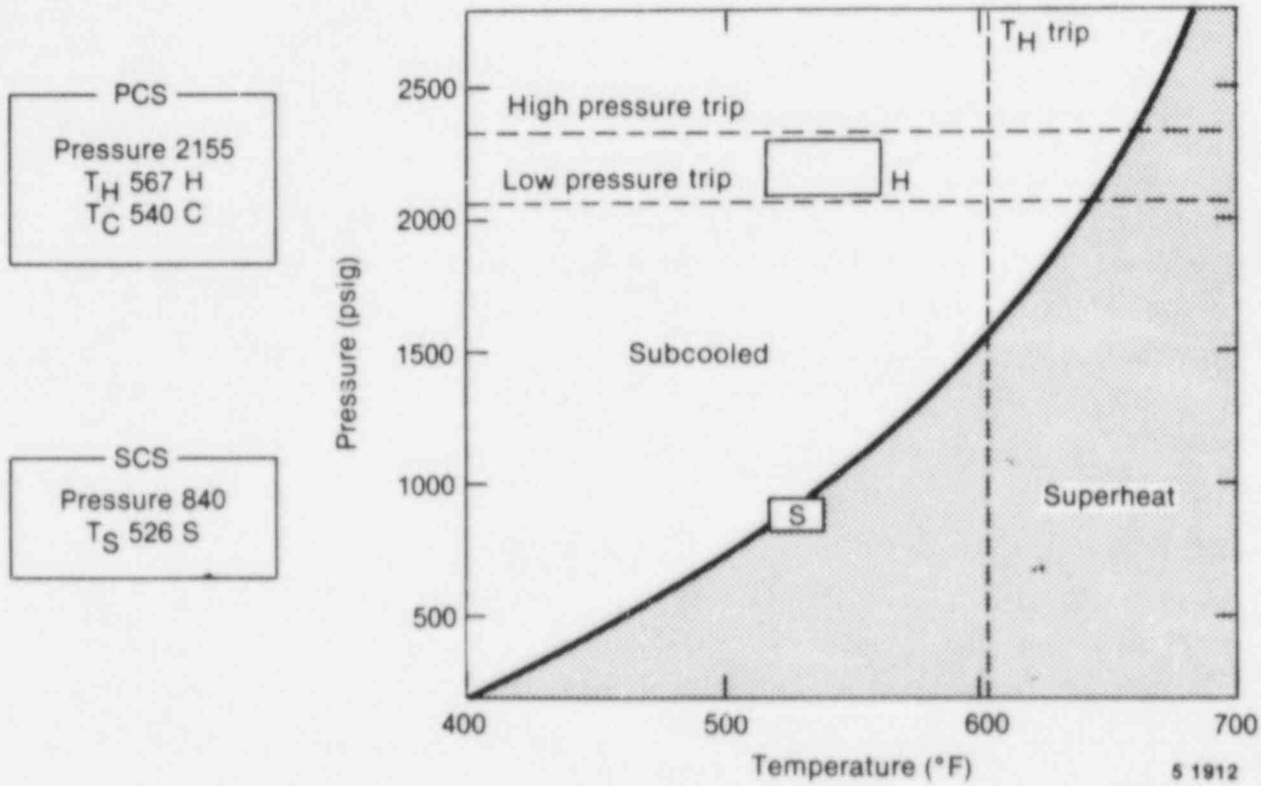


Figure 27. Example of Single Value Line Chart.

Trend Plot

Definition. This information format is simply an X-Y axis with the behavior of the X-Y values described by a function curve. Time is generally plotted on the X axis, while the Y axis is reserved for some parameter value. The plot historically depicts how one or more variables and/or one or more dimensions vary over time.

An example of this information format is presented in Figure 28.

Guidelines.	Research Support	Source
1. 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. (See Note 1.)	Y	30, 115
2. When more than one parameter is presented in a plot, there should be means of identifying each individual parameter. (See Note 2.)	L	8
3. When more than on parameter is displayed on a plot, the grouping of the parameters should enhance the operator's assessment of the safety status of the plant.	L	8, 93
4. CRT-displayed trend plot scales should be consistent with the intended functional use of the data. (See Note 3.)	L	6
5. Graphic lines should contain a minimum of 50 resolution lines per inch. (See Note 4.)	L	6

	Research Support	Source
6. Trend displays should be capable of showing data collected during time intervals of different lengths. (See Note 5.)		
7. If the general shape of the function is important in making decisions, a graph should be chosen rather than a table or scale; if interpolations are necessary, graphs and scales should be used in preference to tables.	L	60
8. 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.	L	60
9. For tasks requiring both time to estimate trends and accuracy, the line graph should be used rather than horizontal bar or column charts.	Y	114
10. Time history displays of safety status parameters should present the 30-minute interval immediately preceding current real time. (See Note 6.)	L	8

NOTE 1: Research has shown that if time is plotted on the X axis, it should increase from left to right (i.e., the most recent data on the right). However, if time is plotted on the Y axis, it should increase from top to bottom, toward the origin, (i.e., the most recent data on the bottom), although this runs counter to the operation of most conventional strip chart recorders.[115]

NOTE 2: It is acceptable to display the minimum parameter set using several plots, each plot containing one or more variables. When more than one parameter is presented in a plot, there should be means of identifying each individual parameter. Color coding of traces is acceptable. Color codes used, however, must not conflict with other uses of color in the display.[8]

NOTE 3: For example, the monitoring of neutron flux at reactor trip may 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.[6]

NOTE 4: A graphic line will appear continuous if the separation between addressable points, or resolution elements, is less than one minute of arc. To provide the illusion of continuity, graphic lines should contain a minimum of 50 resolution elements per inch.

NOTE 5: Trend displays show the values of key variables over a period of time. A useful trend display should be capable of showing data collected during time intervals of different lengths. 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.[93]

NOTE 6: 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 30 min immediately preceding current real time is acceptable. This time period is consistent with the startup time required for activating the Technical Support Center (TSC). Availability of time history data displays on either the primary SPDS display format or on a secondary SPDS display format is acceptable.[8]

Comment. This information format is most applicable when the operator's task requires presentation of historical or trend data. However, the implementation of this format should not violate the following constraints identified by Danchak.[112]

Not to be used:

- o When there are relatively few plotted values in the series
- o When emphasis should be on changes in amounts rather than on movement
- o To emphasize differences between values or amounts on different data
- o When movement of data is extremely violent or irregular
- o When presentation is for popular appeal.

Caution should also be advised not to group more than three parameter lines on a single X-Y axis. Multiple parameter lines on the same axis should also be discriminative by some form of highlighting (dashed lines, solid lines, colors, etc.).

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Ensure compliance with the above guidelines. Determine whether or not the display is within compliance with "good" human factors standards and practices. Interview a group of operators and determine: if the display patterns actually enhance the operators detection of abnormal events, i.e., do they understand the meaning of the display patterns? Have they received any training concerning its use? Are the parameters legible and easily discriminative from each other?

If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format.

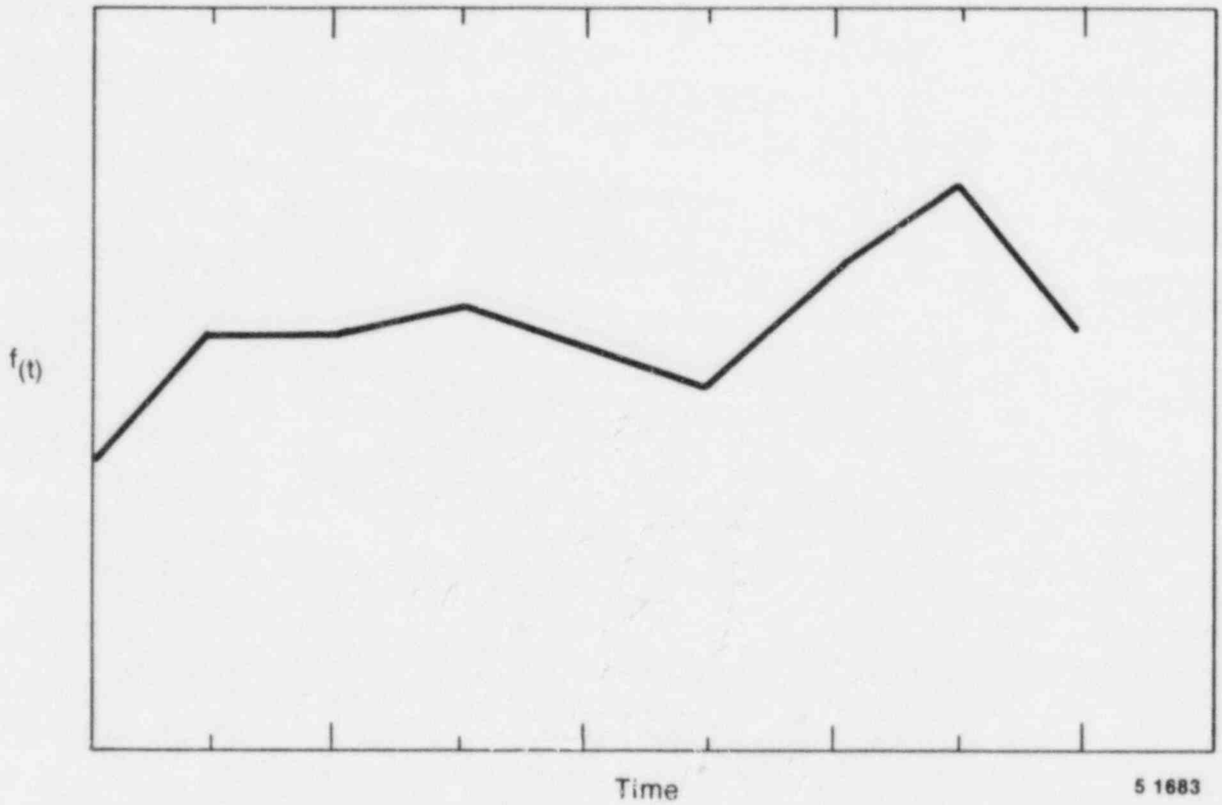


Figure 28. Trend plot.

Mimic Display

Definition. A typical mimic display used for process control systems consists of a combination of graphic and alphanumeric elements. The features of this format generally take on the form of standard Piping and Instrumentation Diagrams (P&IDs). Mimics integrate system components into functionally oriented diagrams that reflect component relationships. Properly designed mimics should decrease the operators decision making load.[6]

An example of this information format is shown in Figure 29.

Guidelines.	Research Support	Source
1. A mimic should contain just the minimum amount of detail required to yield a meaningful pictorial representation. (See Note 1.)	L	30
2. Abstract symbols should conform to common electrical and mechanical symbol conventions whenever possible.	L	6, 30
3. Differential line widths should be used to code flow paths (e.g., significance, volume, level).	L	6
4. Mimic lines should not overlap.	L	6
5. Flow directions should be clearly indicated by distinctive arrowheads.	L	6
6. All mimic origin points should be labeled or begin at labeled compontents.	L	6

	Research Support	Source
7. All mimic destination or terminal points should be labeled or end at labeled components.	L	6
8. Component representations on mimic lines should be identified.	L	6
9. Symbols should be used consistently.	L	6

NOTE 1: A mimic may be simple or detailed, and the symbols may range from abstract to pictorial. In general, one should supply the minimum amount of detail to yield a meaningful pictorial representation.[30]

Extraneous detail will create a more cluttered mimic and may detract from meaningful information. For example, do not display bends in pipes just because there are bends in the actual pipe, unless this conveys useful information. Elements of a system that are physically close to each other should be displayed physically close in a mimic. However, for the sake of clarity, one may wish to move elements around on a display. In this case, demarcation lines may be used to indicate that the elements belong together.

Comment. The uses of a dynamic mimic display to depict overall operational status and control of plant conditions can be an extremely powerful tool. This technique aids the operator as an efficient device for overseeing the operation of various plant systems. Specific research data are limited, and detailed guidelines are dependent on the operator's tasks. In addition, mimic displays are also made up of many components, and an effective mimic cannot be developed without attention to optimizing those other factors (color, graphic symbols, demarcation lines, labels, etc.).

Perhaps the greatest design shortcomings which may underutilize a mimic display's effectiveness are:

- o Screen clutter and layout--attempting to put too much information on the screen and/or adherence to detail beyond the needed requirements (i.e., screen clutter).
- o Graphic symbols and labels--symbols (or labels) with intended meanings that are not meaningful or understandable and/or their placement is not in proximity to the elements they describe.
- o Spatial relationships--the systems being mimicked do not conform to the spatial relationship of the actual process system.

Method for Assessment. Inspect the screen(s) which utilize this information format for assessment. Ensure compliance with the above guidelines. Evaluate the screen(s), addressing the issues contributing to an ineffective design as cited in the Comments section. Determine whether or not the display is within compliance with "good" human factors standards and practices.

Interview a group of operators and determine: if the display patterns actually enhance the operators detection of abnormal events, i.e., do they understand the meaning of the display patterns? Have they received any training concerning its use? Are the parameters legible and easily discriminative from each other?

If discrepancies are noted, either provide recommendations to enhance the format or suggest an alternative format.

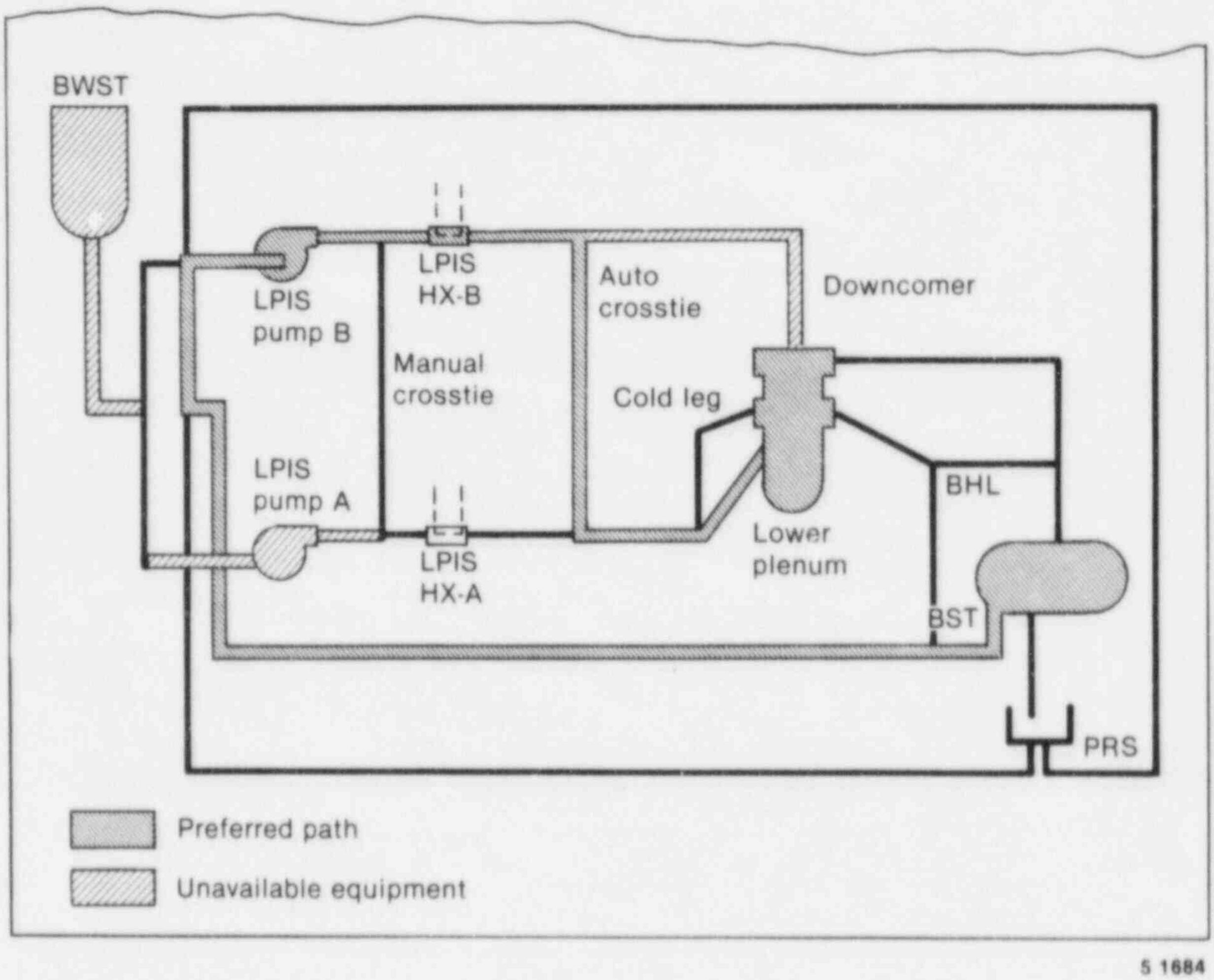


Figure 29. Example of mimic display.

CONTROLS

Keyboard Layout

The variables comprising this subsection concentrate on the following characteristics of the keyboard:

The typical VDU keyboard consists of the following groups of keys:

- o The alphanumeric or main keyset
- o The function keyset
- o A cursor control keyset
- o Numeric key set (optional).

The basic alphanumeric set is comprised of 26 upper and lower case characters, 10 numerals, and a special symbol set. In addition to the standard alphanumeric keyset, the basic keyboard is usually accompanied with a set of function keys. The most common keys might be the "return," "shift," and "reset." A special set of programmable function keys are also

usually available. The cursor control keyset consists of all devices for cursor positioning. This set encompasses the "Tab" key and spacebar. Many keyboards also possess the directional arrow cursor keyset.

A standard QWERTY arranged keyboard, with the key groups previously described, is shown in Figure 30. For english speaking countries, it might be noted that the QWERTY alphanumeric arrangement is the most commonly accepted standard. The other remaining keygroups do not necessarily adhere to any known standardization.

This is also true of the special characters within the QWERTY arrangement (e.g., 0, 1, 7, %, etc). The exception, in terms of numerical arrangement, might be the numerical keyset. The selected locations for the function and cursor control keysets are highly varied (other than perhaps the space bar) and inconsistent amongst models. Examples of this disparity are shown for four models in Table 9. These differences cause initial confusion to the user when transitioning between keyboards of different models. There is an obvious need to standardize all keys, but, for the present, the current human factors data base is incomplete in establishing concrete guidelines.

TABLE 9. DIFFERENCES IN LOCATION, LABELING, AND TYPE OF CONTROL FOR FOUR COMMON DATA ENTRY KEYBOARDS (Source: Reference 17)

Function or Character	Model A	Model B	Model C	Model D
Break	"Attn" Left side	"Break" Right side	"Break" Right side	None
Carriage return	Right side vertical bar	RETURN Right side horizontal bar	RETURN Right side horizontal bar	Right side square key
Enter	Same as above	Same as above	Same as above	"Enter" Bottom right side (separate function)
Numerics	Conventional typewriter (across top)	Conventional typewriter	Three types: conventional, keypunch, and 10 keys on right side (separately)	Conventional key-punch or 10-key type
On-off	Right front rocker switch	Right rear rocker switch	Left rear rocker switch	Right front push-pull control
Clear	None	Right side	Hit "Cntrl" and "L" at same time	Hit "Alt func" and "Clear" at same time
!	Right of "P" (lower case)	Above "1" (upper case)	Above 1 (upper case)	Above 1 (upper case)
:	Right of "L" (upper case)	Right of "0" (lower case)	Right of ; (lower case)	right of L (upper case)

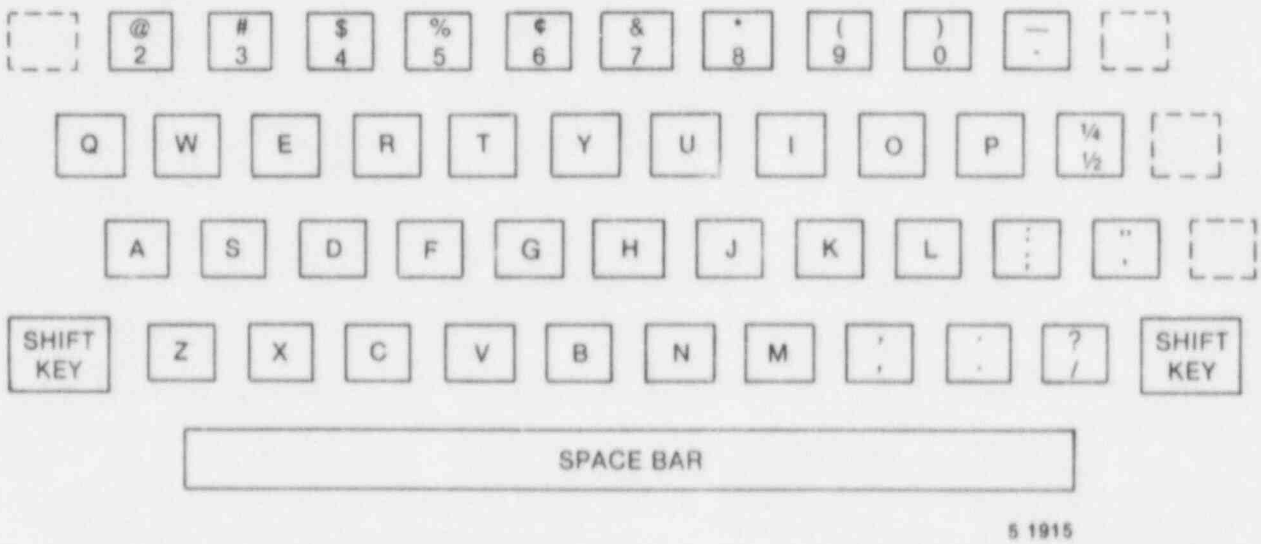


Figure 30: Standard QWERTY keyboard arrangement.

Keystroke Feedback

Definition. The subject of "feedback" in VDU systems can take on many forms. The emphasis for this variable is on the form of feedback as it applies to the keystroke. Specific feedback to the operator can be tactile, auditory, or visual indication that the key has been activated. The assumption is made that the majority of keyboards display the correct symbol on command from the keyboard to the screen via the character generator logic. The presence of lag in the system from input (press key) to output (character presented on screen) is also assumed to be at a minimum. Therefore, with visual feedback interpreted as a "given" in most systems, the guidelines are pointed toward alternative modes of keystroke feedback (i.e., auditory, tactile).

The appropriateness of these forms are task dependent, but the literature indicates some general recommendations which are applicable to the majority of operating conditions.

Guidelines.	Research Support	Source
1. An indication of control activation should be provided (e.g., snap feel, audible click, or associated or integral light). (See Note 1.)	L	6, 16, 22, 24, 57

NOTE 1: The activation of each key should be accompanied by a feedback signal (e.g., audible click, tactile click or snap action). Tactile feedback provided by a collapsing spring or a similar snap-action mechanism gives the key a positive feel which helps the operator to avoid missed or multiple key-strokes through uncertainty or as the result of "teasing" the key.

Comment. Since a portion of research support has been generalized from standard pushbutton controls to keyboards, additional research with specific application to keyboard input is needed. The guidelines tend to overwhelmingly indicate that some form of keystroke feedback is a desirable feature. These guidelines are further substantiated from the author's own informal observations. It has been observed that data entry operators and programmers are generally opposed to keyboards with a "mushy" feel and prefer keyboards with a higher resistance. Evidence also indicates, for the novice or unskilled user, that keying is both faster and more accurate if tactile feedback is provided. However, tactile feedback seems to be less important for skilled operators (though still a desired attribute) and too positive a snap action may actually increase errors.

These recommendations for the merits of keystroke feedback as a function of operator skill may have directed keyboard designers to allow the operators the option of setting a switch to selectively choose the level of tactile/audible feedback desired. No distinction is implied in the current guidelines for one feedback mode (whether auditory or tactile) being superior over another. The choice is limited in situations where specialized membrane keyboards are used. Those devices generally require an auditory signal to compensate for the lack of tactile feedback typically encountered with standard equipment. It should be noted that this special requirement (auditory feedback only) would make the membrane keyboard only appropriate for extremely low frequency keying tasks.

Method for Assessment. (1) Review original equipment specification to verify whether the provision is provided, (2) obtain the equipment advertising brochures and review for reference to tactile or audible feedback features, and (3) physically press a sample of keys to determine if feedback has been provided. If keystroke feedback is not obvious to the evaluator, question a sample of the VDU system users. Does the keyboard provide feedback, such as "snap feel," "audible click," or "release of resistance?" If the response is on the order of either "no" or "not sure," it can be inferred that this particular variable has not been addressed in the equipment design.

Key Actuation Force

Definition. The amount of resistance required to activate a key is usually expressed in Newtons, ounces, or grams. These guidelines are presented within an acceptable maximum and minimum range. In some situations, separate guidelines are provided for "numeric keys" and "alphabetic keys." The speed and accuracy with which a key is activated, as well as its susceptibility to inadvertent operation, are significantly affected by the type and amount of resistance built into the key. The ideal resistance level should produce the optimum combination of (a) precision, (b) speed, (c) control "feel," and (d) smoothness of movement. Selection of key actuation forces in early mechanical typewriters were severely restricted by design constraints. Modern VDU keyboards are no longer subject to those early design constraints and, as a result, greater flexibility is allowed for better taking into account individual task and user requirements.

Guidelines.	Research Support	Source
1. The force required for key displacement should be 0.25 to 1.5 N. (See Note 1.)	Y	6, 16, 22, 24
2. The force required for key displacement should be 0.3 to 0.75 N for repetitive keying tasks.	Y	21

NOTE 1: References 6 and 16 allow a range from 1 to 4 N for displacement of alphanumeric keys. Reference 21 specifies, for experienced operators, poke board membrane keyboard forces of about 0.6 N.

Comment. A small variance exists in the guidelines literature for key actuation force. In the face of this confusion, the guidelines from MILSTD 1472C[16] and NUREG-0700[6] are recommended as the most acceptable standard to implement. This is due to their extensive previous applications in the design of military systems.

Method for Assessment. This type of specification could be adequately assessed using a subjective approach. Physically press a sample of keys to determine if the resistance level produces an optimum combination of (a) precision, (b) speed, (c) control "feel," and (d) smoothness of movement.

Key Roll-Over

Definition. A major characteristic which can help to minimize miskeying problems is key roll-over. When keying at high speed, the user may produce bursts of keystrokes with very short interkeying times. That often results in more than one key being in the depressed state at a given time. The absence of key roll-over results in lost keystrokes. With multiple-key roll-over (often referred to as n-key roll-over), the keyboard is able to store all the keystrokes and generate all the characters in their correct sequence regardless of the number of keys depressed at the same time.

Guidelines.	Research Support	Source
1. N-key roll-over capability should be implemented for the reduction of keying errors.	L	22

Comment. The experimental evidence is limited, but preliminary observations indicate that n-key roll-over is highly preferred among operators. In addition, error rates have been shown to increase significantly when operators familiar with n-key roll-over transfer to a keyboard without that capability.

Method for Assessment. (1) Review original equipment specification to verify whether the provision is provided, (2) obtain the equipment advertising brochures and review for reference to a multiple key roll-over (n-key roll-over) capability, (3)(a) depress an alphanumeric key at random, (b) while holding this key in the down position, depress a second key, (c) lift the second key while continuing to retain pressure on the first key and finally, (d) remove pressure from the first key. Then repeat the process, but alter Step (c) and (d) by lifting the first key while continuing to retain pressure on the second key and then following in series to reduce pressure on the last remaining key. An example of this test scenario for both tests is demonstrated in Figure 31.

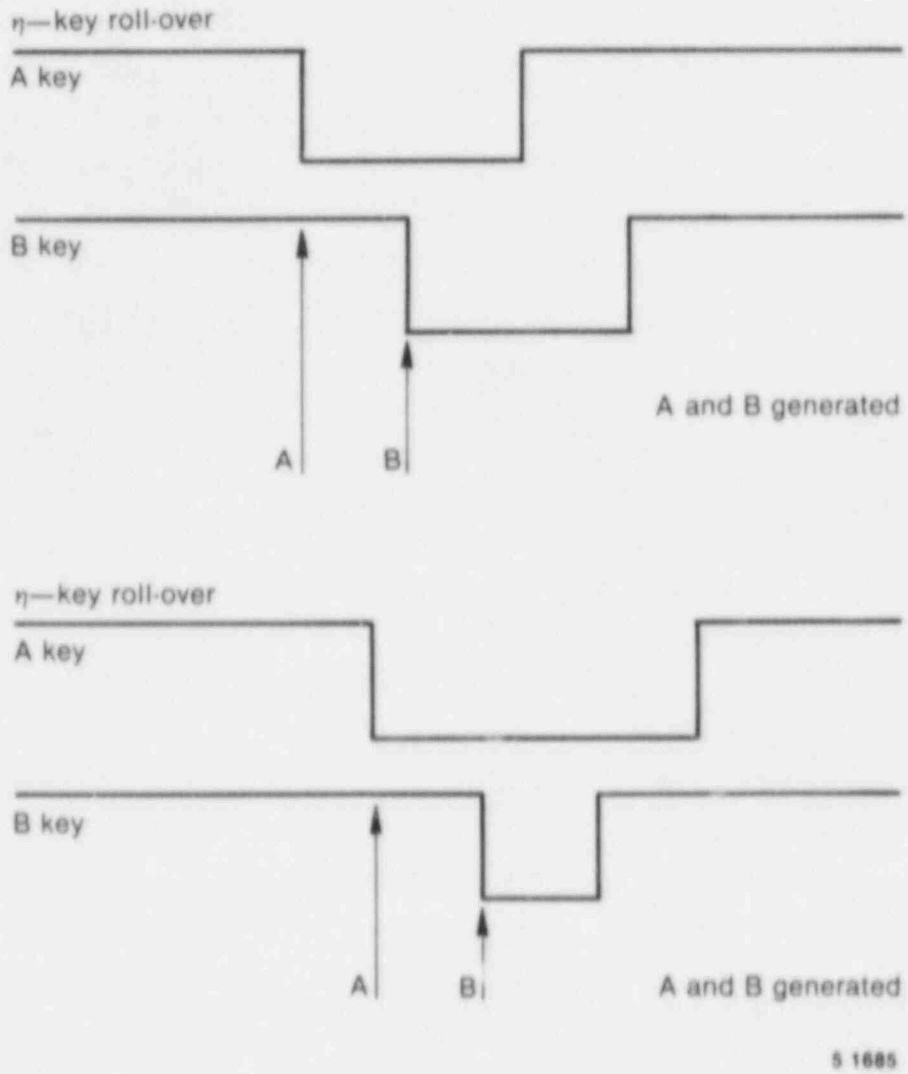


Figure 31. Examples of n-key roll over for two conditions:
a. Depression of two keys when the first key is released before the second.
b. Depression of two keys when the second key is released before the first key (Source: Reference 22).

Key Travel (Displacement)

Definition. The actual distance the key travels in the vertical plane is the key travel or displacement. The distance is usually measured from the key's resting state to the activation point. This value is normally stated in inches (in.) or millimeters (mm). These guidelines, as with the variable key actuation force, are presented within an acceptable maximum and minimum range. In some situations, separate guidelines are provided for both the numeric key set and the alphanumeric keyset. In the same manner as key actuation force (resistance), prior constraints of earlier mechanical keyboards are no longer a major limitation for establishing key travel parameters. Rather, a greater flexibility is provided in modern keyboards for better taking into account individual task and user requirements. It might also be noted that optimal key travel is highly related to key actuation force.

Guidelines.	Research Support	Source
1. Key displacement should be 0.03 to 0.19 inches for numeric keys and 0.05 to 0.25 inches for alpha numeric keys. (See Note 1.)	Y	6, 16
2. Displacement variability between keys should be minimized.	Y	21

NOTE 1: Reference 22 recommends a key displacement of 0.5 to 8 mm. Reference 21 recommends a key displacement of 1.3 to 6.4 mm for a standard key and even less with poke board or touch pad. Reference 17 recommends a key displacement of 1.3 to 6.4 mm. Reference 24 recommends a key displacement of 5 to 8 mm. Reference 14 recommends a key displacement of 0.125 to 0.187 inch. Reference 57 recommends an alphabetic key displacement of 1/16 to 1/4 inch and a numeric key displacement of 1/32 to 3/16 inch.

Comment. A small variance exists in the literature for key travel. This situation is similar to the guidelines for key actuation force. It is recommended, due to extensive previous applications in design of military systems, that the guidelines from MIL-STD-1472C[16] and NUREG-0700[6] be implemented. It is also suggested that, due to the highly interrelated nature of key force with displacement, high force values not be implemented with low displacement. Preliminary research indicates this force-displacement relationship was most disliked and difficult to use.

In conclusion, little reference to criteria for membrane keyboards were cited. Eastman Kodak[21] recommended the values for displacement should be less than that standard keyboard, but no actual data are available. It is not clear from Cakir et al.[22] that their recommendation (0.8 to 8 mm) did not also include specification for a membrane keyboard at the minimum value. It is highly unlikely that 0.8 mm is sufficient for a standard keyboard arrangement.

Method for Assessment. (1) Review original equipment specification to verify whether the provision is provided, (2) obtain the equipment advertising brochures and review for reference to key displacement, and (3) obtain a metric rule. Place in position adjacent to a randomly selected alphanumeric and numeric key. Record values at the neutral and depressed positions. Subtract those numbers to obtain the range. Verify the ranges are within the established maximum and minimum limits.

Key Color/Labeling

Definition. The use of color for key caps satisfies a multiple purpose in keyboard layout: (a) color coding of functional groups, (b) background to provide sufficient contrast for key labels, and (c) glare reduction. In a typical touch typing task, the operators seldom rely on key labels and their function is considered secondary. However, the addition of many specialized function and control keys on modern complex keyboards have created a necessity for good labeling and key coloring techniques for the novice as well as the skilled typist. Even experienced touch typists must occasionally scan the keyboard for specialized keys not within the standard QWERTY arrangement. As a result, the labels and colors incorporated into the keys take on a new importance as an operator aid. These parameters (key color and labels) will be treated as a single variable due to their highly interrelated nature.

Guidelines.	Research Support	Source
1. All controls should be appropriately and clearly labeled in the simplest and most direct manner possible.	L	14
2. Functional highlighting of the various key groups should be accomplished through the use of color coding techniques. (See Note 1.)	L	14
3. Key symbols should be etched to resist wear and colored with high contrast lettering.	L	22
4. Color of alphanumeric keys should be neutral (e.g., beige, grey) rather than black or white or one of the spectural colors (red, yellow, green, or blue.)	L	22

NOTE 1: Color can help to give a structure to the keyboard, which greatly reduces search times and search errors. The combination of colored key tops and keys laid out in blocks imposes an order to the layout of the keyboard that is both functionally desirable and aesthetically pleasing.[22]

Comment. The information is scarce, but the evidence indicates that matt-finished keys are most preferable and neutral colors are the most acceptable key colors for minimization of glare. In summary, the authors conclude from the literature that key labels and colors should conform to the following criteria:

- Keys are matt finished

- Key symbols are etched (molded into the key top) to resist wear and are of suitable contrast for legibility under a wide range of lighting conditions.

- Keys are color coded by functional groups with a neutral color scheme which is readily discriminable and of sufficient glare reducing quality.

- Key labels are simple and direct in a basic, non-stylized font (see also section on "alphanumeric characters").

Method for Assessment. Visually inspect the keyboard for compliance with the characteristics discussed in the comments and above guidelines section.

Key Dimension/Spacing

Definition. The size and spacing of keys are directly related to the keyboard operator's performance. Optimal dimensions and spacing are fundamental to keyboard usability. The size of the key top is to some extent the result of a compromise between providing a large enough target area and surface for the legend and keeping the keyboard dimensions and distance of finger travel down to a manageable size. Key Dimension/Spacing are discussed as a single variable due to their highly functional relationship. Key spacing is generally described as the distance between key centers. Other specifications address key spacing as the distance between adjacent edges.

Guidelines.	Research Support	Source
1. The linear dimensions of the key tops should be from 0.385 to 0.75 in., with 0.5 in. preferred. (See Note 1.)	L	6, 14, 16, 17, 21, 22, 57
2. Separation between adjacent key tops should be 0.25 inch. (See Note 2.)	L	6, 14, 16, 17, 21, 22
3. Pushbutton height for decimal entry key pads should be from 1/4 to 3/8 inch.	L	57
4. Key height for alpha numeric keyboards should be from 3/8 to 1/2 inch.	L	57
5. Key tops should be square or slightly rounded.	L	14, 21

NOTE 1: Reference 22 recommends 12 to 15 mm. Reference 21 recommends 12 mm square and notes that miniature key sets are associated with decreased speed and increased errors. Reference 57 specifies from 3/8 to 1/2 inch.

NOTE 2: Reference 21 recommends 19 mm between key centers. Reference 22 recommends from 18 to 20 mm between key centers.

Comments. The author concludes that the guidelines from MIL-STD-1472C[16] and NUREG-0700[6] as the most accepted standard due to their high application and proven performance in military systems. The guidelines pertaining to key dimension and spacing are summarized below:

- o Key top should be square or slightly rounded with a diameter of 0.5 in. Square tops are generally regarded to be more suitable than round since they provide a bigger target area between key centers.
- o Separation between adjacent edges should be 0.25 in. (center to center spacing, 0.75 in.).
- o Key tops should be concave.

In addition, Reference 22 recommends that the key shape conform to the following general requirements:

- o Aid the accurate location of the users finger
- o Prevent the accumulation of dirt, dust, moisture etc. on the surface, or from falling into the mechanism
- o Be neither sharp nor uncomfortable to press.

In conclusion, it is not apparent why Reference 57 made a distinction for key height between numeric and alphanumeric keys. The author suggests that key height should be dependent on key displacement provided.

Method for Assessment. Obtain a ruler and measure the parameters to verify compliance to the dimensions cited above. Also, visually inspect the keyboard to ensure the key tops are concave.

Keyboard Slope

Definition. The slope is expressed as the angle of the keyboard relative to the horizontal surface. An example of this angle is illustrated in Figure 32. This value is usually expressed as an acceptable range in units of degrees. The angle of the keyboard is important from the point of view of the position and motion of the hands and fingers while keying.

Guidelines.	Research Support	Source
1. Keyboards should have a slope of 15 to 25 degrees from the horizontal, with 12 to 18 degrees preferred. (See Note 1.)	Y	6, 14, 16, 17, 22, 24, 57
2. The keyboard slope should be adjustable.	Y	4

NOTE 1: Reference 14 recommends 11 to 15 degrees. Reference 17 recommends 10 to 35 degrees. Reference 57 recommends 15 to 20 degrees. Reference 22 recommends 5 to 15 degrees. Reference 24 recommends less than or equal to 5 degrees.

Comment. A summary of related keyboard studies is described below:

- o Alden[116] indicates that keying performance was found to be remarkably stable over a wide range of keyboard slopes
- o Studies show that operators prefer some slope to the keyboard, and that, as a result, there is a wide range of individual preferences.

This rationale implies the adjustable keyboard to be the most desired as recommended by Reference 4. Cakir et al.[24], in addition to keyboard slope, also make reference to criteria for keyboard profile. "Stepped," "Sloped," "Dished" were three profiles identified. It is not evident that those factors significantly affect human performance when compared with keyboard slope.

Most of the above guidelines are in general agreement for acceptable ranges. The guidelines from Reference 24 of less than 5 degrees possessed the most deviation from this group. The attempt to minimize keyboard height is the apparent reason for the unusual keyboard slope in that report. The author concludes, if the keyboard is not adjustable, that the guidelines from MIL-STD-1472C[16] and NUREG-0700[6] are the most accepted standard due to their high application and proven performance in military systems.

Method for Assessment. Obtain a protractor and physically measure the angle from the horizontal to ensure compliance with the parameter cited above.

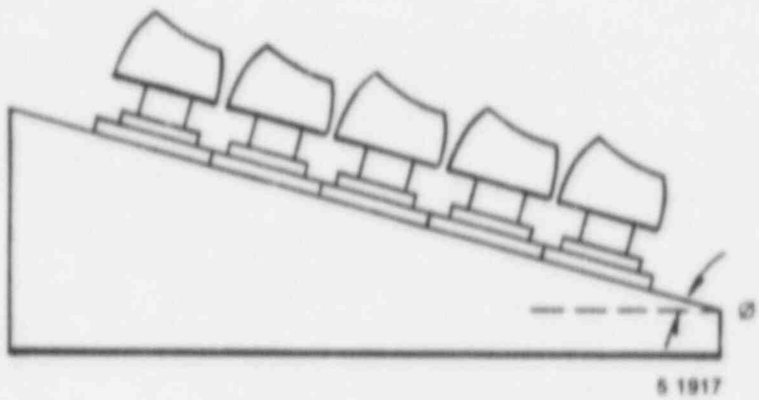


Figure 32. Keyboard angle (0) relative to the horizontal surface it sits on.

Keyboard Thickness

Definition. The value for keyboard thickness is described as the vertical height of the keyboard from its base to the top of the home row keys. This variable is most directly relevant to postural loading of the user by ensuring the correct working level.

Guidelines.	Research Support	Source
1. The thickness of the keyboard, i.e., base to the home row of keys, should be less than 50 mm (acceptable) with 30 mm or less preferred. (See Note 1.)	L	22, 24, 25

NOTE 1: Reference 24 recommends that keyboards more than 30 mm thick be recessed into the table top.

Comment. This variable is highly dependent on the overall layout of the work station. These guidelines imply that "thinner is better." Reference 24 justifies this requirement in order to meet the needs of a suitable "working level." Working level is defined as the distance from the underside of the thighs and the palms of the hand (see Figure 33). This value should fall in the range from 220 to 250 mm. Reference 24 states:

"The practical importance of the working level is best appreciated by considering the need (a) to provide sufficient knee clearance and (b) to provide for a working posture in which the position of the hands and arms is the most favorable when using the keyboard. Generally speaking, the knee clearance should be between 170 and 200 mm. Since desk thicknesses are typically of the order 20 to 40 mm for the desk top with an additional 20 mm allowing for the thickness of the desk frame, both requirements are satisfied only when the

height of the keyboard is of the order 30 mm. Bearing in mind that on most existing types of VDT, the height of the keyboard is usually between 50 and 120 mm, it is clear that very seldom can both requirements be fully satisfied.

"The desk top, desk frame and keyboard should be as thin as possible in order to ensure a working level between 200 and 250 mm. Detached keyboards with a height of more than 30 mm should be set into the desk top. Keyboards which are an integral part of the VDT chassis should not be built into the desk top since the screen is then usually placed in too low a position to permit comfortable viewing. The position of the keyboard should always be adjustable and adequate knee clearance must also be maintained."

Therefore, it is safe to state that a keyboard thickness of less than 30 mm is desired in order to achieve an optimal working level. The merits of a thinner keyboard will also allow the operator to utilize the desk top as a convenient palm rest if it is not readily provided on the keyboard.

Method for Assessment. Obtain a ruler and physically measure the thickness of the keyboard from its base (or table height if it is recessed) to the top of the home row of keys to verify if the distance is less than or equal to 30 mm.

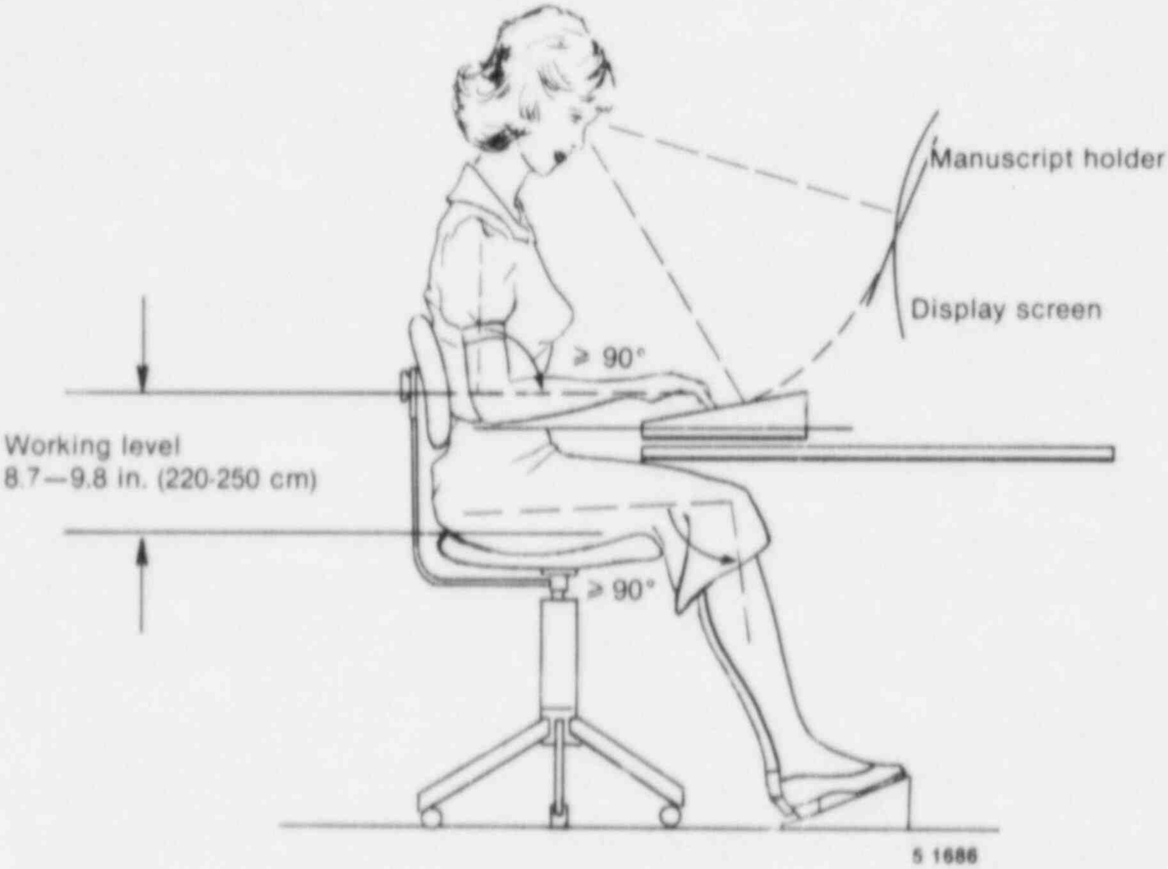


Figure 33. The ideal working level is defined as the distance between the underside of the thighs and the palms of the hands when operating the keyboard with the hands and forearms in an approximately horizontal position (Source: Reference 117).

Special Function Keys

Definition. A typical keyboard often consists of a special function key set in addition to the standard alphanumeric keys. These keys encompass a wide range of control capability. They can be used to perform routine "typewriter" function or as a device to select menus on the screen. This latter function usually involves the user programmable function keys as opposed to the dedicated hardwired function keys.

Guidelines.	Research Support	Source
1. When dedicated controls are used to initiate/activate function, the keys should be grouped together. (See Note 1.)	L	6
2. Function controls should be easily distinguished from other types of keys on the computer console.	L	6
3. Each function control should be clearly labeled to indicate its function to the operator.	L	6
4. If multiple computer consoles exist in the control room, the design and layout of the function controls should be consistent for all consoles.	L	6
5. When function keys are included with an alphanumeric keyboard, the function keys should be physically separate. (See Note 2.)	L	6

	Research Support	Source
6. There should not be more function keys available than the user can easily access, otherwise the excess of choice makes all of them difficult to use.	L	22
7. Keys with major or "fatal" effect should be located so that inadvertent operation is unlikely.	L	22

NOTE 1: It is important that the layout of the keys is such that typical operational sequences form a logical flow on the keyboard. This helps to reduce errors and to maintain the operators' keying rhythm. However it is also important that the layout minimizes the effect of likely errors. Overreaching frequently used keys or failing to change shift are both extremely common and should not result in critical errors.

NOTE 2: Avoid multiple-mode keyboards which utilize the same keys for both alphanumerics and functions by using "shift" keys or mode selection controls.[6])

Comment. It is apparent from reading the above guidelines that they are extremely general in that their origins reside in standard human engineering practices. In the majority of situations, the establishment of specific guidelines are dependent upon the user's task requirements. In spite of these limitations, some general statements can be gleaned from the above items:

- Function keys should be grouped on the keyboard according to one or more of the following techniques: (a) sequence, (b) frequency, (c) function, or (d) importance.
- Function keys should be distinct from the other keys by: (a) color, (b) shape, and/or (c) spacing.

- If more than one keyboard exists in the control room, design and layout of the function keys should be consistent for all keyboards.

- Avoid multiple-mode keyboards that include functions and alphanumeric characters on the same keys which are controlled with a "shift" key or mode select switch. (Function keys should be physically separate.)

Method for Assessment. Visually inspect keyboard to verify function key sets are within compliance with the above guidelines. It may also be beneficial to have the operator(s) describe the meanings of the function key sets.

Auxiliary Controls

The variables discussed in the subcategory of "Auxiliary Controls" are:

Numeric Key Set

Definition. The numeric keypad is an optional or auxiliary device to the standard keyboard. The keys (0-9) are generally layed out in a hand held calculator arrangement. That is, a 3 x 3 matrix with 7, 8 , 9 on the top row, 4, 5, 6 on the second row, and so forth. The "0" key is usually reserved on a separate row immediately below the 3 x 3 matrix. The numeric keypad provides a special capability when rapid entry of large amounts of numerical data is required. In general, the numeric pad operates in precisely the same way as the numeric keys in the main alphanumeric keyset except it is not affected by the shift keys. The numeric keypad is highly beneficial if the task requires a substantial entry of numbers not mixed into text.

Reference 21 states "Redundancy of the numeric keys (across the top of the keyboard and also as a separate numeric set next to the typewriter key set) can be helpful if a terminal may be used as a calculator as well as an alphanumeric data entry keyboard." The layout of the numeric keys within the keyboard is highly debatable, but most researchers agree that the configuration should conform to a 3 x 3 matrix arrangement with "0" at the bottom row. However, some general disagreement exists in the organization of the keys within the matrix. This narrows down to two basic arrangements: (a) the touch tone telephone pad, and (b) the calculator or adding machine layout. Examples of these two schemes are shown in Figure 34.

Guidelines.	Research Support	Source
1. Terminals which are often used as calculators should be provided with an auxiliary numeric key set.	Y	21
2. The configuration of a keyboard used to enter solely numeric information should be a 3 x 3 x 1 matrix with the zero digit centered on the bottom row.	Y	6, 16, 36

	Research Support	Source
3. The layout of keyboard numeric pads should be either "telephone" or "calculator" style. (See Note 1.)	Y	6, 14, 17, 22, 36, 57

NOTE 1: Reference 22 notes that pushbutton telephones are increasingly being used in conjunction with VDUs. References 14, 17, 22, 36, and 57 state preference for the "telephone" style.

Comment. It is interesting to note that many of the guidelines emphasize a specification for keyboard arrangement, i.e., telephone or calculator. Some of the guidelines cite a preference, while NUREG-0700[6] states either is acceptable. Eastman Kodak[21] also leaves the preference optional to the designer. MIL-STD-1472C[16] only recommends the configuration (3 x 3). Cakir et al.[22] defend the telephone arrangement since many users usually time share their tasks across both devices. That would be an acceptable rationale for recommending the telephone arrangement in a NPP control room. That logic, unfortunately, breaks down since many operators perform routine calculations on a hand held calculator as well as talk on the phone. The argument is also certainly moot for most process control applications since substantial high speed entry of data is usually not required of operators.

In summary, the research indicates a slight advantage can be obtained using the telephone arrangement. For applications where a premium is not placed on rapid entry of numerical data, either the calculator or telephone arrangement in a 3 x 3 x 1 matrix is acceptable.[6]

Method for Assessment. Visually inspect the keyboard to verify the numeric pad is in a 3 x 3 x 1 matrix in either a calculator or telephone arrangement.

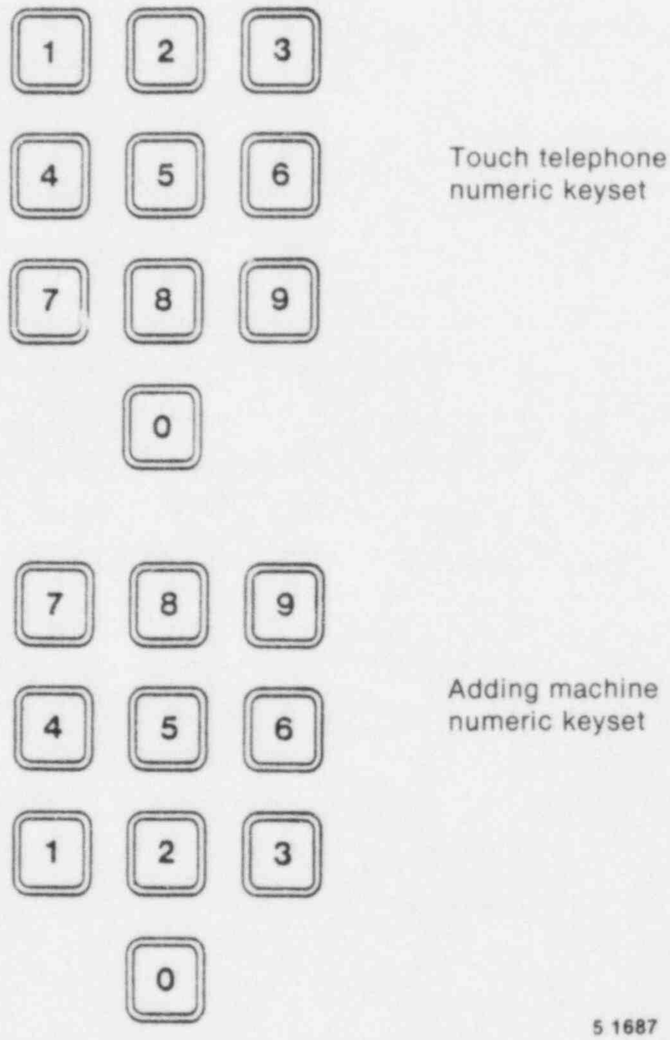


Figure 34. Two basic numeric keypad arrangements.

Alternate Input Devices

Definition. In addition to the keyboard, a variety of other mechanisms can be used to regulate or guide the operation of a machine, apparatus, or system. The following devices are discussed in this section:

- Light Pen (Light Sticks) (see Figure 35)
- Isotonic/Displacement Joystick (see Figure 36)
- Ball Control (see Figure 37)
- Grid-and-Stylus Devices (see Figure 38)
- Free-Moving X-Y Controller (Mouse) (see Figure 39)
- Automatic Speech Recognition (Voice Input Device)

There are six items to consider in the selection of an alternate control type:

1. Type of control input required by CRT (discrete state or continuous range)
2. If discrete changes are needed, how many states are required? If continuous range is appropriate, what is the value, precision, force, and speed of movement required?
3. Is there a danger of confusing controls?
4. What feedback is there that the system has accepted the control input?
5. How can unintentional control operation (bumping) be reduced?
6. What population stereotypes relative to control movements, shape, and size are considered natural and compatible?

Guidelines.	Research Support	Source
1. Guidelines for light pens are as follows:		
a) Light pens should be used for cursor placement, text selection, command construction, and interactive graphical dialogues in general, including drawing. (See Note 1.)	Y	16, 118, 119, 120
b) Tasks involving light pens should not require frequent, alternating use of the light pen and the keyboard. (See Note 2.)	Y	118, 119, 120
c) Tasks involving light pens should not require long, continuous intervals of light pen use. (See Note 3.)	Y	118, 119, 120
d) The light pen should be 12 to 18 cm (4.7 to 5.1 in.) long and 0.7 to 2 cm (0.3 to 0.8 in.) in diameter.	Y	16, 30
e) Convenient clips should be provided at the lower right side of the CRT to hold the pen when it is not in use.	Y	16
f) Movement of the pen in any direction on the screen should result in smooth movement of the follower in the same direction.	Y	16

	Research Support	Source
g) Discrete placement of the stylus at any point on the screen should cause the follower to appear at that point and remain steady in position so long as the pen is not moved.	Y	16
h) Refresh rate for the follower should be sufficiently high to ensure the appearance of a continuous track whenever the pen is used for generation of free-drawn graphics.	Y	16

2. Guidelines for joysticks are as follows:

	Research Support	Source
a) Joystick controls should be used for tasks that require precise or continuous control in two or more related dimensions.	Y	16
b) When positioning accuracy is more critical than positioning speed, isotonic/displacement joysticks should be selected over isometric joysticks.	Y	16
c) Isotonic/displacement joysticks should be used for such functions as data pickoff and generation of free-drawn graphics.	Y	16
d) In rate control applications which allow the follower to transit beyond the edge of the display, indicators should be provided to aid the operator in bringing the follower back onto the display.	Y	16

	Research Support	Source
e) Isotonic joysticks which are used for rate control should be spring-loaded for return to center when the hand is removed.	Y	16
f) Isotonic joysticks should not be used in connection with automatic sequencing of a CRT follower unless they are instrumented for null return or are zero-set to the instantaneous position of the stick at the time of sequencing. Upon termination of the automatic sequencing routine, joystick center should again be registered to scope center.	Y	16
g) Isotonic/displacement joysticks should be 1/4 to 5/8 inch in diameter and 3 to 6 inches long.	Y	16, 30
h) Resistance force of the joystick should be 12 to 32 ounces.	Y	16, 30
i) Full displacement of the joystick should not exceed 45 degrees.	Y	16, 30
j) Isotonic/displacement joysticks should be provided with the following clearances:	Y	16, 30

(1) Display to stick--15-3/4 in.
(2) Around stick--4 in.
(3) Stick to shelf front--4-3/4 in. to 9-7/8 in.

	Research Support	Source
k) Movement should be smooth in all directions, and rapid positioning of the follower on the display should be attainable without noticeable backlash, cross-coupling, or need for multiple corrective movements.	Y	16
l) Control ratios, friction, and inertia should meet the dual requirements of rapid gross positioning and precise fine positioning.	Y	16
m) Recessed mounting or pencil attachments may be utilized to provide greater precision of control	Y	16
n) When used for generation of free-drawn graphics, the refresh rate for the follower on the CRT should be sufficiently high to ensure the appearance of a continuous track.	Y	16
o) Delay between control movement and the confirming display response should be minimized and should not exceed 0.1 second.	Y	16
3. Guidelines for isometric joysticks are as follows: (See Note 5.)		
a) The isometric joystick should be used for such functions as data pickoff. (See Note 6.)	Y	16

	Research Support	Source
b) In rate control applications which may allow the follower to transit beyond the edge of the display, indicators should be provided in order to advise the operator how to bring the follower back onto the display.	Y	16
c) Isometric sticks should ordinarily not be used in any application where it would be necessary for the operator to maintain a constant force on the stick to generator a constant output over a sustained period of time.	Y	16
d) Finger-grasped isometric joysticks should comply with the same dimensional criteria as isotonic joysticks.	Y	16
e) Hand-grasped isometric joysticks, when integral switching is required, should be between 4.3 to 7.1 in. long, have a maximum grip diameter of 2 in.	Y	16
f) Hand-grasped isometric joysticks should have minimum clearances of 4 in. at the sides and 2 in. at the rear.	Y	16
g) Hand-grasped isometric joysticks should have a maximum resistance force of 26.7 lb for full output.	Y	16

	Research Support	Source
h) The isometric stick should deflect minimally in response to applied force, but may deflect perceptibly against a stop at full applied force.	Y	16
i) The X and Y output should be proportional to the magnitude of the applied force as perceived by the operator.	Y	16
4. Guidelines for ball controls are as follows: (See Note 7.)		
a) A ball control should be used for such tasks as data pickoff. (See Note 8.)	Y	16
b) In any application which would allow the ball to drive the follower on the display off the edge of the display, indicators should be provided to advise the operator how to bring the follower back onto the display.	Y	16
c) When ball controls are used to make precise or continuous adjustments, wrist support or arm support or both should be provided.	Y	16
d) Ball controls should conform to the dimensions listed in Table 10. (See Note 9.)	Y	16, 30

	Research Support	Source
e) The ball control should be capable of rotation in any direction so as to generate any any combination of X and Y output values.	Y	16
f) When moved in either the X or Y directions alone, there should be no apparent cross-coupling (follower movement in the orthogonal direction).	Y	16
g) While manipulating the control, neither backlash nor cross-coupling should be apparent to the operator.	Y	16
h) Control ratios and dynamic features should meet the dual requirement of rapid press positioning and smooth, precise fine positioning.	Y	16
5. Guidelines for grid-and-stylus devices are as follows: (See Note 10.)		
a) Grid and stylus devices should be used for data pickoff, entry of points on a display, generation of free-drawn graphics, and similar control applications. (See Note 11.)	Y	16, 118
b) Transparent grids which are used as display overlays should conform to the size of the display.	Y	16

	Research Support	Source
c) 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 (i.e., a vertical plane passing through the north/south axis on the grid shall pass through or be parallel to the north/south axis on the display).	Y	16
d) Movement of the stylus in any direction on the grid surface should result in smooth movement of the follower in the same direction.	Y	16
e) 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 in position so long as the stylus is not moved.	Y	16
f) Refresh rate for the follower should be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used in generation of free-drawn graphics.	Y	16

6. Guidelines for the free-moving X-Y controller (mouse) are as follows:

	Research Support	Source
a) The free-moving X-Y controller should be used for mean item selection, scrolling, data retrieval, and data entry. (See Note 12.)	Y	16
b) The controller should have physical dimensions of 1-1/2 to 3 in. width, 3 to 5 in. length, and 1 to 2 in. thickness. (See Note 13.)	Y	16, 30
c) 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 ±175 mrad (10°) of the correct orientation without visual reference to the controller. (See Note 14.)	Y	16
d) The controller should be easily movable in any direction without a change of hand grasp and should result in smooth movement of the follower in the same direction ±175 mrad (10°).	Y	16
e) The controller should be cordless and should be operable with either the left or right hand.	Y	16
f) A complete excursion of the controller from side to side of the maneuvering area should move the follower from side to side on the display regardless of	Y	16

	Research Support	Source
scale setting or offset unless expanded movement is selected for an automatic sequencing mode of operation.		
g) If any application which would allow the controller to drive the follower off the edge of the display, indicators should be provided to assist the operator in bringing the follower back onto the display.	Y	16
7. Automatic speech recognition (voice input devices) should be limited to relatively simple input tasks. (See Note 15.)	Y	94
8. Guidelines for touch screens are as follows: (See Note 16.)		
a) Touch screens should be used for mean item selection, scrolling, data retrieval, and data entry.	Y	121
b) The terminal should recognize a person's touch in approximately 100 ms.	Y	121
c) The system should accept only one command at a time, indicate the command has been accepted and respond in a time commensurate with the activity.	Y	121
d) The sensitive areas should be large enough to allow entry using fingers and allow for parallel due to CRT screen curvature.	Y	121

NOTE 1: Reference 16 states that a simple light pen may be used as a track-oriented readout device. That is, it may be positioned on the display screen to detect the presence of a computer-generated track by sensing its refresh pattern; the display system will then present a follower (hook) on the designed track. With suitable additional circuitry, a follower can be made to track the movement of the light pen across the surface, thus allowing it to function as a two-axis controller capable of serving the same purposes as the grid and stylus devices.

References 118, 119, and 120 state that light pens can be used effectively for cursor placement and text selection, command construction, and for interactive graphical dialogues in general, including drawing. However, there is evidence that greater accuracy may be possible with a mouse in discrete tasks, and with a trackball in drawing tasks.

NOTE 2: Mode mixing, as by alternating use of light pen and keyboard, can significantly disrupt performance, since the light pen must be picked up and replaced with each interval of use.[118,119,120]

NOTE 3: Continuous use of a light pen, at least on commercially available CRT terminals with vertical display surfaces, can be quite fatiguing.[118,119,120]

NOTE 4: Reference 94 states, "There are many studies of the use of joysticks for continuous tracking tasks, but few studies of its use for discrete or continuous operand selection or graphical input tasks. Those studies which have been performed have found the mouse, light pen, and trackball preferable in terms of speed, accuracy, or both. Joysticks are sometimes used for windowing and zooming control in graphical displays. No research on this topic was found, although the results of tracking studies may be applicable here. Otherwise, no clear recommendations for joystick properties emerged from the survey, even with respect to basic issues like position vs. rate vs. acceleration control. These issues may be fairly task-specific."

NOTE 5: Isometric Joystick (also known as stiff stick, force stick, or pressure joystick: a lever that doesn't move, output a function of applied force.)

NOTE 6: Isometric joysticks are particularly appropriate for applications: (a) which require return to center after each entry or readout; (b) in which operator feedback is primarily visual from some system response rather than kinesthetic from the stick itself; and (c) where there is minimal delay and tight coupling between control and input and system reaction.[16]

NOTE 7: Ball Control (Also known as track ball, ball tracker, joyball and rolling ball.)

NOTE 8: The ball control cannot provide an automatic return to point of origin, hence if used in applications requiring automatic return to origin following an entry or readout, the interfacing system must provide this. 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. Ball controls 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).[16]

NOTE 9: The smaller diameter ball controls should be used only where space availability is very limited and when there is no need for precision. Preferred mounting is on a shelf or desk top.[16]

NOTE 10: These provisions cover various techniques which utilize some means of establishing an X and Y grid and a stylus for designating specific points on that grid for control purposes (e.g., time-shared X and Y potential grids and a voltage-sensitive stylus).[16]

NOTE 11: Reference 16 states that grid and stylus devices may be used for data pickoff from a CRT, entry of points on a display, generation of free-drawn graphics and similar control applications. 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.) shall be presented on the display at the coordinate values selected by the stylus. Devices of this type should be used only for zero order control functions (i.e., displacement of the stylus from the reference position causes a proportional displacement of the follower).

Reference 118 states that graphical input tablets are capable of fairly high pointing accuracy (within 0.08 cm, according to one study). They are commonly used for freehand drawing, but may be inferior for discrete position input tasks. They may also involve a performance decrement due to low stimulus-response compatibility when the drawing surface is separate from the display surface.

NOTE 12: This type of 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. It may be used for data pickoff or for entry of coordinate values. It should be used for zero order contro only (i.e., generation of X and Y outputs by the controller results in proportional displacement of the follower). It should not be used for generation of free-drawn graphics.[16]

NOTE 13: Reference 16 recommends the following dimensions:

	Minimum	Maximum
Width (spanned by thumb to finger grasp)	40 mm (1.6 in.)	70 mm (2.8 in.)
Length	70 mm (2.8 in.)	120 mm (4.7 in.)
Thickness	25 mm (1.0 in.)	40 mm (1.6 in.)

NOTE 14: That is, 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 CRT shall be between 6110 and 175 mrad (350° and 10°). The controller shall be easily movable in any direction without a change of hand grasp and shall result in smooth movement of the follower in the same direction ±175 mrad (10°).

NOTE 15: The current state of this technology limits its use to relatively simple input tasks. Even there, there are problems with different speakers, noise, etc. Although speech input seems like a very desirable and natural input mode, and is clearly preferred over other communication modes for interpersonal communication, it is not clear whether it will prove to be widely applicable for human-computer interaction tasks. Very little information was found which would assist the designer in recognizing tasks for which speech input is appropriate, or in selecting an appropriate speech input device.[94]

NOTE 16: Reference 122 states, "These offer the most natural action of all: You simply point with your finger at something on the screen. Touch-sensitive screens adopt many technologies to locate your finger. Hewlett Packard's model 150 microcomputer puts an array of infrared light-emitting diodes and phototransistor detectors around the screen; the system resolves 160 locations (there are 1920 characters, or 199,680 pixels, on the screen).

"Touch Technology uses glass coated with conductive indium tin oxide; its system senses the capacitance change when a finger touches the coating. The screen positions can be either fixed, with 32 or 64 discrete coating patches, or relative, where two bus bars sense the relative capacitance anywhere over a completely coated screen surface. Resolution is limited to about 100 by 200 points over the surface.

"Still other touch systems use two flexible transparent plastic sheets with parallel strips of conductive coating, laid together at right angles; a finger pressing the two sheets together effectively closes a switch.

"Touch screens have major drawbacks. Fingers are much larger than the characters on the screen; touching the screen obscures what you are pointing at. Holding your arm up to the screen for long periods is tiring. And fingers leave prints on the screen.

"With adequate pointing resolution, software tricks could solve some touch screen problems. For example, the software could offset the finger location from the cursor, so the cursor remains visible at a constant half inch above your finger.

"Touch screens are the easiest pointing devices to use. They work well for novices and in situations where you are simply passing through--at a store display, for instance. Most let you perform menu selections, something you can do more quickly from the keyboard with a little experience."

Reference 4 states, "No standards reviewed by these authors contained any useful guidelines regarding the utility, application, or specifications for touch panels. They are a valid input medium, but research is needed to determine the optimal amount of screen area needed for presentation, errors in activations, etc."

Comment. Other than the hard data on preferred dimensions and accepted uses for the alternate input devices indicated, no real data exist concerning what feedback is needed, whether the control can be confused for another, or how unintentional bumping can be reduced. Further, the term "natural," used in the various control device settings, is not defined.

These are relatively new input devices compared to the keyboard, etc. which has been in use for over a century. Additional research is needed to provide data on what is appropriate for each control device.

Method for Assessment. (1) Identify the type of input to be performed by the controller [discrete (data entry), continuous (X-Y motions, etc.)], (2) determine from available guidelines whether selected controller is appropriate for that type of input, (3) verify dimensions for

controller are within specifications, and (4) physically attempt to perform some required functions to ensure feedback is provided and that the system feels "natural."

Table 10. Minimum, maximum, and preferred dimensions of Ball controls.

	DIMENSIONS		RESISTANCE		CLEARANCE		
	D DIAM	A SURFACE EXPOSURE	PRECISION REQUIRED	VIBRATION OR ACCEL CONDITIONS	S DISPLAY CL TO BALL CL	C AROUND BALL	F FALL TO SHELF FRONT
MINIMUM	50 mm (2 in.)	1545 mrad (100°)			0	50 mm (2 in.)	120 mm (4-3/4 in.)
MAXIMUM	150 mm (6 in.)	2445 mrad (140°)	1.0 N (3.6 oz)	1.7 N (6 oz)	320 mm (12-5/8 in.)		250 mm (9-3/4 in.)
PREFERRED	100 mm (4 in.)	2095 mrad (120°)	0.3 N (1.1 oz)				

5 1919

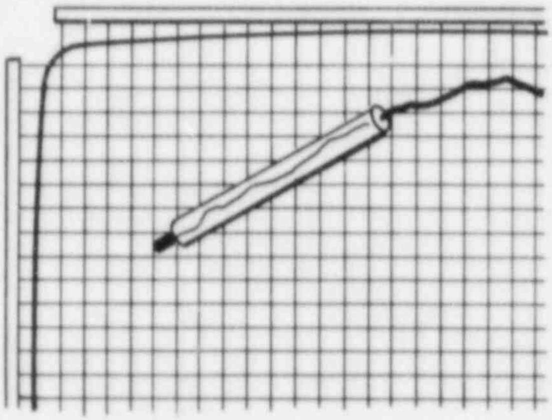


Figure 35. Light pen.

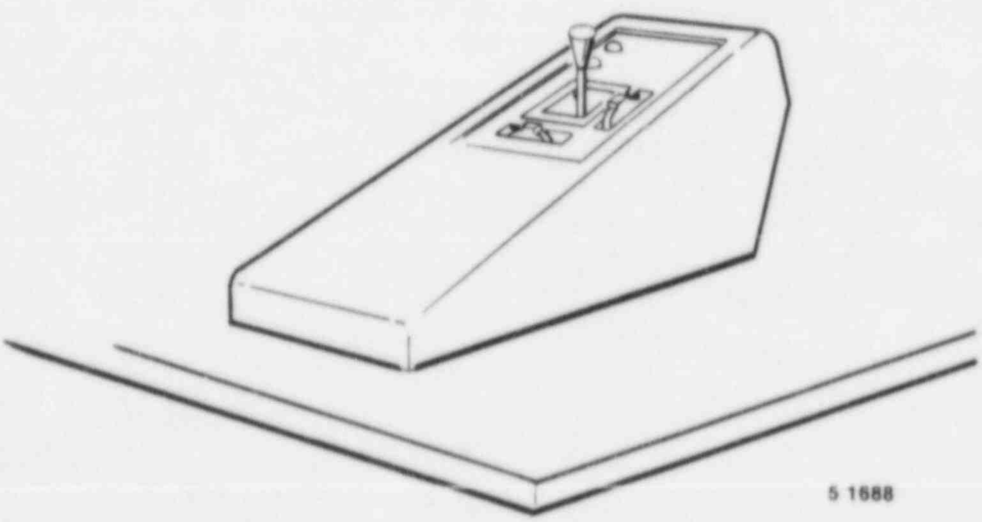


Figure 36. Joystick.

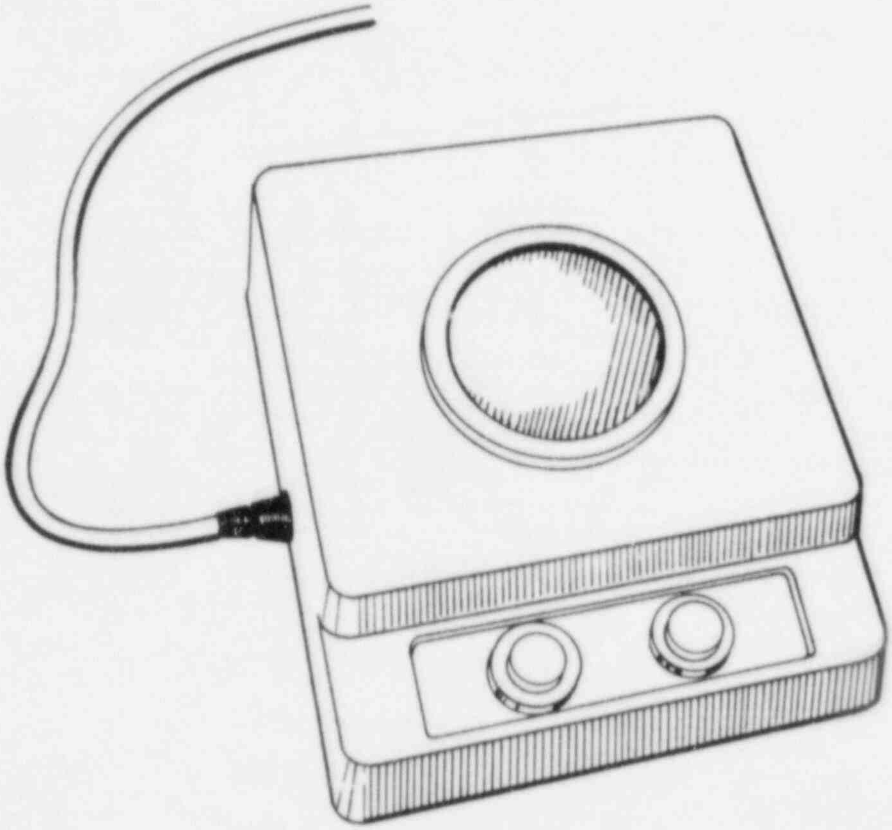
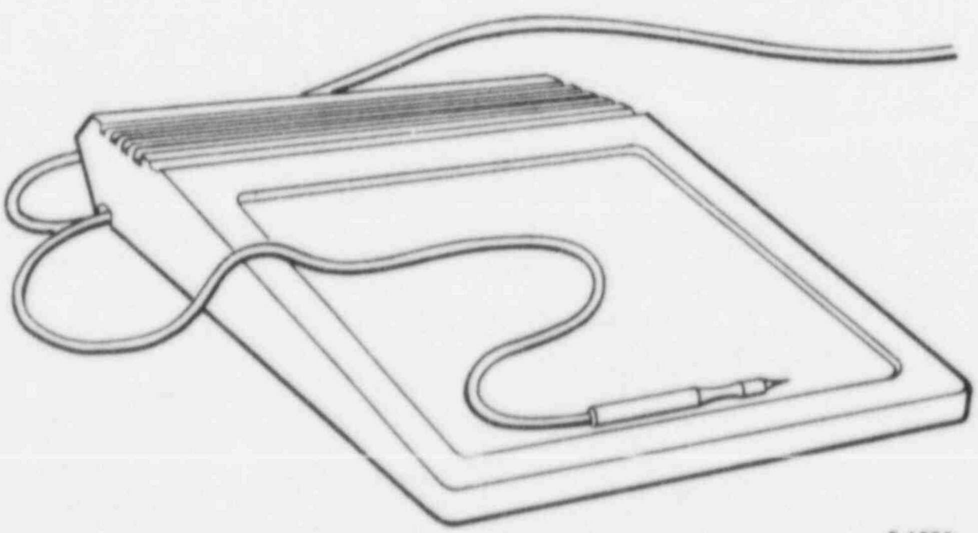
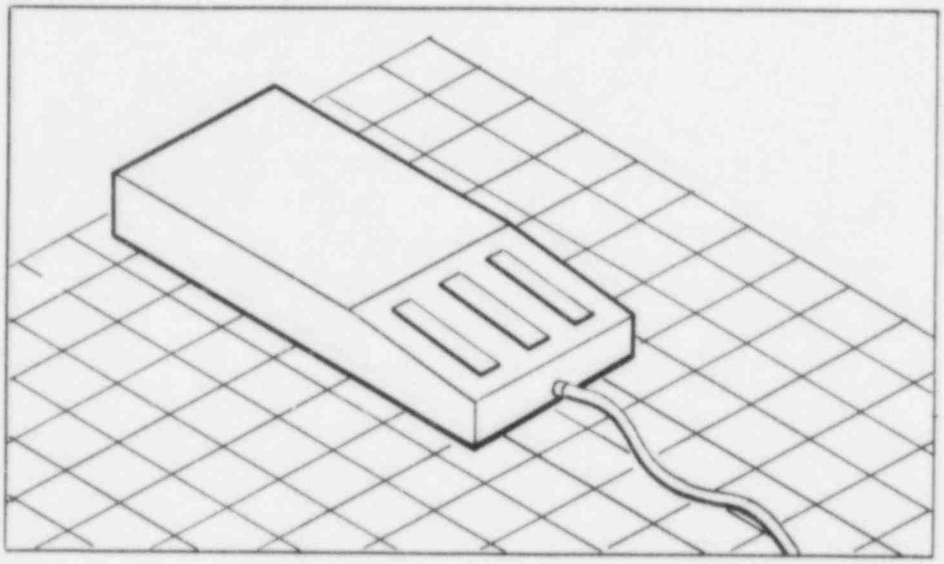


Figure 37. Ball control.



5 1689

Figure 38. Grid-and-stylus devices.



5 1914

Figure 39. Free-moving X-Y controller (mouse).

CONTROL/DISPLAY INTEGRATION

User Dialogue

User considerations related to dialogue design are covered in this subcateogry. In the context of user computer interaction, "dialogue" refers to the sequence of transactions which mediate user-system interaction.[34] Several types of dialogue design are available for developing an effective human/computer interaction. Many of these techniques are dependent on the task to be performed by the operator. That is, selection of an appropriate dialogue must require prior knowledge of the specific job requirements and the type of user. The following dialogues used in a variety of interactive applications are examined:

Question-and-Answer

Definition. This is a computer-initiated sequence of transactions between the user and the system that provides explicit prompting in performing task and control activities for the unskilled, occasional user.

Guidelines.	Research Support	Source
1. Question-and-answer dialog should be used primarily for routine data entry tasks where the user has little or no training.	N	34
2. The data items should be known and their ordering constrained.	N	34
3. The computer response should be moderately fast.	N	34

Comment. Brief question-and-answer sequences can be used to supplement other dialogue types for special purposes, such as for log-on routines or for resolving ambiguous control or data entries.

Method for Assessment. Examine the dialogue type to ensure compliance with the above guidelines.

Form-Filling

Definition. This is a computer-initiated sequence of transactions between the user and the system that provides flexibility in data entry activities for moderately trained users.

Guidelines.	Research Support	Source
1. Form-filling dialogue should be used when some flexibility in data entry is needed, such as the inclusion of optional as well as required items, where users will have moderate training, and/or where computer response may be slow.	N	34

Comment. None.

Method for Assessment. Examine the dialogue type to ensure compliance with the above guidelines.

Menu Design

Definition. This is a user-initiated sequence of transactions between the user and the system that provides explicit, single-choice task and control activities for the unskilled user.

Guidelines.	Research Support	Source
1. Menu selection should be used for tasks such as scheduling and monitoring that involve little entry of arbitrary data and where users may have relatively little training. (See Note 1.)	N	34
2. Computer response should be fast. (See Note 2.)	N	34
3. Each menu display should require just one selection by the user. (See Note 3.)	N	34
4. When menu selection is the primary means of sequence control, and especially if extensive lists of control options must be displayed, selection should be accomplished by direct pointing (e.g., by light pen). (See Note 4.)	N	34
5. When menu selection is a secondary (occasional) means of control entry and/or only short option lists are needed, selection should be accomplished by keyed entry of corresponding codes or by other means such as programmed multifunction keys labeled in the display margin.	N	34

	Research Support	Source
6. When menu selection is accomplished by code, that code should be keyed into a standard command entry area (window) in a fixed location on all displays. (See Note 5.)	N	34

Example: In a customary terminal configuration, (the display located above the keyboard) command entry should be in the bottom line of the display.

7. Menu options should be worded so as to permit direct selection by pointing or by code entry, rather than worded as questions.	N	34

Example: For option selection by pointing,

USE: +PRINT
DON'T USE: PRINT?

For option selection by code entry,

USE: p = Print
DON'T USE: Print? (Y/N)

8. When control entries will be selected from a discrete set of options, those options should be displayed at the time of selection.	N	34

	Research Support	Source
9. If menu selection is used in conjunction with (as an alternative to) command language, displayed options should be worded in terms of recognized commands or command elements. (See Note 6.)		
10. If menu selections must be made by keyed codes, each code should be the initial letter (or letters) of the displayed option label rather than an arbitrary number. (See Note 7.)	N	34

USE: Enter sex (M/F): __

DON'T USE: Enter sex: __

1 Male
2 Female

	Research Support	Source
11. If letter codes are used in menu selection, then insofar as possible those codes should be used consistently in designating options at different steps in a transaction sequence.	N	34

	Research Support	Source

Example: The same action should not be given different names and hence different codes (F = FORWARD and N = NEXT); the same code should not be given to different actions (Q = QUIT and Q = QUEUE).

	Research Support	Source
12. If menu options are included in a display intended also for data review and/or data entry (which is often a practical design approach), the labels for control entry should be located consistently in the display and should incorporate some consistent distinguishing feature to indicate their special function.	N	34

Example: All control options might be displayed beginning with a special symbol, such as a plus sign (+FORWARD, +BACK, etc.)

	Research Support	Source
13. Displayed menu options should be listed in a logical order; if no logical structure is apparent, then options should be displayed in order of their expected frequency of use, with the most frequent listed first. (See Note 8.)	N	34

	Research Support	Source

USE: Indicate vehicle type.

c = passenger car

t = pick-up truck

b = bus

DON'T USE: Indicate vehicle type.

t = pick-up truck

b = bus

c = passenger car

	Research Support	Source
14. Displayed menu lists should be formatted to indicate the hierarchic structure of logically related groups of options, rather than as an undifferentiated string of alternatives. (See Note 9.)	N	34

Example: In vertical listing of options, subordinate categories might be indented.

	Research Support	Source
15. If menu options are grouped in logical sub-units, those groups should be displayed in order of their expected frequency of use.	N	34

	Research Support	Source
16. If menu options are grouped in logical subunits, each group should be given a descriptive label that is distinctive in format from the option labels themselves. (See Note 10.)	N	34
17. A displayed menu should include only options appropriate at that particular step in a transaction sequence and for the particular user. (See Note 11.)	N	34

Example: a. Displayed file directories should contain only those files actually available to the user.

b. An UPDATE option should be offered only if the user has update rights for the particular data file being used.

	Research Support	Source
18. Insofar as possible, a displayed menu should include all options appropriate at that particular step in a transaction sequence.[34] (See Note 12.)	N	34
19. 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 multi-page menu. (See Note 13.)	N	34

	Research Support	Source
20. When the user must step through a sequence of menus to make a selection, the hierarchic structure should be designed, insofar as possible within the constraints of display space, to minimize the number of steps required. (See Note 14.)	N	34
21. When hierarchic menus are used, they should be designed to permit the user immediate access to critical or frequently selected options.	N	34
22. When hierarchic menus are used, the user should be given some displayed indication of current position in the menu structure. (See Note 15.)	N	34
23. When hierarchic menus are used, care should be taken to ensure consistent display formats at each level.	N	34
24. When hierarchic menus are used, a single key action should permit the user to return to the next higher level.	N	34
25. Menus provided in different displays should be designed so that option lists are consistent in terminology and ordering.	N	34

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.

	Research Support	Source
26. When a control option has been selected and entered and there is no immediately observable natural response, some other form of acknowledgment should be displayed. (See Note 16.)	N	34
27. Experienced users should be provided means to by-pass a series of menu selections and make an equivalent command entry directly.	N	34
28. When a user can anticipate menu selections before they are presented, means should be provided to enter several "stacked" selections at one time. (See Note 17.)	N	34

NOTE 1: Menu selection, in conjunction with other dialogue types for other task requirements, is a generally good means of mediating control entries by untrained users.[34]

NOTE 2: When display output is slow, as for a printing terminal or for an electronic display constrained by a low-bandwidth channel, it may be tiresome for a user to wait for display of menu options.[34]

NOTE 3: Novice users will be confused by any more complicated procedure, such as a "Chinese menu" requiring one choice from Column A, two from Column B, etc.[34]

NOTE 4: If menu selection is handled by pointing, dual activation should be provided, the first action to designate (position a cursor on) the selected option, followed by a separate action to make an explicit control entry.[34]

The two actions 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 light pen, then a dual-action "trigger" on the light pen should be provided for positioning and control entries.[34]

This recommendation assumes that accuracy in selection of control entries is more important than speed. In some applications that may not be true. USI (User System Interface) design will involve a trade-off considering the criticality of wrong entries, ease of recovery from wrong entries, and user convenience in making selections.[34]

NOTE 5: In effect, the command entry area should be positioned to minimize user head/eye movement between the display and the keyboard.

For experienced users, coded menu selections can be keyed in a standard area identified only by its consistent location and use; if the system is designed primarily for novice users, that entry area should be given an appropriate label such as ENTER CHOICE HERE: __.[34]

NOTE 6: Where appropriate, sequences of menu selections should be displayed in an accumulator until the user signals entry of a completely composed command.[34]

This practice will speed the transition for a novice user, relying initially on sequential menu selection, to become an experienced user composing coherent commands without such aid.[34]

NOTE 7: An exception to Guideline 10, options might be numbered when a logical order or sequence is implied, and, when menu selection is from a long list, line number might be an acceptable alternative to letter codes.[34]

Letters are easier than numbers for touch typists; options can be reordered on a menu without changing letter codes; it is easier to memorize

meaningful names than numbers, and so letter codes can facilitate a potential transition from menu selection to command language when those two dialogue types are used together.[34]

USI (User System Interface) designers should not create unnatural option labels just to ensure that the initial letter of each will be different. There must be some natural difference among option names, and a two- or three-letter code can probably be devised to emphasize that difference.[34]

NOTE 8: If the first menu option is always the most likely choice, then for some applications it may be useful for efficiency of sequence control if a null entry defaults to the first option. If that is done, it should be done consistently.[34]

NOTE 9: Logical grouping of menu options will help users learn system capabilities.[34]

When logical grouping requires a trade-off against expected frequency of use, USI (User System Interface) designers should resolve that trade-off consistently throughout the menu structure.[34]

NOTE 10: 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.

NOTE 11: As an exception to Guideline 17, menu displays for a system still under development might indicate future options not yet implemented, but those options should be specially designated in some way.[34]

A seeming exception might be a process control display in which current values of a number of variables must be monitored (i.e., must be displayed continuously), and where supplementary data (e.g., trend analysis) can be called out for some variables but not others. Here some means must be found to signal the user which variables can be selected and which not.[34]

NOTE 12: A familiar set of general control options always available may be omitted from individual displays, and accessed as needed by a +OPTIONS entry.[34]

NOTE 13: 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 require the user 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.[34]

Beginning users may prefer a menu permitting a single choice from all available options, when those can be displayed on one page. Experienced users, however, may perform faster with a sequence of choices from a hierarchy of separately displayed sub-menus.[34]

A single menu that extends for more than one page will hinder learning and use. The USI (User System Interface) designer can usually devise some means of logical segmentation to permit several sequential selections among few alternatives instead of a single difficult selection among many.[34]

NOTE 14: 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.

When space permits, it may be desirable to display further (lower) choices in the hierarchic structure, to give the user a deeper view of the structure and permit direct selection of specific lower-level options.

NOTE 15: 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 an optional HELP display.[34]

NOTE 16: 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 computer acknowledgment.[34]

NOTE 17: If necessary, stacked sequential entries might be separated by a special character, such as a slash, comma or semicolon. It would be preferable, however, if they were simply strung together without special punctuation.[34]

Comment. A menu-driven dialogue is perhaps the most popular interactive technique available. In summary, menu-selection dialogue is most applicable if the users are inexperienced. It is also a benefit when the task requirements are routine and/or when the command set is so large that users are not likely to commit all command sets to memory.

Method for Assessment. Examine the dialogue type to ensure compliance with the above guidelines.

Command Language

Definition. This is a user-initiated sequence of transactions between the user and the system that provides high flexibility and efficient performance in task and central activities for highly skilled users.

Guidelines.	Research Support	Source
1. Command language dialogue should be used for tasks involving a wide range of user control entries, where users may be highly trained in the interests of achieving efficient performance and computer response is expected to be relatively fast. (See Note 1.)	L	34
2. When command language is used for control entry, an appropriate entry area should be provided in a consistent location on every display, preferably at the bottom. (See Note 2.)	L	34
3. The words chosen for a command language should reflect the user's point of view and not the programmer's, corresponding consistently with the user's operational language.	L	34
4. Abbreviation of entered commands (i.e., entry of the first 1-3 letters) should be permitted to facilitate entry by experienced users. (See Note 3.)	L	34

	Research Support	Source
Example: If a "P" uniquely identifies a print command (i.e., no other commands start with "P") than the user should be able to enter PRINT, or PR, or P, or any other truncation to initiate printing.		
5. All words in a command language and their abbreviations should be consistently used and standardized in meaning from one transaction to another and from one task to another.	L	34
Example: Do not use EDIT in one place, MODIFY in another, UPDATE in a third, all referring to the same kind of action.		
6. To minimize user confusion, words in a command language should be chosen to be distinctive from one another and to emphasize significant differences in function. (See Note 4.)	L	34
Example: Do not label two commands DISPLAY and VIEW, when one permits editing displayed material and one does not.		

	Research Support	Source
7. A command language should provide flexibility, permitting the user to assign personal names to files, frequently used command sequences, etc. (See Note 5.)	L	34
8. A command language should be supported by whatever computer processing is necessary so that the user can manipulate data without concern for internal storage and retrieval mechanisms. (See Note 6.)	L	34

Example: The user should be able to request display of a file by name alone, without having to enter any further information such as file location in computer storage.

	Research Support	Source
9. The features of a command language should be designed in groups (or "layers") for ease in learning and use. (See Note 7.)	L	34
10. The user should be able to request prompts as necessary to determine required parameters in a command entry or to determine available options for an appropriate next command entry. (See Note 8.)	L	34

	Research Support	Source
Example: Keying a question mark in the command entry area would be a satisfactory method of requesting prompts, or else using an explicitly labeled HELP function key.		
11. When command entries are prompted automatically, it should be possible for an experienced user to key a series of commands at one time ("command stacking") so as to shortcut the prompting sequence.	L	34
12. Insofar as possible, the user should be able to enter commands without punctuation. (See Note 9.)	L	34
13. Neither the user nor the computer program should have to distinguish between single and multiple blanks in a command entry.	L	34
14. Where the set of potential command entries is well defined, the computer should be programmed to recognize common misspellings of commands and to display inferred correct commands for user confirmation rather than requiring re-entry. (See Note 10.)	L	34

	Research Support	Source
15. When command entries are subject to misinterpretation (as in the case of voice input) or when an interpreted command may have disruptive consequences, the user should be given an opportunity to review and confirm a displayed interpretation of the command before it is executed. (See Note 11.)	L	34
16. When a command entry is not recognized, the computer should initiate a clarification dialogue rather than rejecting the command outright. (See Note 12.)	L	34

NOTE 1: Command language should also be considered for data entry in arbitrary sequences.[34]

NOTE 2: Adjacent to the command entry area there should be a defined display window used for prompting control entry, 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).[34]

NOTE 3: As a corollary, misspelling of command entries should also be tolerable within the limits of computer recognition. The computer can interrogate the user as necessary to resolve ambiguous entries.[34]

Variable abbreviation, i.e., keying only enough characters of a command to uniquely identify it, should probably not be used when the command set is changing. For the user, an abbreviation that works one day may not work the next. For the programmer, the addition of any new command may require software revision of recognition logic for other commands.[34]

NOTE 4: In general, do not give different commands semantically similar names, such as SUM and COUNT.[34]

NOTE 5: Frequently used commands should be made easy to accomplish. Where users will differ in the frequency of the commands they use, the designer should provide for flexibility in command naming.[34]

NOTE 6: Where file names are not unique identifiers, the computer should be programmed to determine whatever further context is necessary for identification, automatically in relation to the current transaction sequence, or perhaps by asking the user to designate a "directory" defining a subset of files of current interest.[34]

NOTE 7: The fundamental core, or bottom 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.[34]

NOTE 8: In some applications it may be desirable to let an inexperienced user simply choose a general "prompt mode" of operation, where any command entry produces automatic prompting of (required or optional) parameters and/or succeeding entry options.[34]

NOTE 9: If punctuation is needed, perhaps as a delimiter to distinguish optional parameters or the separate entries in a stacked command, one standard symbol should be used consistently for that purpose, preferably the same symbol (slash) used to separate a series of data entries.[34]

NOTE 10: This practice should permit a sizable reduction in wasted keying without serious risk of misinterpretation. The necessary software logic is akin to that for recognizing command abbreviations.[34]

NOTE 11: For beginning users, it might be desirable to permit review of interpreted commands for every transaction. Skilled users, however, should be able to suppress such routine review.

NOTE 12: Poorly stated commands should not simply be rejected. Instead, the computer should be programmed to guide the user toward a proper formulation, preserving the faulty command for reference and modification, and not require the user to re-key the entire command just to change one part.[34]

Comment. Unlike Menu dialogue, Command Language Dialogues should be reserved for sophisticated and highly trained users and where computer response is expected to be relatively fast.

Method for Assessment. Examine the dialogue type to ensure compliance with the above guidelines.

Query Language

Definition. This is a user-initiated sequence of transactions between the user and the system that provides flexible and efficient performance in information retrieval tasks for moderately trained users.

Guidelines.	Research Support	Source
1. Query language dialogue should be used as a specialized sub-category of general command language for tasks emphasizing unpredictable information retrieval (as in many analysis and planning tasks), with moderately trained users and fast computer response. (See Note 1.)	L	34
2. When the organization of the computer data base is reflected in the query language, that organization should match the data structure perceived by users to be natural. (See Note 2.)	L	34
3. One single representation of the data organization should be established for use in query formulation, rather than multiple representations. (See Note 3.)	L	34
4. The need for quantificational terms in query formulation should be minimized. (See Note 4.)	L	34
5. Use of operators subject to frequent semantic confusion, such as "or more" and "or less," should be minimized.	L	34

Example: A user should not have to convert "over 50 years old" into "51 or more."

NOTE 1: All recommendations for command language design would apply equally to query languages.[34]

NOTE 2: The users' natural perception of data organization can be discovered through experimentation or by survey.[34]

NOTE 3: Beginning or infrequent users may be confused by different representational models.

NOTE 4: Reference 34 excepts "no" or "none."

People have difficulty in using quantifiers unambiguously. When quantifiers must be used, it may be desirable to have the user select the desired quantifier from a set of sample statements so worded as to maximize their distinctiveness.

Comment. In conclusion, Query Languages should: (a) display a restatement of the users inquiry to assure correct interpretation of the user's intended meanings, (b) present user confirmation of system interpretation of meaning before the system executes the command, (c) display information in the form needed by the user even if the format differs from that contained in the data base or the form in which the data were originally entered, and (d) be such that the user's perception of the

data base should be sufficiently structured so as to enable rapid identification of those parts in which the user is interested.[123]

Method for Assessment. Examine the dialogue type to ensure compliance with the above guidelines.

Natural Language

Definition. This is a developing user-initiated sequence of transactions between the user and the system that will provide flexibility and efficient performance in task and control activities for moderately skilled users and eventually unskilled users.

Guidelines.	Research Support	Source
1. Unconstrained natural language dialogue should not be considered for USI (User System Interface) design at this time. (See Note 1.)	L	34

NOTE 1: Natural language may find future use in applications where task requirements are broad ranging and poorly defined, where little user training can be provided, and where computer response will be fast.[34]

Computer processing of natural language is now being developed on an experimental basis. For current applications where task requirements are well defined, other types of dialogue will prove more efficient.[34]

Comment. The recommendations by Smith and Aucella[34] appear to be somewhat pessimistic towards the utility of natural language dialogue. Some form of "restricted" natural language is feasible when one cannot teach a command set and syntax or vocabulary size does not hinder problem formulation. Restricted natural-language, though not an ideal panacea, should be considered (a) when it is impossible to teach a formal query language to potential users and the system's task is narrow and well-defined or (b) when unsophisticated users must use a system with a moderate number of functions.

However, in defense of Smith and Aucella's recommendations, natural language should be implemented into a system cautiously. Otherwise, ambiguities commonly employed in conversational english may tend to confuse the sytem, making it difficult if not impossible to operate.

Method for Assessment. A Natural Dialogue is not likely to be encountered in process control environment. If some form of natural language is available, ensure it is accepted and efficient for the user.

System Feedback

System feedback is critical in person-to-person, person-to-machine, and machine-to-machine communicatio . When interacting with a VDU terminal, immediate feedback is essential for establishing the user's confidence, satisfaction, and ability to perform his or her specific tasks effectively. At all times, the user must know where he is, where he has been, and where he can go. Throughout this interaction process, the user must also know whether the system is operating and information status if immediate feedback is delayed or interrupted.

This subcategory is devoted to those features which directly impact the effectiveness of "closing the loop" between the man-machine interface. A variety of techniques is available for accomplishing this mission. Two of these techniques are related to I/O aspects of the computer system. Display Update Rate deals with the time to present information to the operator. The latter addresses the time it takes for the system to respond after an operator initiated control input (Response Time). Other techniques entail the mechanisms for the presentation of guidance and status information to the operator. Such mechanisms include System Status Indication and Routine Status Information (error messages, prompts).

The variables discussed in this section are:

Display Update Rate

Definition. The term update rate is defined as the frequency of CRT update per unit time and the amount of time delay between the change of a system parameter and its graphic or numeric update on a CRT screen. For example, if the hot leg changes in the plant but the CRT display update lags that change by 5 s, the update rate is said to be 5 s. There are numerous factors that significantly influence the update rate of displayed parameters to operators while interacting with a computer system. Some of these variables include: sampling rate, memory, I/O overhead, cable length, type of CRT terminal, computer architecture, complexity of averaging algorithm, number and type of sensing transducers, and port configuration.[5]

Relevant Guidelines are presented below.

Guidelines.	Research Support	Source
1. Update rates for continuous, real-time tracking tasks should not exceed 0.5 s. (See Note 1.)	Y	5
2. In general, update rates should not exceed 3 s. (See Note 2.)	L	5

NOTE 1: Feedback delays of visual information greater than 0.5 s will seriously impede a continuous real-time control tracking task.[124]

NOTE 2: In informal research conducted at the Loss-of-Fluid Test (LOFT) Facility using interactive graphic displays and LOFT operators, the authors found that update rates of 3 s were acceptable to the operators. These observations were made, however, under conditions where all operating personnel were expecting a transient to occur. Because of this expectancy effect and also because the control task was not randomly ordered, the observations are more directed at operator preference than performance.[5]

Comment. The many constraints which influence update rate of displayed parameters make it difficult if not impossible to establish minimum values. Obviously, the shorter the update time the better, but it may be realistic to identify update rates only for critical tasks, e.g., those tasks wherein a delay of information will seriously impede safe operation of a physical control process.[5] Therefore, the update rate should be analytically determined by systematically examining (a) the type of process being controlled, (b) the type of tasks performed by operators, (c) safety critical value of control parameter, (d) consequences of delayed information on a worst-case basis, and (e) temporal response requirement of a system.

If such analysis is not feasible, a good rule of thumb might be the observational derived criteria for update rates collected at INEL (update rates of 3 s were acceptable to the operators). It should be noted that this data must be interpreted and implemented with caution due to the lack of formal experimental validation. The work performed by Smith and Smith[124] is the product of a more formalized study, but the specific experimental task and findings may not be directly generalizable to process control applications.

Method for Assessment. Without access to detailed system design specifications, the procedure for assessing this dimension cannot be fully objective. If those resources are not readily available, a reasonable approach for determining update rate could be accomplished by surveying the operators. Ask a group of operators whether or not the update rate of the displayed parameters is sufficient for performance of their tasks, i.e., is there lag in the update rate between the component and the displayed values on the screen that will present problems in doing your job? Are the parameter values reliable real time indications of the system process?

If discrepancies are noted (update times greater than 3 s and/or performance degradation is reported), provide recommendations for decreasing update rates.

Response Time

Definition. The concept of computer response time most often refers to the time that the user must wait for a computer response following a command. In other words, it is the elapsed time between a user request and a meaningful reply.[14] The ideal situation is, of course, when there is no response time at all. Since this is not always feasible, some acceptable guidelines should be established based on tradeoff analysis between the user's ability to perform his or her task and hardware/software limitation. The determination of acceptable response times are highly task specific. That is, the user's expectations may differ between situations. As a result, much of the literature cites a set of response times as they apply to specific tasks. Operator's willingness to wait is functionally related to the perceived complexity of the task and time when the request was made. Other research points out that it may not only be the magnitude of the response time but the variability of the delays which significantly impact operator performance and acceptance of a system.

Guidelines.	Research Support	Source
1. Response times should be within the maximums shown in Table 11.	L	36
2. Response time deviations should be less than one-half the mean response time. (See Note 1.)	Y	58

NOTE 1: Carbonell et al.[125] point out that it is the variability of delays, not their magnitude, which is frequently the most distressing factor to users. From a consistency standpoint, a good rule of thumb is that the response time deviations should never be more than half the mean response time (e.g., if the mean response time is 4 s, the variation should be confined to the range of 3 to 5 s--a 2-s deviation).

Comment. Adequate values for determining response times are highly task specific and reliable research data are limited. The values sited in Engel and Granda[36] are only educated or "armchair estimates." However, for lack of more concrete data, those values can also be construed as reasonable rules of thumb if the specific task requirements are known. If specific tasks are not identified, the most often recommended "armchair" estimates range from 2 to 4 s maximum systems response time.[126]

Method for Assessment. Direct interaction with the VDU being assessed is perhaps the best method for determining whether the system response times are acceptable. If "slow" responses are noted, survey a group of operators for their opinion. If there is consensus, provide recommendations to set response times into a more acceptable range.

TABLE 11. ACCEPTABLE RESPONSE TIMES (Source: Reference 126, as presented in Reference 36

User Activity	Maximum Response Time (s)
1. Control activation (for example, keyboard entry)	0.1
2. System activation (system initialization)	3.0
3. Request for given service:	
Simple	2
Complex	5
Loading and restart	15-60
4. Error feedback (following completion of input)	2-4
5. Response to ID	2
6. Information on next procedure	<5
7. Response to simple inquiry from list	2
8. Response to simple status inquiry	2
9. Response to complex inquiry in table form	2-4
10. Request for next page	0.5-1
11. Response to "execute problem"	<15
12. Light pen entries	1.0
13. Drawings with light pens	0.1
14. Response to complex inquiry in graphic form	2-10
15. Response to dynamic modeling	--
16. Response to graphic manipulation	2
17. Response to user intervention in automatic process	4

System Status Indication

Definition. This term is used to describe a method, technique, or signaling device (auditory or visual) that permits the operator of a CRT terminal to easily, accurately, and rapidly detect whether the computer is functioning normally.

Guidelines.	Research Support	Source
1. An indicator that the computer is functioning normally should be provided on the CRT display. (See Note 1.)	N	4, 127

NOTE 1: Reference 127 recommends continuous display of a sweeping vector (similar to the second hand of a watch) in the upper quadrant of the screen. Reference 4 recommends a 0.5-in. diameter circle or 0.5-in. square that pulses from black to white at a rate of 1 pulse/s.

Comment. The criterion above describes passive alarms which may not have the same attention-getting capability as an active failure alert system incorporated in the CRT display. For example, the installation of a self-powered circuit that would emit a periodic "beeping" tone when the system fails would have more attention-getting characteristics than a passive visual stimulus. Therefore, the author recommends that an active alert system take precedence over a passive mode when feasible. A digital clock placed in a corner of screen is not an adequate mode for alerting the operators of a system failure. There is observational evidence that indicates the digital clock, as a stand alone status indicator, does not provide adequate attention-getting quality and should not substitute for the criterion mentioned above.

Method for Assessment. Observe the screen under both operational and nonoperational mode and verify the adequacy of the status indicator implemented.

Routine Status Information

Definition. The various mechanisms for informing the operator of current system status are examined in this section. All to often, the operator must know the state of displayed information throughout the interactive process.

It should be noted that many of these techniques encompass a substantial number of other variables addressed in this document. Therefore, the reader is encouraged to review supporting guidelines information. The sections for errors and message design and content are recommended.

Guidelines.	Research Support	Source
1. When system functioning requires the operator to stand by, such as when the computer is searching for requested data, periodic feedback should be provided the operator to indicate normal system operation and the reason for the delay. (See Note 1.)	L	6, 14, 34
2. 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.	L	6
3. If at any time the keyboard is locked or the terminal is otherwise disabled, that condition should be signaled by disappearance of the cursor from the display and (especially if infrequent) by some more specific indicator such as an auditory signal.		34

	Research Support	Source
4. In applications where task performance requires data exchange and/or interaction with other users, status information should be available concerning other users of the system.	L	34
5. In applications where task performance is affected by operational load (e.g., number of on-line users), status information should be available indicating current load and/or current system performance. (See Note 2.)	L	34
6. In applications where task performance requires data exchange and/or interaction with other systems, relevant status information for external systems should be available to the user.	L	34
7. In applications where task performance requires or implies the need to assess currency of information, date-time signals should be available to users as an annotation on displays. (See Note 3.)	L	34
8. In applications where alarm signals are established on the basis of logic defined by users, status information should be available concerning the current status of alarm settings, in terms of dimensions/variables covered and values/categories established as critical. (See Note 4.)	L	34

	Research Support	Source
9. Every input by a user should consistently produce some perceptible response output from the computer. (See Note 5.)	L	34
10. Computer response to user entries should be rapid, with consistent timing as appropriate to different types of transactions.	L	34
11. Following user interrupt of data processing, an advisory message should be displayed assuring the user that the system has returned to its previous status.	L	34

NOTE 1: Reference 34 states, "After making an entry to the computer, the user needs feedback to know whether that entry is being processed properly. Delays in computer response longer than a few seconds can be disturbing to the user, especially for a transaction that is usually processed immediately. In such a case, some intermediate feedback should be provided, perhaps an advisory message that processing has been initiated, and ideally with an estimate of how long it will take to complete.

"In some applications, system status may be continuously displayed. 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 might be provided only on user request, following a general or specific query.

"Status information is particularly needed, of course, when system operation is unreliable for any reason. Under those conditions, if status information is not provided by design, users will often devise their own repertoire of harmless but time wasting test inputs to check system performance."

Reference 14 states, "Keep in mind that providing a timely response to users may mean having the computer present a status message. Users sitting at the terminal and waiting for a response may wonder if the computer is still working, if the terminal is still connected to the computer, if the computer lost the input, or if the computer is in a 'never ending' loop. A short message--STILL PROCESSING--that appears every 10 s indicating that the computer is still working on the problem provides the user with some assurance. As we indicated earlier, the first such message should appear within 1 or 2 s after the command is sent, should be taken off the screen after 5 s, and then should be noticeably updated in about ten seconds. This cycle should be repeated until the expected response occurs."

NOTE 2: Such load information is primarily helpful when system use is optional, i.e., when a user can choose to defer work until low-load periods. But load status information may help in any case by establishing realistic user expectations for system performance.[34]

NOTE 3: Date-time status might be displayed continuously or periodically, as on displays that are automatically updated, or by user request, depending on the application.[34]

In some applications, request for date-time display can provide an innocuous means for a user to check on general system response.[34]

NOTE 4: Alarm status information will be particularly helpful in monitoring situations where responsibility may be shifted from one user to another.[34]

NOTE 5: Keyed entries should appear immediately on the display. Function key activation or command entries should be acknowledged either by evident performance of the requested action or by an advisory message indicating an action in process or accomplished. Unrecognized inputs should be acknowledged by an error message.[34]

Absence of system response is not an effective means of signaling acceptable entry. At best, a dialogue without feedback will be disconcerting to the user, as when we talk to an unresponsive human listener. At worst, the user may suspect system failure with consequent disruption and/or termination of the interaction sequence.[34]

Comment. All of the above guidelines echo a similar theme: the operator must be provided information at all times giving an up to date account of the systems status, i.e., what is the system doing? A variety of techniques is available for satisfying the criteria.

Method for Assessment. Assess the VDU by ensuring that some mode is available for informing the operator of the current system status. If the mechanism for performing this function is inadequate, provide recommendations to resolve these discrepancies using the data presented in the above guidelines.

Performance/Job Aids

Definition. Bailey[14] provides the most precise definition of a performance or job aid, "Performance aids are devices that store information for immediate use." They can be in either written hard copy form or computer based. This section is devoted to those performance aids adapted for a CRT generated media. Performance aids satisfy a similar function with step-by-step proceduralized instructions. A major difference, however, resides in the level of detailed information. Performance aids are usually characterized by having less to read in a quick access format. Performance aids should be considered as a supplement to detailed procedures and/or training.

Guidelines.	Research Support	Source
1. At any point in a transaction sequence, specific user guidance information should be available for display. (See Note 1.)	L	34
2. To serve as a "home base" or consistent starting point at the beginning of a transaction sequence, a general menu of control options should always be available for user selection.	L	34
3. Menu options should be grouped logically to aid user learning and selection among displayed alternatives.	L	34
4. When hierarchic menus must be used, they should be organized and labeled to guide the user within the hierarchic structure. (See Note 2.)	L	34

	Research Support	Source
5. At any point in a transaction there should be displayed guidance telling the user how to continue.	L	34

USE: Data base status is current through March 1983. Press STEP key to continue.

DON'T USE: Data base is current through March 1983.

6. Control options that are generally available at any step in a transaction sequence should be treated as implicit options, i.e., need not be included in a display of step-specific options. (See Note 3.)	L	34
7. The computer should be programmed to provide prompting, i.e., to display advisory messages to guide users in entering required data and/or command parameters. (See Note 4.)	L	34
8. Prompts for command entry should be displayed next to the command entry area, at the bottom of the display.	L	34

	Research Support	Source
9. When users vary in experience (which is often the case), prompting should be an optional guidance feature that can be selected by novice users but can be omitted by experienced users. (See Note 5.)	L	4
10. When the results of a user entry are contingent upon context established by previous entries, some indication of that context should be displayed to the user.	L	34

Example: a. Selection of operational modes.

b. If the user is editing a data file, both the file name and an indication of EDIT mode should be displayed.

---

11. Implicit cues for data entry should be provided by consistent and distinctive formatting of data fields. (See Note 6.)	L	34

Example: A colon could be used consistently to indicate that an entry can be made, followed by an underscored data field to indicate item size, such as

Enter part code: _ _ _ _ _

	Research Support	Source
or perhaps just simply PART CODE: _ _ _ _ _		
12. Following computer generation of display output, the cursor should automatically be positioned on the display in a location consistent with the type of transaction. (See Note 7.)	L	34
13. Reference material should be available for on-line display to the user describing system capabilities and procedures. (See Note 8.)	L	34
14. In applications where the user has selective access to stored data, the computer should provide an on-line data index to help guide user selection. (See Note 9.)	L	34
15. In applications where a user may employ command entry, the computer should provide an on-line command index to help guide user selection and composition of commands. (See Note 10.)	L	34
16. A complete dictionary of abbreviations used for data entry, data display, and command entry should be available for on-line user reference and in system documentation. (See Note 11.)	L	34

	Research Support	Source
17. When codes are assigned special meaning in a display, a definition should be provided at the bottom of the display. (See Note 12.)	L	34
18. In system applications where it is warranted, the user should be able to request a displayed record of past transactions in order to review prior actions.	L	34
19. In addition to explicit aids (labels, advisory messages) and implicit aids (cueing) provided in user interface design, there should also be a capability for a user to request further on-line guidance by a request for HELP. (See Note 13.)	L	34
20. The HELP request should be initiated consistently by some simple, distinctive user action. (See Note 14.)	L	34

Example: HELP could be requested by an appropriately labeled function key, or perhaps by keying a question mark.

---

21. Computer response to HELP request should be tailored to task context and the current transaction. (See Note 15.)	L	34

	Research Support	Source
22. When a request for HELP is ambiguous in context, the computer should initiate a dialogue in which the user can specify what data, message, or command requires explanation.	L	34
23. When an initial HELP display provides only summary information, more detailed explanations should be available in response to repeated user requests for HELP. (See Note 16.)	L	34
24. Novice users should be able to browse on-line HELP displays, just like a printed manual, to gain familiarity with system functions and operating procedures.	L	34
25. For many system applications, an on-line training capability should be provided to introduce new users to system capabilities and to permit simulated "hands on" experience in data handling tasks. (See Note 17.)	L	34
26. On-line training capabilities should be adapted to the needs of different users. (See Note 18.)	L	34
27. In applications where complex user skills must be developed, computer-mediated training should adapt automatically to current user skill levels. (See Note 19.)	L	34

Research Support | Source

Example: On-line tracking and other skilled control tasks.

NOTE 1: Do not require a user to remember information currently displayed. The user should not have to remember what actions are available or what action to take next. Human memory is unreliable, and without guidance the user can be excepted to make errors.[34]

NOTE 2: Users will learn menus more quickly if a map of the menu structure is provided as HELP.[34]

NOTE 3: The user may be expected to remember continuously available options, once they have been learned, without their specific inclusion in a display of guidance information. Perhaps the best design expedient is to implement implicit options on appropriately labeled function keys, which will aid user learning and provide a continuing reminder of their availability.[34]

NOTE 4: Prompting in advance of data/command entry will help reduce errors, particularly for inexperienced users. If a default value has been defined for null entry, that value should be included in the prompting information.[34]

NOTE 5: Flexibility in prompting can also be provided by multi-level HELP options, so that additional guidance information can be obtained if the standard prompt is not adequate.[34]

NOTE 6: Consistent use of implicit prompting cues can sometimes provide sufficient guidance to eliminate the need for more explicit advisory messages.[34]

NOTE 7: For data entry displays, the cursor should be placed initially at the first data field, or else at the first wrong entry if an error has been detected. In other displays, the cursor should be placed at a consistent HOME position, or at the first control option for menu selection, or else in a general command entry area, depending upon the type of display.

Consistent cursor positioning will provide an implicit cue for user guidance.[34]

NOTE 8: Many systems are not utilized effectively, by experienced users as well as by novices, because users do not fully understand system capabilities. On-line access to a description of system structure, components, and options will aid user understanding. On-line guidance can supplement or in some instances substitute for off-line training. An investment in designing user aids may be repaid by reduced costs of formal training as well as by improved operational performance.[34]

NOTE 9: The data index should indicate file names and structure as needed to access different categories of data.[34]

NOTE 10: Such a command index may help the user to phrase a particular command, but will be more generally useful as a reference for discovering related commands and learning the overall command language.[34]

NOTE 11: In applications where users can create their own abbreviations, as in the naming of command "macros," it will be helpful to provide aids for users to create their own individual on-line dictionaries.[34]

NOTE 12: This practice will aid user assimilation of information, especially for display codes that are not already familiar.[34]

NOTE 13: It is difficult for an interface designer to anticipate the degree of prompting that may be required to guide all users. Moreover, even when prompting needs are known, it may be difficult to fit all needed guidance information on a working display. A supplementary HELP display can be provided to deal with such situations.[34]

NOTE 14: The user should be able to request HELP at any point in a transaction sequence. It will help more if the procedure is always the same, whether the user wants an explanation of a particular data entry, or displayed data, or command option.[34]

NOTE 15: If a data entry error has just been made, HELP should display information concerning correct entry requirements for that particular data item. 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 parameter, etc.[34]

NOTE 16: It is necessarily a matter of judgment just what information should be provided in response to a HELP request. Designing the HELP function to provide different levels of increasing detail permits users to exercise some judgment themselves as to just how much information they want.[34]

NOTE 17: On-line simulation, using the same hardware, user interface software, and data processing logic as for the real job, can prove an efficient means of user training. Care must be taken, however, to separate and distinguish simulated from actual system operation.[34]

NOTE 18: Instruction on keyboard use and light pen selection of menu options might be provided for novice users, while a tutorial on command language might be provided at several levels for more experienced users. In systems supporting different user jobs, on-line instruction might describe the procedures for each different data handling task.[34]

NOTE 19: Adaptive training will require some means for computer assessment of appropriate components of user performance.

Comments. Despite the relative importance of job aids as an integral part of user dialogue, two problems constrain their full capabilities:

1. They are not considered at all

2. Performance aids are installed, but they are either incomplete or so difficult to access and use in the dialogue, the user fails to utilize it.

Specific design criteria for development of a performance aid from the top down is beyond the scope of these guidelines. However, implementation of the above guidelines should enhance the "user friendly" capabilities of existing performance-aiding devices.

Method for Assessment. Perform an interactive walk-through of the user interface. Check for conformance of the performance-aiding capabilities with the above guidelines. If discrepancies are noted, provide recommendations accordingly. Also, survey a group of operators to ensure that all essential instructional information is available to them. If there is an indication of ambiguity, suggest guidance information to be stored on line as first priority. As a second priority, ensure, as a minimum, that all necessary documentation is at least available in hard copy format and made accessible to the operators.

Software Security

This subcategory will examine some specific issues which make up only a small portion of this broad area. Basically, the issue of Software Security encompasses two areas: (a) the need to protect data from unauthorized access and tampering and (b) the need to protect data from authorized users who may induce errors causing loss and "trashing" of data files.

Techniques and methods for ensuring that data can be protected from both external threat and user error will be examined in this subsection under the variable Data Protection.

Data Protection

Definition. Computer systems used for process control often store data of a proprietary nature. As a result, the system designer is often encumbered to develop a system that is not only secure from unauthorized tampering but remains accessible to authorized users. Provisions must also be implemented which will minimize the probability of damaging or losing data through errors which might have consequence for safety and availability.

Guidelines.	Research Support	Source
1. Data security should be protected by automatic measures whenever possible, relying on computer capabilities rather than on fallible human procedures.	L	34
2. User interface design should provide consistent procedures for data transactions, including data entry and error correction, data change, and deletion. (See Note 1.)	L	34
3. Inputs to the computer, including data entries and control entries, should require explicit user actions. (See Note 2.)	L	34
4. When the result of user action is contingent upon prior selection among differently defined operational modes, that mode selection should be continuously indicated to the user, particularly when user inputs in that mode might result in unintended data loss. (See Note 3.)	L	34

	Research Support	Source
Example: DELETE mode when editing displayed data.		
5. User interface design should deal appropriately with all possible control entries, correct and incorrect, without introducing unwanted data change. (See Note 4.)	L	34
6. For both data entry and control entry, the user should be able to edit composed material before initial entry and also before any required reentry. (See Note 5.)	L	34
7. For both data entry and control entry, the user should be required to resolve any detected ambiguity requiring computer interpretation.	L	34
Example: Resolving ambiguous abbreviation by selection among displayed alternatives.		
8. The user should be warned of potential threats to data security by appropriate messages and/or alarm signals.	L	34

NOTE 1: Consistent procedures will reduce the likelihood of user confusion and error and are especially important for any transaction that risks data loss.[34]

NOTE 2: Reference 34 lists automatic cross-file updating as an exception to Guideline 3. An exception can also be made for repetitive tasks, as when correct entry of one data set in a form-filling dialogue might automatically result in display of the next (empty) form, without specific user request.[34]

In effect, a computer should not initiate data changes unless requested (and possibly confirmed) by a user. Interface designers are sometimes tempted to contrive "smart shortcuts" in which one user action may automatically produce several other associated data changes, perhaps saving the user a few keystrokes. Since such shortcuts cannot generally be made standard procedures, they will tend to confuse novice users and so may a potential threat to data protection.[34]

Example: DELETE mode when editing displayed data.

NOTE 3: A user cannot be relied upon to remember prior actions. Any action whose results are contingent upon previous actions represents a potential threat to data protection.[34]

NOTE 4: The interface designer must try to anticipate every possible user action, including random keying and perhaps even malicious experimentation. The user interface must be "bullet-proofed" so that an unacceptable entry at any point will produce no more significant computer response than an error message.[3]

NOTE 5: This capability will permit a user to correct many entry errors before computer processing. When errors are made, the user will be able to fix them without having to regenerate correct items and risk introducing further errors.[34]

Comment. The above guidelines should be a functional part of tne overall security philosophy for process control systems. Further, it appears that many potential problems concerning data protection could be minimized if a top level "user friendly" system is a major consideration in the overall design.

Method for Assessment. Visual inspection and personal interaction of the VDU for assessment might be somewhat laborious and time consuming. Perhaps a more feasible approach is to survey the users with the guidelines to verify that the various features and concepts are implemented. Personal opinion and case history of incidents relating to data protection would also be useful information toward assessing this issue.

WORKPLACE LAYOUT

Anthropometrics

The following variables will be examined in this subcategory:

There are essentially three basic types of workplaces where VDUs could be used in NPP Control. Those are the sitting workplace, the standing workplace, and the sitting/standing workplace. (See Figures 40, 41, and 42, respectively.)

The decision as to which one is appropriate depends on the general control room layout and encompasses the following considerations:

Sitting workplaces are best in the following situations:

- o All items needed in the short-term task cycle can be easily supplied and handled within the seated work space.

- The items being handled do not require the hands to work at an average level of more than 15 cm (6 in.) above the work surface.

- No large forces are required, such as handling weights greater than 4.5 kg (10 lb) (adapted from Reference 137). (Large forces may be eliminated by using mechanical assists.)

- Fine assembly or writing tasks are done for a majority of the shift.

Standing workplaces will be the best alternative in the following circumstances:

- If the workplace or work station does not have knee clearance for a seated operation.

- Objects weighing more than 4.5 kg (10 lb) are handled.

- High, low, or extended reaches, such as those in front of the body, are required frequently.

- Operations are physically separated and require frequent movement between work stations.

- Downward forces must be exerted, as in wrapping and packing operations.

Sitting/standing workplaces should be considered in these instances:

- Repetitive operations are done with frequent reaches more than 41 cm (16 in.) forward and/or more than 15 cm (6 in.) above the work surface. Operations would be done at a sitting workplace if it were not for the reach requirements.

- Multiple tasks are performed, some best done sitting and others best done standing. Provision for both may not be feasible owing to space constraints.

For the items which follow, numerous sources have developed a recommended range of dimensions appropriate for that item. For the most part, these are based on the 5th percentile (small) woman and the 95th percentile (large) male population as appropriate.

From review of the literature, it becomes obvious that you cannot please all the people all the time even if designs are within the recommended specifications. Because people are individuals and because they need to change positions periodically, adjustability within the recommended range is highly recommended. This adjustability accommodates those human traits. An example of an adjustable workstation is shown in Figure 43.

All these individual items, even if within guidelines, cannot guarantee a satisfactory workplace layout. The task to be performed, the manuals which are needed, and numerous other incidental considerations need to be addressed. This check probably goes beyond the VDU workplace to consideration of the overall control room or station design. How the VDU workplace fits into the overall system needs to be kept in mind.

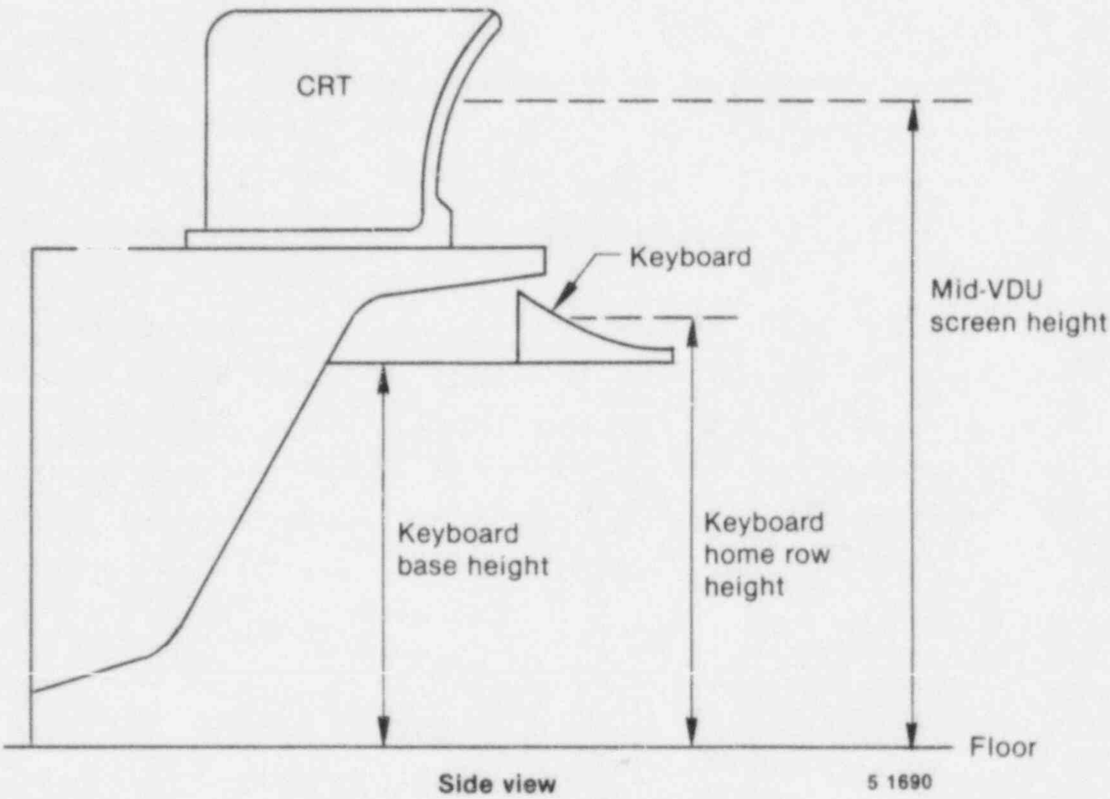


Figure 40. Seated VDU workplace.

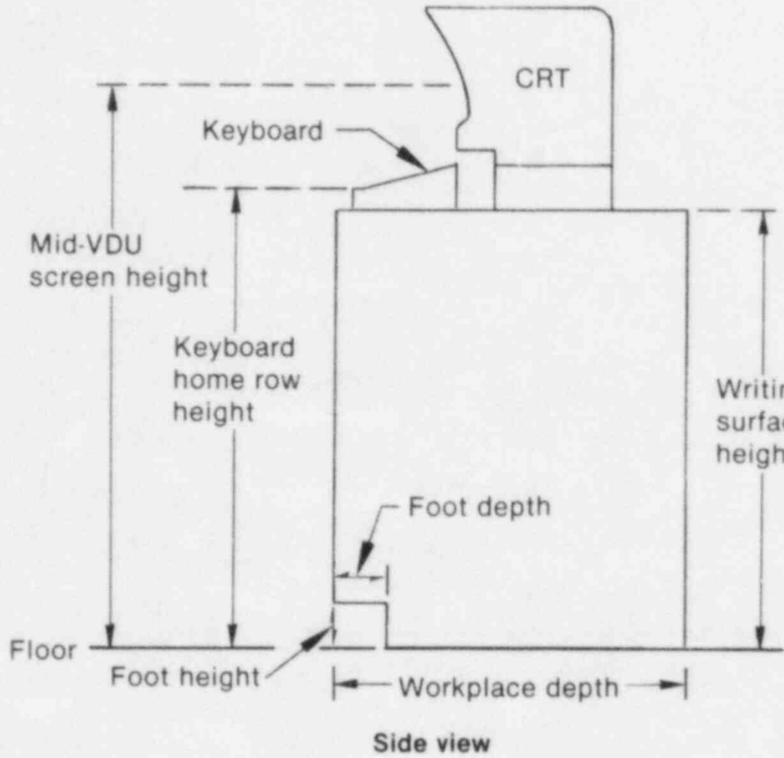


Figure 41. Standing VDU workplaces (adapted from Reference 21).

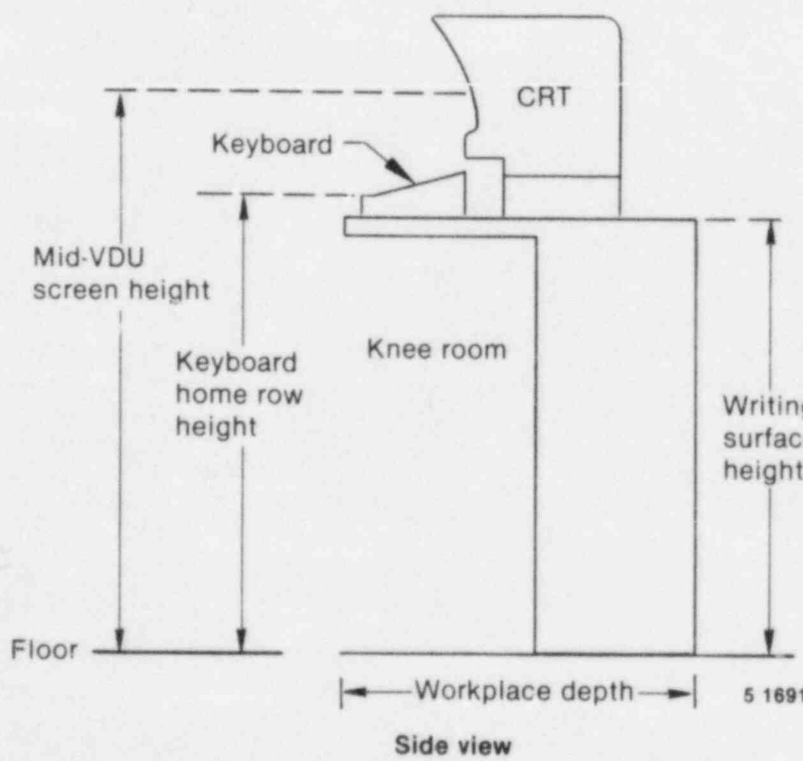
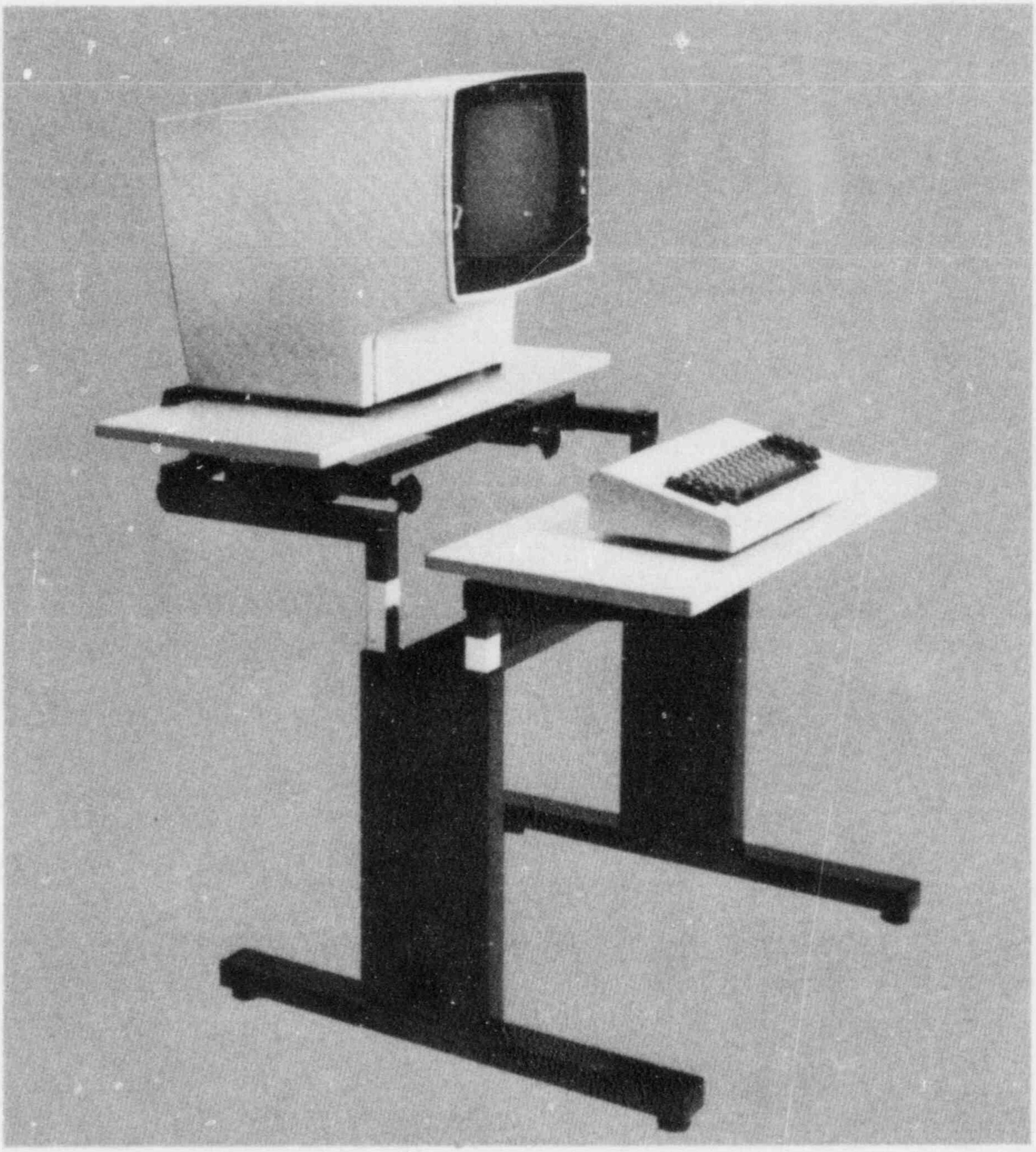


Figure 42. Sitting/standing VDU workplaces (adapted from Reference 21).



5 1692

Figure 43. Adjustable VDU workstation. Capability is provided for independent height adjustment of the keyboard and screen surface.

Keyboard Base

Definition. The work surface height upon which keyboards and other CRT related controllers are placed (see Figure 44).

Guidelines.	Research Support	Source
1. The keyboard base height for a seated workplace should be from 56 to 77 cm (22 to 30 in.). (See Note 1.)	Y	6, 14, 40, 129, 130
2. The keyboard base height for a standing or a sitting/standing workplace should be from 90 to 93 cm (35.5 to 36.5 in.).	Y	131

NOTE 1: Based on short female (5th percentile) and tall male (99th percentile). Reference 40 recommends a range of 46 to 93 cm (18 to 36.5 in.).

Comment. The references cited provide the range of recommendations for keyboard base height assuming various workplace situations and population profiles. Again, adjustability over the recommended range to accommodate variations in personnel is strongly suggested.

Method of Assessment. (a) verify user population falls within the ranges outlined, (b) measure keyboard base height to ensure it falls within the appropriate range, (c) check for adjustability to accommodate user population.

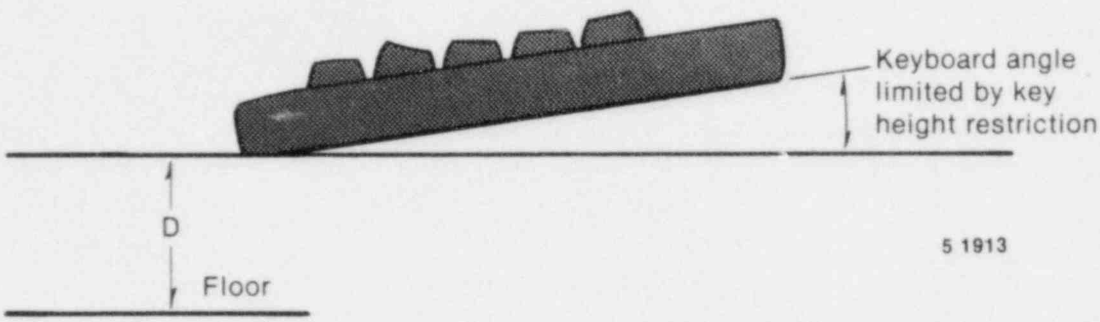


Figure 44. Keyboard base height (D) (adapted from Reference 128).

Working Level

Definition. The working surface near a CRT which is utilized for writing, logging, or manipulative tasks not involving a CRT controller or keyboard. (See Figure 45.)

Guidelines.	Research Support	Source
1. Working level height for a sitting workplace should be from 66 to 81 cm (26 to 32 in.).	Y	6, 14, 16, 22, 129, 130, 132, 133
2. Working level height for a standing workplace should be from 90 to 107 cm (35.5 to 42 in.).	Y	16, 132, 134
3. Working level height for a sitting/standing workplace should be from 90 to 102 cm (35.5 to 40 in.).	Y	16, 132, 134
4. Working level width should be from 61 to 76.5 cm (76.5 cm preferred).	Y	6, 14, 16, 57
5. Working level depth should be from 41 to 64 cm (64 cm preferred).	Y	6, 14, 16, 57

Comment. These values reflect standard design practices in use industry wide. Adjustability here, as before, was recommended.

Method for Assessment. Measure working level width, height, and depth to ensure they fall within the appropriate range.

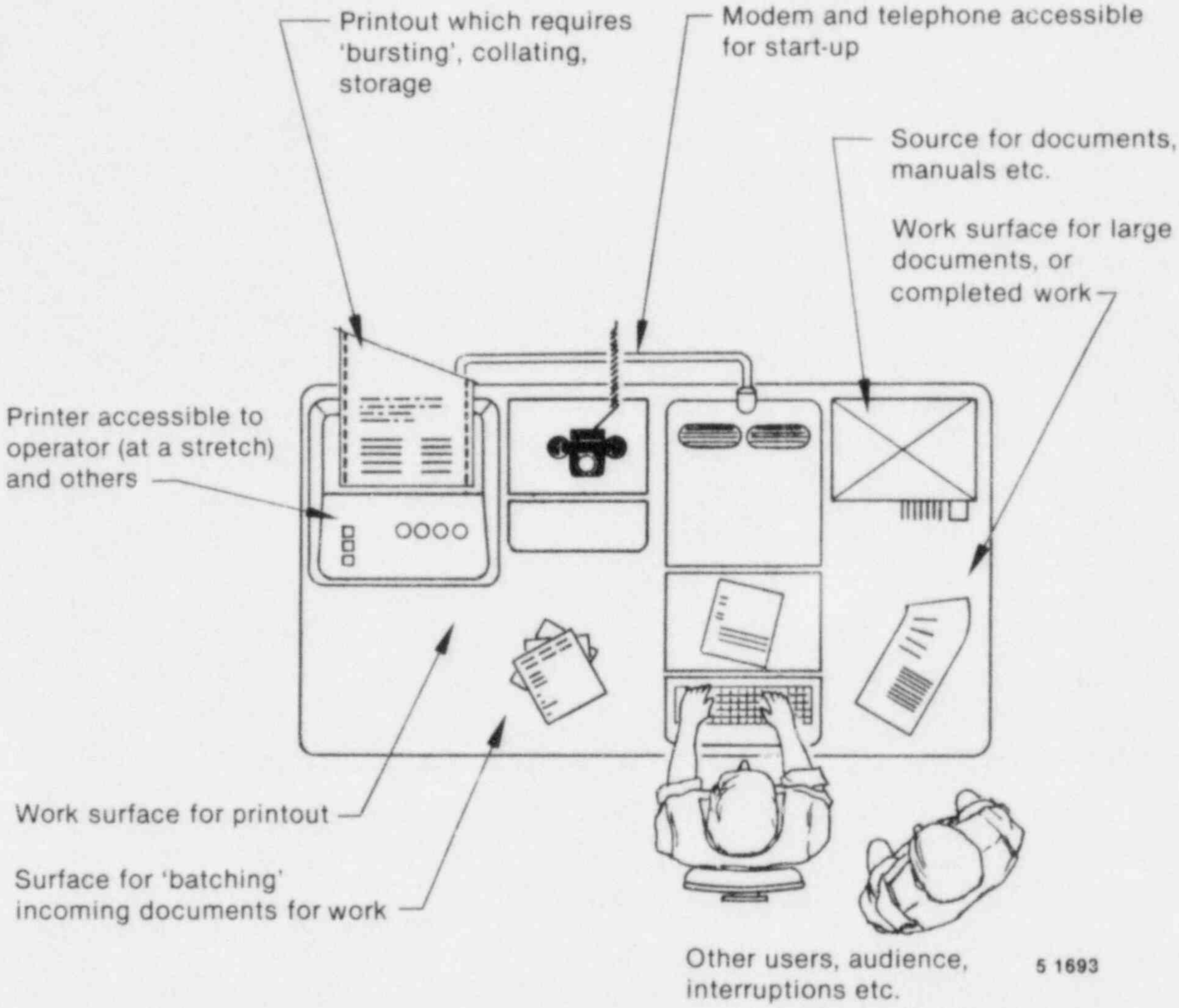


Figure 45. Overhead view of VDU workstation showing work areas (adapted from Reference 22).

Keyboard Home Row

Definition. The distance from the floor (for seated operator) to the center of the home position for the right index fingertip on a Sholes or QWERTY keyboard (the center of the J key top). (See Figure 46.)

Guidelines.	Research Support	Source
1. Keyboard home row height should be 66 to 78 cm (26 to 30.5 in.).	Y	22, 133

Comment. These values reflect standard design practices in use industry wide. Adjustability to suit the individual, here as before, was recommended.

Method for Assessment. Measure keyboard home row height to ensure it falls within the guideline.

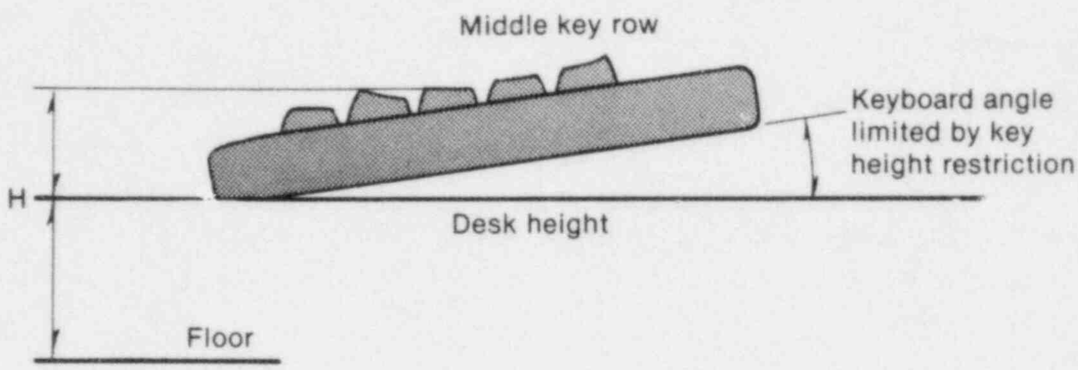


Figure 46. Keyboard home row height (H).

Screen

Definition. The reference point for measuring screen height (display height) and viewing angle is that on the outermost surface of the screen midway between vertical and horizontal extremes of the portion used for displays. The display is the surface containing the images on which the eye is to focus and excludes filters, implosion covers, and similar added surfaces. (See Figure 47.)

Guidelines.	Research Support	Source
1. The screen height for a seated workplace should be from 15 to 117 cm (6 to 46 in.), with 99 cm (39 in.) preferred.	Y	16, 135
2. The screen height for a standing workplace should be from 104 to 178 cm (41 to 70 in.).	Y	16
3. The screen viewing angle should be within 35 degrees of the horizontal line of sight, with about 15 degrees below the horizontal line of sight preferred. (See Note 1.)	Y	6, 22, 40, 57, 136

NOTE 1: Reference 6 recommends the viewing angle be within the upper limit of the visual field (75° above the horizontal line of sight) of the 5th percentile female and angle from the line of sight to the face plane is 45° or greater. The maximum lateral spread of controls and displays at a single-operator workstation should not exceed 72 in.

Comment. These values reflect standard design practices in use industry wide. Adjustability to suit the individual, here as before, was recommended.

Method for Assessment. Measure screen height and viewing angle to ensure they fall within the guidelines.

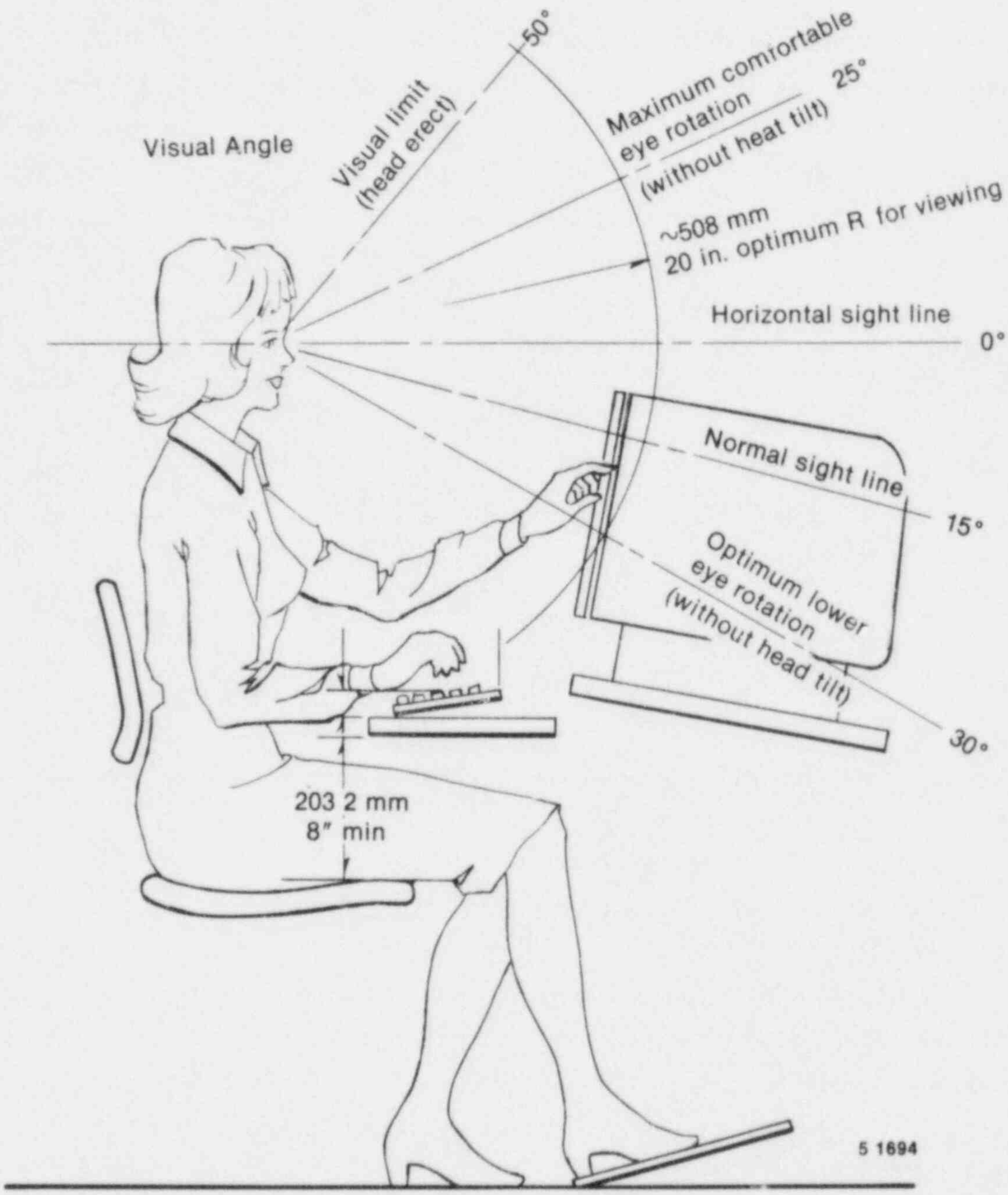


Figure 47. Display height (H) and visual angles for VDU workstation (adapted from Reference 22).

Viewing Distance

Definition. The distance from the operator's eye to the surface containing the image being observed (see Figure 48).

Guidelines.	Research Support	Source
1. The viewing distance should be 33 to 80 cm (13 to 30 in.), with 46 to 61 cm (18 to 24 in.) preferred.	Y	6, 21, 22, 40, 129, 130, 133, 136

Comment. All references fell within the range shown, with most showing a preference for the 18 to 24 in. range.

Method for Assessment. Measure the viewing distance to ensure it falls within the guideline.

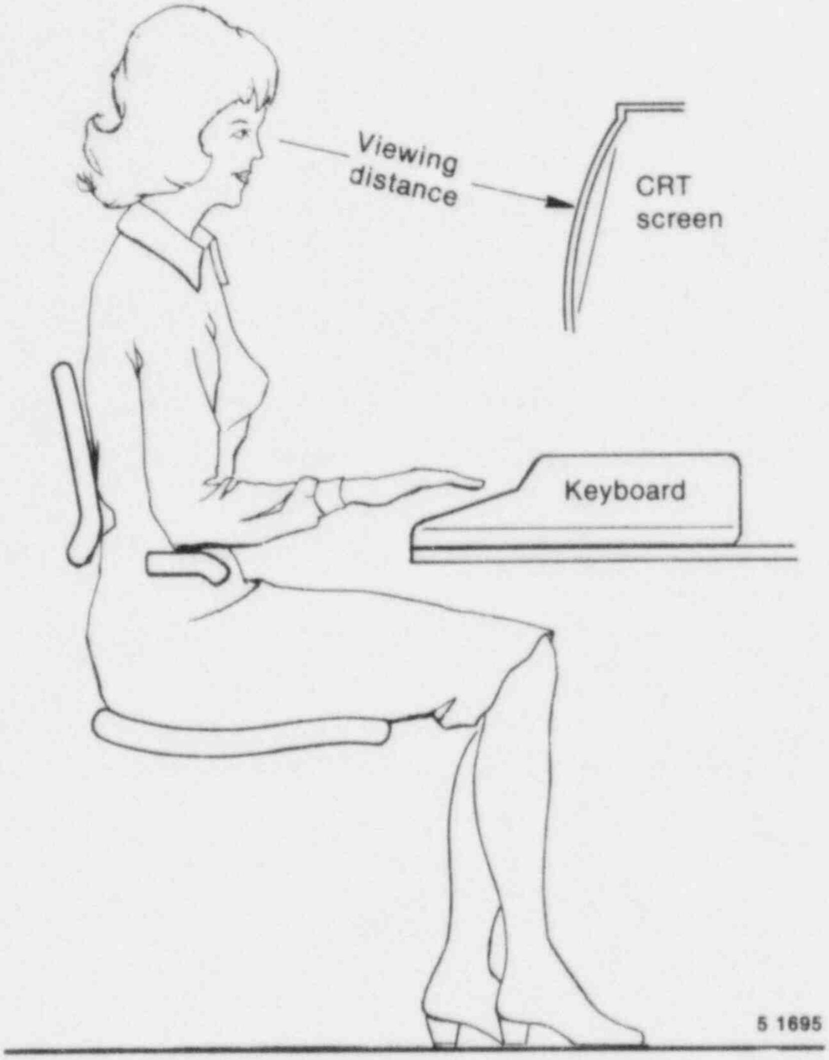


Figure 48. Viewing distance for VDU workstation.

Footrest

Definition. A surface for the operator's use which adds leg comfort and reduces fatigue.

Guidelines.	Research Support	Source
1. The footrest should be 18 in. below the level of the seat and should be adjustable in 2 in. increments of height.	Y	6, 22, 57
2. Rectangular footrests should be 30 cm (12 in.) deep by 41 cm (16 in.) wide.	Y	21
3. Circular footrests should have a diameter of 18 inches.	Y	6, 22, 57
4. The footrest should be circular if it is part of the chair.	Y	6, 22, 57

Comment. The bottom line for footrests is "provide them if needed." Apparently, only shorter people express a desire for them.

Method for Assessment. Verify footrest, if provided, falls within dimensional criteria.

Reach Envelope

Definition. Functional reach envelope (often referred to as thumb-forefinger grasping reach) is the measured distance from a constant Reference Point to the maximum reach limits of a stationary operator (see Figure 49).

Guidelines.	Research Support	Source
1. The functional reach envelope should be from 64 to 88 cm (25.2 to 34.6 in.).	Y	16, 138

Comment. The cited references fall within the above guideline for reach envelope.

Method for Assessment. Verify controls, etc. are within prescribed reach envelope.

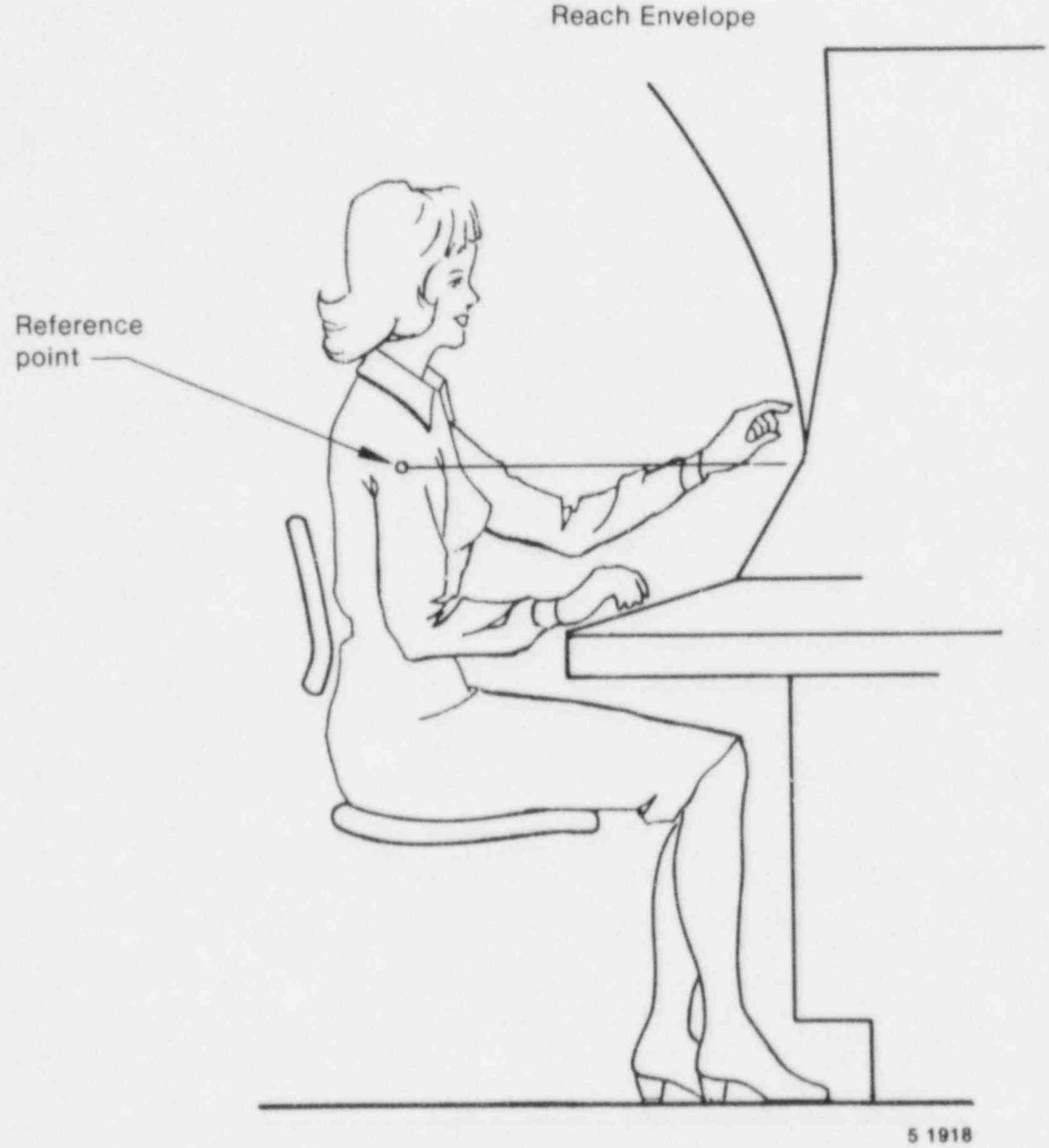


Figure 49. Functional reach envelope for seated operator.

Position and Movement of the Head

Definition. The inclination of the head with respect to the horizontal plane.

Guidelines.	Research Support	Source
1. The normal inclination angle of the head should be from 16 to 22 degrees. (See Note 1.)	Y	22
2. A document holder should be provided to reduce head movement while keying data from a document.	Y	22

NOTE 1: The most comfortable viewing angle is between 32 and 44° below the horizontal plane. Head inclination is approximately one-half of this (16 to 22°).[22]

Comment. This guideline was developed with extensive keying in mind. However, the criteria are desirable (not mandatory), even where only occasional use of documents and keyboard/controls is employed.

Method for Assessment. Verify document holder, etc. are provided to minimize head movement.

Leg, Knee, and Foot Room

Definition. Relevant dimensional requirements for leg, knee, and foot room for the seated/standing operator are presented in this section.

Guidelines.	Research Support	Source
1. For a sitting workplace, the following clearances should be provided:	Y	21, 57
a) knee clearance (depth) - 46 to 51 cm (18 to 20 in.)		
b) leg clearance (depth) - 100 cm (39 in.)		
c) leg clearance (width) - 51 cm (20 in.)		
2. For a standing workplace, the following clearances should be provided:	Y	21, 57
a) knee clearance (depth) - 10 to 50 cm (4 to 20 in.)		
b) foot clearance (depth) - 10 to 13 cm (4 to 5 in.)		
c) foot clearance (height) - 10 to 12 cm (4 to 5 in.)		
d) foot clearance (width) - 51 to 70 cm (20 to 28 in.)		

Comment. None.

Method for Assessment. Verify dimensions of workplace are within prescribed envelope.

Screen Orientation

Definition. The angle the screen has with respect to straight-ahead horizontal viewing. (See Figure 50.)

Guidelines.	Research Support	Source
1. Screen orientation should be no greater than 45 degrees away from or toward the operator, with 15 degrees away from the operator preferred. (See Note 1.)	Y	21, 30, 40, 131, 135
2. Screen orientation should be adjustable.	Y	40, 131, 135

NOTE 1: The tilt angle of a display should consider the trade off between reduction in the angular size of the symbols and glare.[136]

Comment. An adjustable CRT angle is desirable because it allows compensation for varying glare conditions (as the control room is built and modified). If it is certain that glare can be adequately controlled (through use of dimmers, etc.), a fixed-angle CRT is acceptable.

Method for Assessment. Verify adequate CRT character visibility from all anticipated viewing distances, angles, and lighting conditions.

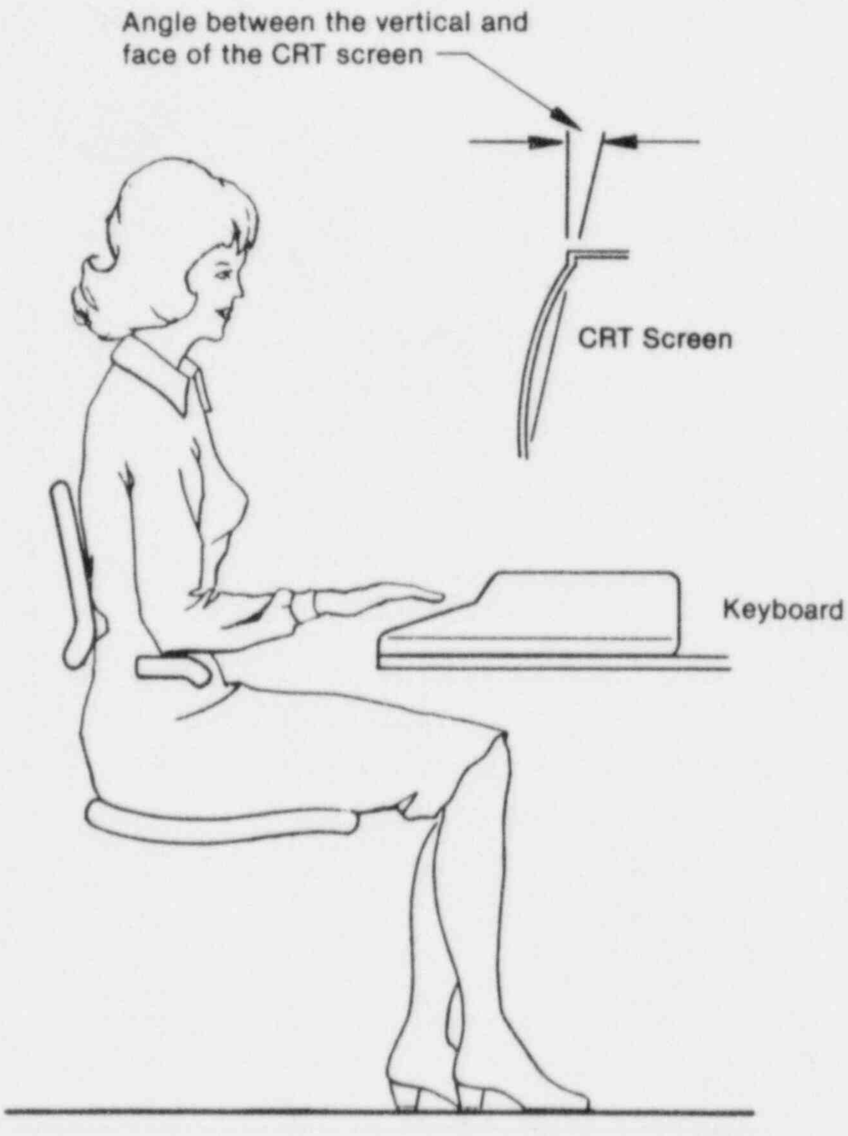


Figure 50. Screen Orientation (Tilt) for VDU workstation.

Chair

Definition. Relevant dimensions for chair design are presented in this section (see Figure 51).

Guidelines.	Research Support	Source
1. The chair design should allow the user to maintain the following posture: knees flexed at an angle ≥90 degrees, elbows flexed at an angle ≥90 degrees, and torso at an angle slightly greater than 90 degrees (100 to 155 degrees).	Y	16, 22
2. Seat height should be adjustable from 35 to 55 cm (14 to 22 in.).	Y	6, 16, 21, 129, 130, 133
3. When the chair is provided with a footrest, it should be adjustable from 51 to 76 cm (20 to 30 in.), with the footrest a constant 46 cm (18 in.) below the seat.	Y	6, 21
4. The seat width should be 43 to 51 cm (17 to 20 in.).	Y	6, 21
5. The seat depth should be 38 to 46 cm (15 to 18 in.).	Y	6, 21
6. Backrest height should be 15 to 23 cm (6 to 9 in.).	Y	21
7. Backrest width should be 30 to 36 cm (12 to 14 in.).	Y	21

	Research Support	Source
8. The cushion should be at least one inch thick.	Y	16
9. The arm rests should be 5 cm (2 in.) wide, 20 cm (8 in.) long, and 19 to 28 cm (7.5 to 11 in.) above the compressed sitting surface. (Swing-away if appropriate.)	Y	16

Comment. In addition to the "hard" data provided above, consideration should be given to "soft" issues such as: the chair shape should allow freedom and ability to change posture at frequent intervals, providing appropriate support in these alternate postures; the chair adjustments should be easily manipulated; the seats should be upholstered to reduce sweating; the chair should have casters and provide a swivel feature to allow easy positioning; the composition of the seat surface should not be too "hard" or too "soft"; and the chair should be stable on the floor. There is an unconventional approach to seating which suggests an approximate 20° forward seat angle because it imposes much less strain on the neck and back. Only time will tell whether this approach becomes popular.

Method for Assessment. (a) verify seat dimensions fall within guidelines, (b) assess the ease of adjustment, and (c) utilize the seat in its normal workspace and verify its functional utility.

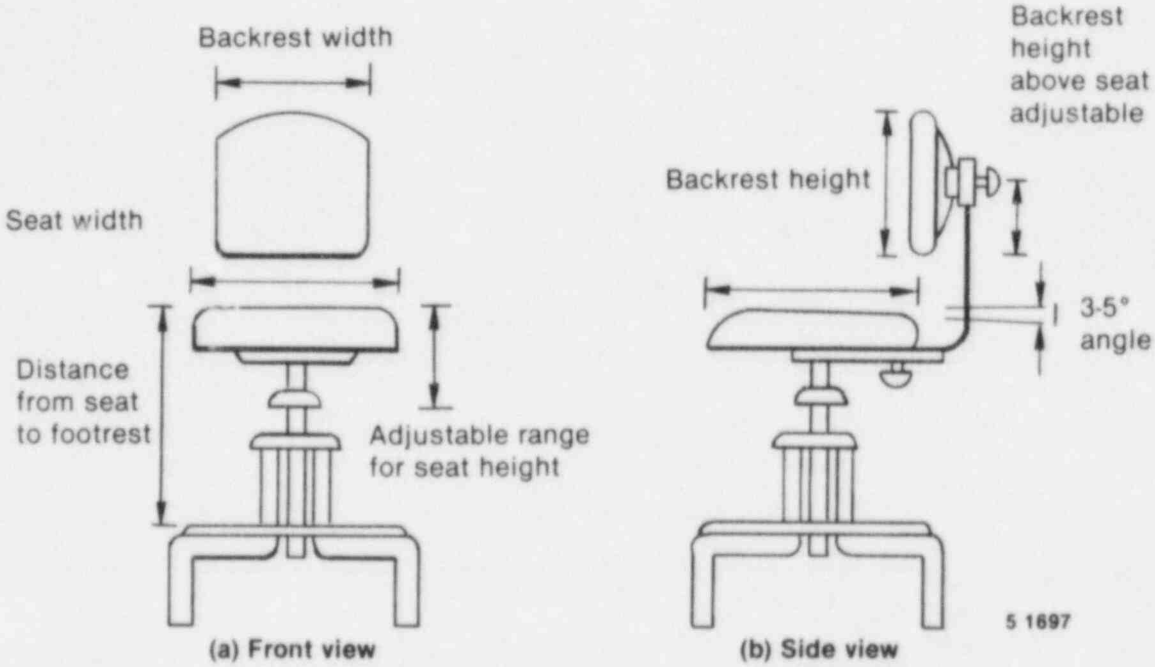


Figure 51. Chair dimensions for VDU workstation (adapted from Reference 21).

Hardcopy Printer

Definition. The implementation of a printer in process control often serves to provide a historical record of all parameters monitored by the computer as well as real time "display," whether or not the data are presented on CRT screens. Printers, until recently, have received little attention from the human factors discipline. This is partially due to the overshadowed emphasis on the primary computer interfaces (i.e., VDU and workstation). There is a new awareness to address printer design since it has been recognized they also comprise a principal interface between the computer and the operator. As a result, the following guidelines should be considered for enhancement of the printer interface.

Guidelines.	Research Support	Source
1. Hard-finish, matte paper should be used to avoid smudged copy and glare.	L	6
2. There should be a positive indication of the remaining supply of recording materials.	L	6
3. Instructions for reloading paper, ribbon, ink, etc. should appear on an instruction plate attached to the printer.	L	6
4. A takeup device for printed materials should be provided which requires little or no operator attention and which has a capacity at least equal to the feed supply.	L	6
5. The operator should always be able to read the most recently printed line.	L	6

	Research Support	Source
6. Printed material should have an adequate contrast ratio to ensure easy operator reading.	L	6
7. It should be possible to annotate the print copy while it is still in the machine.	L	6
8. When the printer is down during reloading, data and information which would normally be printed must not be lost.	L	6
9. The recorded matter should not be obscured, masked, or otherwise hidden in a manner which prevents direct reading of the material.	L	6
10. Printers should be part of the process computer system and be located in the primary operating area.	L	6
11. Control room printers should provide the capability to record alarm data, trend data, and plant status data.	L	6
12. The system should, if possible, be designed to provide hard copy of any page appearing on the CRT at the request of the operator.	L	6
13. If the copy will be printed remote to the operator, a print confirmation or denial message should be displayed.	L	6
14. Printer operation should not alter screen content.	L	6

	Research Support	Source
15. Printed information should be presented in a directly usable form with minimal requirements for decoding, transposing, and interpolating.	L	6
16. Printer used for recording trend data, computer alarms, and critical status information should have a high-speed printing capability of at least 300 lines a minute to permit printer output to keep up with computer output.	L	6

Comment. Perhaps the most important consideration for printers is that it should be assessable. Request for hard copy commands should be simple and "user friendly." In many cases it might also be advantageous to specify a graphics print capability and flexibility for printing out data on standard 8-1/2 x 11 or legal-size paper.

Method for Assessment. Visually inspect the printer(s) for compliance with the above guidelines.

Health and Safety

Definition. The general features of mechanical, electrical, and radiation safety of VDUs are addressed below.

Guidelines.	Research Support	Source
1. The VDT should be provided with implosion safeguards. (See Note 1.)	Y	22
2. No fans, voltage, gears, or belts should be accessible to the user's fingers or body.	Y	40
3. No parts hotter than 140°F should be accessible to the user.	Y	40
4. Physical barriers and warnings should be provided for all "live" parts.	Y	40
5. Barriers should prevent hardware and small items from falling into areas of high voltage.	Y	40
6. All exposed corners and sharp edges should be smooth and rounded.	Y	40
7. Reviews of the literature (on radiation safety) and new surveys to attempt to measure radiations[139] led to the conclusion that there is no radiation hazard for VDT operators and further routine surveys are not necessary.		40

NOTE 1: Because the VDT operator sits in close proximity to the VDT, it is usual to provide some form of protection for the viewer in the event of CRT breakage. Under normal office circumstances, the risks of such a failure are slight, but in some working environments where VDTs have been introduced, e.g., factory floor environments, the risks of damage and breakage may be higher.[22]

The CRTs which are used in VDT equipment are usually of the so-called rim guard type with a metal band (the rim band) stretched under tension around the edges of the CRT face. This helps to hold the broken pieces of the tube together during failure. Additional protection may be provided by an implosion shield to safeguard against flying fragments from the rear of the tube.[22]

Comment. A full treatment of all safety features associated with VDUs is beyond the scope of this document. However, the general guidelines cited above should be considered as the top level basics when performing a safety review of VDUs.

Method for Assessment. Visually inspect the VDU for compliance with the above guidelines.

Environmental Factors

It seems that the most overlooked system during design and construction of a facility, yet the most complained about once a facility is occupied, is the environmental system (lighting, heating, ventilation, air conditioning, etc.). Combining all those factors to produce a functional and comfortable environment requires a large number of considerations. The guidelines presented below are rudimentary to insure conditions could be acceptable. The blending of these conditions in just the proper ratio will insure that acceptable conditions can be achieved. Here, as in the anthropometric section, adjustability needs to be stressed. Without the ability to, for example, direct air flow to ones' front side rather than back and to adjust illumination levels, a satisfactory situation is unattainable. The rudimentary guidelines discussed in this subcategory are:

Background Noise

Definition. The maximum ambient noise level (generated by HVAC fans, transformers, lights, etc.) which allows communication with a normal or slightly raised voice level.

Guidelines.	Research Support	Source
1. Ambient noise level should be less than 70 dB(A) [less than 65 dB(A) preferred] in routine task areas and less the 55 dB(A) in task areas requiring a high level of concentration. (See Note 1.)	Y	6, 22, 30, 40
2. Ambient noise should be free from high frequency tones (>8000 Hz) and external (or extraneous), high-noise-level equipment.	Y	22, 30

NOTE 1: Background noise should not impair verbal communication between any two points in the primary operating area. Verbal communications between these points should be intelligible using normal or slightly raised voice levels.[6]

Comment. The prime consideration for these guidelines is allowing for the ability to communicate under the worst conditions which can be encountered over the longest distances to be encountered (alarms actuated but not silenced and two operators at the opposite ends of the control room).

Method for Assessment. (a) Verify ambient noise levels are 70 dB(A) or less everywhere in control room with alarms activated (utilize

calibrated meter), (b) ensure no excessive reverberation or echoes are noted, and (c) carry on conversations under those conditions from the furthest points in the control room to ensure no more than a slightly raised voice level is necessary for communication.

Temperature and Humidity

Definition. The range of temperature and humidity combinations which conform to the comfort standard recommended by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)[140] for lightly clothed, sedentary individuals in spaces with low air movement (less than 45 fpm).

Guidelines.	Research Support	Source
1. Ambient temperature should be maintained from 18 to 29.5 K (65 to 85°F), with 21 to 27 K (70 to 80°F) preferred.	Y	6, 16, 22, 40, 140
2. Relative humidity should be from 20 to 60%. (See Note 1.)	Y	6, 16, 22, 40, 140
3. There should be no more than a 10°F difference between head and floor level.	Y	6

NOTE 1: Reference 16 recommends that approximately 45% relative humidity should be provided at 21°C (70°F). This value should decrease with rising temperature but remain above 15%.

Comment. From experience, the equipment (VDT and associated circuitry) drive environmental requirements. As a result, the requirements are typically more restrictive in terms of range and rate of variations within that range than are the personnel comfort requirements.

Method for Assessment. Verify temperature and humidity are within the guidelines. Utilize calibrated instrumentation as needed.

Lighting

Definition. Sufficient illumination must be delivered to the level of the desk top and/or displays so that displays and printed material can be read accurately. Direct and reflected glare must be minimized.

Guidelines.	Research Support	Source
1. Workplace illuminance should be from 92 to 927 lx (adjustable), with a mean of 240 lx during the day shift and a mean of 184 lx during night shift. (See Note 1.)	Y	6, 16, 22, 30, 40, 133, 141
2. Emergency lighting level should be from 10 to 50 lx.		57

NOTE 1: Only Reference 133 make a distinction between day and night shift, recommending 105 to 927 lx during day shift and 92 to 332 lx during night shift. References 6 and 141 recommend 200 to 700 lx. References 16, 22, 30, and 40 recommend 300 to 540 lx. All references recommend adjustable illuminance.

Comment. The intent of the guidelines is to provide adequate light for document reading and still allow adequate contrast for easy VDT observation. Minimizing the difference in luminance between surfaces and minimizing glare eases eye fatigue but is difficult to achieve.

Method for Assessment. Verify lighting levels are adjustable and within recommended values. Verify glare from surfaces, lights, etc. is at a level low enough to prevent VDT reading interference from any possible operator viewpoint.

Ventilation

Definition. The quantity, quality, and velocity of air introduced to the conditioned space.

Guidelines.	Research Support	Source
1. Air should be introduced at a minimum rate of 15 cfm per occupant, approximately 2/3 of which should be outside air that is filtered to remove hazardous or irritating particles. (See Note 1.)	Y	6, 16, 22 57
2. Air velocity should not exceed 45 feet per minute (fpm) measured at operator head level and should not produce a noticeable draft. (See Note 2.)	Y	6, 16, 22, 57

NOTE 1: Reference 16 recommends a minimum of 0.85 m^3 (30 ft^3) per minute per occupant.

NOTE 2: Reference 22 recommends a maximum of 0.1 m/s (20 fpm). Reference 16 recommends a maximum of 30 m (100 ft) per minute, with less than 20 m (65 ft) per minute preferred.

Comment. With the type and quantity of electronic equipment normally included in a control room, the air quantity requirements will never be determined by personnel needs, but rather by equipment heat removal needs. Additionally, an outside air requirement of 0.75 to 2 cfm/ft^2 of floor space is recommended for an office environment (which a control room essentially is).[140] Additionally, and most important, the direction of air flow should be toward the operators front (most preferable) or the operators side (less preferable), but never toward his back. This is also stressed in Reference 140 but overlooked in the cited sources.

Method for Assessment. (a) Verify adequate outside air and air circulation are provided by determining the absence of odors and (b) occupy all operator positions and verify correct air flow direction and lack of drafts. (Actual measurements are impossible unless sophisticated equipment and access to the HVAC equipment is available.)

Static Electricity

Definition. The electricity contained or produced by charged bodies.

Guidelines.	Research Support	Source
1. Relative humidity should be maintained at 40 ± 10%, and should not be allowed to fall below 20%.	Y	57, 140
2. An earth line should be provided between each VDT and the main system earth connection and carpeting material with a copper wire interweave should be provided.	Y	22

Comment. Because of the sensitivity of VDTs to static electricity, both passive (humidity control) and active (grounding pads and conducting systems) static electricity control systems should be provided.

Method for Assessment. Verify static electricity is controlled.

REFERENCES

1. R. Dallimonti, "Challenge for the 80s: Making Man-Machine Interfaces More Effective," Control Engineering, 29, 2, January 1982, pp. 26-30.

2. E. Grandjean and E. Vigliani (eds.), "Ergonomic Aspects of Visual Display Terminals," Proceedings of the International Workshop, Milan, March 1980, London: Taylor & Francis Ltd., 1983.

3. W. D. Penniman, "Past Chairman's Message," SIG Newsletter No. UOI-10, Washington: American Society for Information Science, May 1979.

4. W. W. Banks, D. I. Gertman, R. J. Petersen, Human Engineering Design Consideration for Cathode Ray Tube-Generated Displays, NUREG/CR-2496, April 1982.

5. W. W. Banks et al., Human Engineering Design Considerations for Cathode Ray Tube-Generated Displays, 2, NUREG/CR-3003, July 1983.

6. U.S. Nuclear Regulatory Commission, Guidelines for Control Room Design Reviews, NUREG-0700, September 1981.

7. U.S. Nuclear Regulatory Commission, Functional Criteria for Emergency Response Facilities - Final Report, NUREG-0696, February 1981.

8. U.S. Nuclear Regulatory Commission, Human Factors Acceptance Criteria for the Safety Parameter Display System (Draft), NUREG-0835, October 1981.

9. U.S. Nuclear Regulatory Commission, Office of Reactor Regulation, Division of Human Factors Safety, Evaluation Criteria for Detailed Control Room Design Review, NUREG-0801 (Draft), October 1981.

10. U.S. Nuclear Regulatory Commission, NRC Action Plan Developed as a Result of the TMI-2 Accident, 1 and 2, NUREG-0660, May 1980.

11. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Licensing, Clarification of TMI Action Plan Requirements, NUREG-0737, November 1980.

12. U.S. Nuclear Regulatory Commission, Supplement 1 to NUREG-0737, Requirements for Emergency Response Capability, Generic Letter No. 82-33, December 17, 1982.

13. U.S. Nuclear Regulatory Commission, Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident, NRC Regulatory Guide 1.97, Rev. 2, December 1980.

14. R. W. Bailey, Human Performance Engineering: A Guide for System Designers, Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1982.

15. U.S. Department of Defense, Human Factors Engineering, AFSC DH 1-3, January 1, 1977.

16. U.S. Department of Defense, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, MIL-STD-1472C, May 2, 1981.

17. R. D. Huchingson, New Horizons for Human Factors in Design, New York: McGraw-Hill Book Co., 1981.

18. E. J. McCormick and M. S. Sanders, Human Factors in Engineering and Design, 2nd edition, New York: McGraw-Hill Book Co., 1982.

19. H. P. Van Cott and R. G. Kinkade, Human Engineering Guide to Equipment Design, Washington, D.C.: U.S. Government Printing Office, 1972.

20. W. E. Woodson, Human Factors Design Handbook, New York: McGraw-Hill, 1981.

21. Eastman Kodak Co., Ergonomic Design for People at Work, 1, Belmont, CA: Lifetime Learning Publications, 1983.

22. A. Cakir, D. J. Hart, T. F. M. Stewart, Visual Display Terminals, Chichester: John Wiley & Sons, 1980.

23. D. Meister, Human Factors: Theory and Practice, New York: Wiley-Interscience, a Division of John Wiley & Sons, Inc., 1971.

24. A. Cakir et al., Anpassung von Bildschirmarbeitsplatzen an die Physische und Funktionsweise des Menschen, April 1978.

25. Draft DIN Standard 66234, Characteristic Values for the Adaptation of Work Stations with Fluorescent Screens to Humans.

26. E. L. Gorrel, A Human Engineering Specification for Legibility of Alphanumeric Symbology on Video Monitor Displays, Defense and Civil Institute of Environmental Medicine (DCIEM), Technical Report No. ?8746, December 1978.

27. IBM Human Factors Center, Human Factors of Workstations With Visual Displays, 3rd edition, International Business Machines Corp., January 1984.

28. Human Factors for Designers of Naval Equipment, 2, Chapter VI and VII, London, England: HMRN, 1971.

29. H. L. Snyder and M. E. Maddox, Information Transfer from Computer-Generated Dot-Matrix Displays, HFL-78-3/ARO-78-1, Virginia Polytechnic Institute and State University, October 1978.

30. Electric Power Research Institute (EPRI), Computer-Generated Display System Guide, 1, Research Project 2184 (Draft Report), March 1983.

31. R. W. Swezey and E. G. Davis, A Case Study of Human Factors Guidelines in Computer Graphics, IEEE CG&A, November 1983.

32. S. L. Smith and N. C. Goodwin, "Blink Coding for Information Display," Human Factors, 13, 3, 1971, pp. 283-290.

33. Y. Waern and C. Rollenhagen, "Reading Test from Visual Display Units (VDUs)," Journal of Man Machine Studies, 18, 1983, pp. 441-465.

34. S. L. Smith and A. F. Aucella, Design Guidelines for the User Interface to Computer-Based Information Systems, ESD-TR-83-122, MTR-8857, March 1983.

35. P. Muter et al., "Extended Reading of Continuous Text on Television Screens," Human Factors, 24, 5, October 1982, pp. 501-508.

36. S. E. Engel and R. E. Granda, Guidelines for Man/Display Interfaces, Technical Report TR 00.2720, Poughkeepsie, New York: IBM, December 1975.

37. W. O. Galitz, Handbook of Screen Format Design, Wellesley, MA: Q.E.D. Information Science, 1981.

38. E. J. McCormick, Human Factors in Engineering and Design, 4th edition, New York: McGraw-Hill Book Co., 1976.

39. B. B. Murdock, "The Serial Effect of Free Recall," Journal of Experimental Psychology, 64, 1962, pp. 482-488.

40. D. M. Brown et al., Human Factors Engineering Criteria for Information Processing Systems, Sunnyvale, CA: Lockheed, June 1981.

41. J. B. Carroll, P. Davies, B. Richman, Word Frequency Book, New York: Houghton Mifflin Co. (American Heritage), 1971.

42. U.S. Department of Defense, "Markings for Aircrew Station Displays," Design and Configuration, MIL-M-18012.

43. C. A. Semple et al., Analysis of Human Factors Data for Electronic Flight Display Systems, AS-884-770, Northridge, California: Manned Systems Sciences, Inc., January 1971.

44. D. A. Shurtleff, How to Make Displays Legible, La Mirada, CA: Human Interface Design, 1980.

45. W. C. Howell and C. L. Kraft, Size, Blur, and Contrast as Variables Affecting the Legibility of Alphanumeric Symbols on Radar-Type Displays, Wright-Patterson Air Development Center Technical Report, September 1959, pp. 59-536.

46. R. S. Soar, "Height-Width Proportions and Stroke Width in Numeral Visibility," The Journal of Applied Psychology, 39, 1955, pp. 43-46.

47. C. Berger, "I, Stroke-Width, Form and Horizontal Spacing of Numerals as Determinants of the Threshold of Recognition," Journal of Applied Psychology, 28, 1944, pp. 208-231.

48. C. Berger, "II, Stroke-Width, Form and Horizontal Spacing of Numerals as Determinants of the Threshold of Recognition," Journal of Applied Psychology, 28, 1944, pp. 336-346.

49. V. M. Reading (ed.), Visual Aspects and Ergonomics of Visual Display Units, Department of Visual Science, Institute of Opthalmology, University of London, 1978.

50. P. A. Kolers, R. L. Duchnicky, D. C. Ferguson, "Eye Measurement of Readability of CRT Displays," Human Factors, 23, 5, pp. 517-527.

51. M. A. Tinker, Legibility of Print, Ames, Iowa: Iowa State University Press, 1963.

52. A. G. Vartabedian, "Effects of Parameters of Symbol Formation on Legibility," Information Display, May 1970.

53. Nuclear Software Services, Inc., A Primer on Colorgraphic Display Systems for Nuclear Power Plants, NSAC/45, April 1982.

54. A. Chapanis, Research Techniques in Human Engineering, Baltimore, Maryland: Johns Hopkins Press, 1959.

55. M. M. Danchak, "Effective CRT Display Creation for Power Plant Applications," Proceedings of the Nineteenth International ISA Power Instrumentation Symposium, May 9-12, 1976, San Fransisco, CA.

56. J. E. Barmack and H. W. Sinaiko, Human Factors Problems in Computer Generated Graphic Displays, Report S-234, Institute for Defense Analyses, 1966.

57. R. G. Kinkade and J. Anderson, Human Factors Guide for Nuclear Power Plant Control Room Development, Prepared for Electric Power Research Institute (EPRI), (Draft Report), 1983.

58. W. O. Galitz, Human Factors in Office Automation, Atlanta, GA: Life Office Management Association, Inc., 1980.

59. B. G. Knapp, F. L. Moses, L. H. Gellman, Information Highlighting on Complex Displays, A. Badre and B. Shneidnerman (eds.), Directions in Human/Computer Interaction, Norwood, New Jersey: Ablex Publishing Corp., 1982, pp. 195-215.

60. AFSC DH 1-3, Human Factors Engineering, 3rd ed., Revision 1, 1977.

61. R. N. Parrish et al., "Development of Design Guidelines and Criteria for User/Operator Transactions with Battlefield Automated Systems," Provisional Guidelines and Criteria for the Design of User/Operator Transactions, 4, (Draft Final Report, Phase I), Alexandria, VA: U.S. Army Research Institute, 1981.

62. R. E. Christ, "Review and Analysis of Color Coding Research for Visual Displays," Human Factors, 17, 1975, pp. 542-570.

63. C. Chapanis and R. Halsey, "Absolute Judgments of Spectrum Colors," Journal of Psychology, 42, 1956, p. 99.

64. C. Conover, The Amount of Information in the Absolute Judgment of Munsell Hues, WADC-TN58-262, Wright Air Development Center, WPAFB, Ohio, 1959.

65. A. H. Munsell, Book of Color, Baltimore: Munsell Color Book Co., 1942.

66. R. E. Warren, Color association of alarm and status labels, private communication, March 1980.

67. S. D. Parsons, S. K. Ekert, J. L. Seminara, "Human Factors Design Practices for Nuclear Power Plant Control Rooms," Proceedings of the Human Factors Society 22nd Annual Meeting, 1978.

68. H. Dreyfus, Symbol Sourcebook, New York: McGraw-Hill, 1972.

69. R. S. Sleight, "The Relative Discriminability of Several Geometric Forms," Journal of Experimental Psychology, 43, 1952, p. 424.

70. S. L. Smith and D. W. Thomas, "Color Versus Shape Coding in Information Displays," Journal of Applied Psychology, 48, 1964, p. 137.

71. P. W. Hemingway, A. L. Kubala, G. D. Chastain, Study of Symbology for Automated Graphic Displays, ARI Technical Report TR-79 A18, U.S. Army Research Institute for the Behavioral and Social Sciences, May 1979.

72. H. M. Bowen et al., Optimal Symbols for Radar Displays, Technical Report 2682 (00) (AD 227 014), Office of Naval Research, Washington, D.C., September 1959.

73. J. R. Williams and R. P. Falzon, "Comparison of Search Time and Accuracy Among Selected Outlined Geometric Forms," Journal of Engineering Psychology, 2, July 1963, pp. 112-1128.

74. C. J. Davis, Radar Symbology Studies Leading to Standardization: II, Discrimination in Mixed Displays, Technical Memorandum 5-69 (AD688 125), Human Engineering Laboratories, Aberdeen Research and Development Center, Aberdeen Proving Grounds, Maryland, March 1969.

75. L. E. King and G. Tierney, Legibility: Symbols Versus Word Highway Signs, West Virginia University, Highway Research Information Service No. 54-225961, 1970.

76. C. M. Mavrides, "Codability of Polygon Patterns," Perceptual and Motor Skills, 37, 1973, pp. 343-347.

77. R. C. Casperson, "The Visual Discrimination of Geometric Forms," Journal of Experimental Psychology, 40, 1950, pp. 668-681.

78. M. W. Riley, D. J. Cochran, J. L. Ballard, "An Investigation of Preferred Shapes for Warning Labels," Human Factors, 24, 6, 1982, pp. 737-742.

79. W. Schiff, Perception: An Applied Approach, Boston: Houghton Mifflin Co., 1980.

80. D. S. Ciccone, M. G. Samet, J. B. Channon, A Framework for the Development of Improved Tactical Symbology, Technical Report 403, U.S. Army Research Institute for the Behavioral and Social Sciences, August 1971.

81. Graphics Symbols for Process Flow Diagrams in the Petroleum and Chemical Industries, ANSI Y32.11.

82. Instrument Society of America (ISA), Graphic Symbols for Process Displays (Draft Standard), ISA-dS5.5, February 1984.

83. P. F. Muller et al., The Symbolic Coding of Information of Cathode Ray Tubes and Similar Displays, Report No. WADC-TR-55-375, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, 1955.

84. C. A. Baker and W. F. Grether, Visual Presentation of Information, WADCTR54-160, Wright Air Development Center WPAFB, Ohio, 1954.

85. P. A. Moore, R. R. Pierce, D. Shamonsky, How to Design an Effective Graphics Presentation, 17, Cambridge, Massachusetts: Harvard Graduate School of Design, 1981.

86. H. S. Oberly, "The Range of Visual Attention Cognition and Apprehension," American Journal of Psychology, 35, 1924, p. 332.

87. E. A. Alluisi, Lineal Inclination in Encoding Information Symbolically on Cathode Ray Tubes and Similar Displays, ADS TR 61-741, Aeronautical Systems Division, WPAFB, Ohio, 1961.

88. S. L. Smith, "Angular Estimation," Journal of Applied Psychology, 46, 1962, pp. 240-246.

89. S. L. Smith, Man-Machine Interface (MMI) Requirements Definition and Design Guidelines: A Progress Report, ESD-TR-81-113, February 1981.

90. W. M. Newman and R. F. Sproull, Principles of Interactive Computer Graphics, New York: McGraw-Hill, 1979.

91. J. D. Foley, V. L. Wallace, P. Chan, The Human Factors of Graphics Interaction: Tasks and Techniques, Report No. GWU-IIST-81-3, Washington D.C.: George Washington University, January 1981.

92. J. Cohen and A. J. Dinnerstein, Flash Rate as a Visual Coding Dimension for Information, WADCTR57-64., 1958, Wright Air Development Center, WPAFB, Ohio.

93. A. B. Dickinson, "Remember Operator Needs When Selecting CRT Displays," Instruments and Control Systems, 52, 4, March 1979.

94. H. R. Ramsey and M. E. Atwood, Human Factors in Computer Systems: A Review of the Literature, Technical Report SAI 79-111-DEN, Science Applications, Inc., 1979.

95. S. L. Smith and N. C. Goodwin, "Blink Coding for Information Display," Human Factors, 13, 1971, pp. 283-290.

96. A. G. Vartabedian, "Effects of Parameters of Symbol Formation on Legibility," Information Display, 7, 5, 1970, pp. 23-26.

97. R. S. Shirley, The Foxboro Co., Foxboro, Mass. private communication, October 15, 1983.

98. R. N. Parish, Development of Design Guidelines and Criteria for User/Operator Transactions with Battlefield Automated Systems, Synetics, Fairfax, VA., August 1980.

99. I. Polack, "Auditory Displays and Noise," R. W. Pew and P. Green (eds.) Human Factors Engineering Short Course Notes, 25th edition, Ann Arbor Michigan: University of Michigan, Chrysler Center for Continuing Engineering Education, 1984.

100. A. Badre and B. Shneiderman, Directions in Human/Computer Interaction, Norwood, NJ: Allex Publishing Corp., 1982.

101. M. M. Danchak, Alarms Within Advanced Display Systems: Alternative and Performance Measures, NUREG/CR-2776, September 1982.

102. W. W. Banks and M. P. Boone, Nuclear Control Room Annunciators: Problems and Recommendations, NUREG/CR-2147, September 1981.

103. V. Mitchell-Bishop, "Human Operator Performance in Computer-Based Message Switching Systems: A Case Study," Proceedings of the 1979 Human Factors Society Meeting, Boston, Mass., October 29-November 1, 1979, pp. 45-49.

104. W. O. Galitz, "Debut II--The CNA Data Entry Utility," Proceedings of the 1979 Human Factors Society Meeting, Boston, Mass. October 29-November 1, 1979, pp. 50-54.

105. R. W. Pew, A. W. Rollins, G. A. Williams, "Generic Man-Computer Dialogue Specification: An Alternative to Dialogue Specialists," Proceedings of the International Ergonomics Association 1976, London: Taylor and Francis, pp. 251-254.

106. M. M. Danchak, "The Content of Process Control Alarm Displays," ISA International Conference and Exhibit, Astrohall, Houston, Texas, October 20-23, 1980.

107. J. D. Foley and V. L. Wallace, "The Art of Natural Graphic Man-Machine Conversation," Proceedings of the IEEE, 62, 4, 1974, 62(4), pp. 462-471.

108. J. W. Kling and L. A. Riggs (ed.), Woodworth and Schlosberg's Experimental Psychology, 3rd edition, Volume 1: Sensation and Perception, New York: Holt, Rinehart and Winston, Inc., 1972.

109. R. Sekuler and P. D. Tynan, Sourcebook of Temporal Factors Affecting Information Transfer from Visual Displays, Technical Report 540, U.S. Army Research Institute for the Behavioral and Social Sciences, June 1981.

110. A. Burg, "Visual Acuity as Measured by Static and Dynamic Tests: A Comparative Evaluation," Journal of Applied Psychology, 50, 1966, pp. 460-466.

111. J. W. Miller and E. Ludvigh, "The Effect of Relative Motion on Visual Acuity," Survey Ophthalmology, 7, 1962, pp. 83-116.

112. M. M. Danchak, Techniques for Displaying Multivariate Data on Cathode Ray Tubes with Applications to Nuclear Process Control, Hartford, Conn.: Hartford Graduate Center, October 1980.

113. J. Martin, Design of Man-Computer Dialogues, Englewood Cliffs, NJ: Printice-Hall, 1973.

114. H. G. Schultz, "An Evaluation of Format for Graphic Trend Displays--Experiment II, Human Factors, 3, 1961, pp. 99-107.

115. C. G. Koch and T. R. Edman, "Evaluating Options for CRT Display of Process Trend Data," Proceedings Human Factors Society 26th Annual Meeting, Seattle, Washington, 1982, pp. 49-53.

116. D. G. Alden, Human Factors Principles for Keyboard Design and Operation--A Summary Review, Honeywell Systems and Research Division, March 26, 1970.

117. D. Hendricks et al., Human Engineering Guidelines for Management Information Systems, Management Information Systems Directorate/Human Engineering Laboratory, November 1, 1982.

118. W. K. English, D. C. Engelbart, M. L. Berman, "Display Selection Techniques for Text Manipulation," IEEE Transactions on Human Factors in Electronics, HFE-8, 1967, pp. 5-15.

119. N. C. Goodwin, "Cursor Positioning on an Electronic Display Using Lightpen, Lightgun, or Keyboard for Three Basic Tasks," Human Factors, 17, 1975, pp. 289-295.

120. G. W. Irving et al., ODA Pilot Study II: Selection of an Interactive Graphics Control Device for Continuous Subjective Functions Applications (Report No. 215-2), Santa Monica, CA: Integrated Sciences Corp., April 1976.

121. H. H. Ng and S. J. Puchkoff, "Touchsensitive Screens Ensure a User Friendly Interface," Computer Design, The Magazine of Computer Based Systems, August 1981.

122. C. Lu, "Computer Pointing Devices: Living With Mice," High Technology, January 1984.

123. F. A. Muckler (ed.), Human Factors Review: 1984, Santa Monica, CA.: The Human Factors Society, Inc., 1984.

124. K. U. Smith and W. M. Smith, Perception and Motion: An Analysis of Space Structured Behavior in Gregory's R. L. Eye and Brain, New York: McGraw-Hill Book Co., 1966.

125. J. R. Carbonell, J. I. Elkind, R. S. Nickerson, "On the Psychological Importance of Time in a Time-Sharing System," Human Factors, 10, 1968, pp. 135-142.

126. R. B. Miller, "Response Time in Man-Computer Conversational Transactions," AFIPS Conference Proceedings (Fall Joint Computer Conference, 1968), Washington, D.C.: Thompson Book Company, 1968.

127. J. Mahaffey, private communication, Georgia Institute of Technology, February 23, 1983.

128. J. A. Odom, Applying Manual Controls and Displays: A Practical Guide to Panel Design, MICRO SWITCH, a Honeywell Division, 1984.

129. Proceedings of the International Workshop, Milan, March 1980, London: Taylor & Francis Ltd., 1983.

130. W. Hunting, T. H. Laubli, E. Grandjean, "Constrained Postures of VDU Operators." E. Grandjean and E. Vigliani (eds.), "Ergonomic Aspects of Visual Display Terminals," Proceedings of the International Workshop, Milan, March 1980, London: Taylor & Francis Ltd., 1983.

131. W. Miller and T. W. Suther III, "Display Anthropometrics: Preferred Height and Angle Settings of CRT and Keyboard," Human Factors, 25, 4, 1983, pp. 401-408.

132. T. D. Faulkner and R. A. Day, "The Maximum Functional Reach for the Female Operator," AIIE Transactions, 2, 1970, pp. 126-131.

133. H. Shahnavaz, "Lighting Conditions and Workplace Dimensions of VDU-Operators," Ergonomics, 25, 12, 1982, pp. 1165-1173.

134. K. H. E. Kroemer, "Seating in Plant and Office," American Industrial Hygiene Association Journal, 32, 10, 1971, pp. 633-652.

135. C. R. Brown and D. L. Schaum, "User-Adjusted VDU Parameters," E. Grandjean and E. Vigliani (eds.), Ergonomic Aspects of Visual Display Terminals, Proceedings of the Internation Workshop, Milan, March 1980, London: Taylor & Francis Ltd., 1983.

136. IBM, Human Factors of Workstations With Visual Displays, 3rd edition, G320-6102-2, January 1984.

137. S. Rehulund, Ergonomic (translated from the Swedish by C. Soderstrom), Bildungskoncern: A. B. Volvo, 1973.

138. H. L. Parris and V. T. McConville, Anthropometric Data Base for Power Plant Design, NP-1918-SR, Palo Alto, CA: Electric Power Research Institute, 1981.

139. W. E. Murray et al., "A Radiation and Industrial Hygiene Survey of Video Display Terminal Operations," Human Factors, 23, 4, 1981, pp. 413-420.

140. ASHRAE, Handbook of Fundamentals, New York: American Society of Heating, Refrigeration and Air Conditioning Engineers, 1972.

141. J. E. Kaufman and J. F. Christensen (eds.), IES Lighting Handbook, 5th edition, New York: Illuminating Engineering Society, 1972.

142. H. R. Luxenberg and Kuehn (eds.), Display Systems Engineering, New York: McGraw-Hill, 1968.

APPENDIX A

EVALUATION FORM: HUMAN ENGINEERING GUIDELINES FOR THE EVALUATION AND ASSESSMENT OF VIDEO DISPLAY UNITS (VDUs)

APPENDIX A

EVALUATION FORM: HUMAN ENGINEERING GUIDELINES FOR THE EVALUATION AND ASSESSMENT OF VIDEO DISPLAY UNITS (VDUs)

The intent of this handbook is to treat it as a "live" document. Future revisions will be conducted to enhance its overall usability and acceptance by the user population. To produce a document that improves on previous iterations, your feedback is needed. Please take a few minutes to fill out the attached evaluation form and return it to:

Walter Gilmore
Idaho National Engineering Laboratory/EG&G Idaho, Inc.
Human Factors Safety Evaluation Branch
P.O. Box 1625
Idaho Falls, ID 83415

I. Please rate each of the following statements concerning the handbook by circling your response on the scale provided. A "Comments" space is also provided for each statement. Make any statements or suggestion you wish to make that would clarify your rating. Be as straightforward and critical as you like. It would help us if you could use specific examples to illustrate your points.

A. The Handbook's contents are well organized.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

B. The Handbook contains the information needed to perform an evaluation and assessment of VDU systems.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

C. The guidelines are arranged and presented in a ready-to-use format.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

D. Specific information is easily accessible with a minimum amount of search time.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

E. The information is concise and easily understandable.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

F. The Handbook is useful as an aid to the user for making a human factors appraisal of VDU systems in process control applications.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

G. The "Definition" section is beneficial to the user.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

H. The "Guidelines" section is beneficial to the user.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

I. The "Comment" section is beneficial to the user.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

J. The "Method for Assessment" section is highly useful.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

K. The use of specific examples would be beneficial.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

L. The Handbook makes effective use of figures and tables.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

M. Printing and reproduction quality is acceptable.

Strongly disagree			Neither agree or disagree			Strongly agree
1	2	3	4	5	6	7

Comment:

II. Please answer the following questions below. Be as specific as possible.

A. How does this Handbook compare with other similar guidelines documents with which you are familiar?

B. Are there any guidelines missing from the Handbook that should be included in future revisions?

C. Are there any guidelines that should be deleted from the Handbook in future revisions?

D. Are there any changes/additions that should be made to the existing guidelines for future revisions?

APPENDIX B

INFORMATION FORMAT SUMMARIES

APPENDIX B

INFORMATION FORMAT SUMMARIES

This appendix contains tables taken from the report by Danchak (Reference 112). These tables summarize the Information Formats discussed in the text of this report. The Information Formats are listed below:

- Analog
- Digital
- Binary Indicator
- Bar/Column Charts
- Band Chart
- Circular Profile
- Linear Profile
- Single Value Line Chart
- Trend Plot
- Mimic Display

The original contents of these tables have been preserved, but their reference numbers are changed. Detailed "References" from the original tables have also been omitted. In addition, this series of tables represents only a fraction of the total set of Information Formats examined by Danchak. The reader is referred to the original source document for a comprehensive treatment of those formats not presented here.

The majority of the terminology within these tables is self-explanatory. However, the meaning of "Input Data", as it is used in the tables, may not be intuitively obvious to the reader. In order to avoid any ambiguity, a description of "Input Data Type" is discussed prior to presentation of the tables.

Description of Input Data Type

In order to classify the techniques according to data type, one needs a mechanism for describing the data that is to be displayed. Figure B-1 illustrates the classification scheme chosen. Data was "typed" according to the number of independent dimensions involved, the number of variables, and the number of samples. Those axes form the three-dimensional representation of Figure B-1. Each axis of the figure was further subdivided into three parts to yield a 3 x 3 x 3 array for a total of 27 separate cells. Each cell deals with data whose type is closely defined.

The Number of Independent Dimensions refers to the units of the variable. For example, a point in two-dimensional space would have both x and y units and be classified as Duodimensional whereas a single temperature or pressure would qualify as Unidimensional. The Number of Variables refers to the number of unique quantities that may assume a value. If only one temperature reading were displayed, the data would be Univariate. If five or less different temperatures were required, the display would be Limited Mulitvariate. More than five variables were categorized as Multivariate. The "number of samples" axis implies the number of different values for the same variable. If one displayed the current temperature only, the data type would be Discrete. Less than 14 values for the same temperature, i.e., a history, is labeled Limited Series whereas more than 14 is labeled Series.

To illustrate this scheme further, imaging that one has a single temperature. The data type would be Unidimensional-Univariate-Discrete because there is one dimension (°F), one variable (the given temperature),

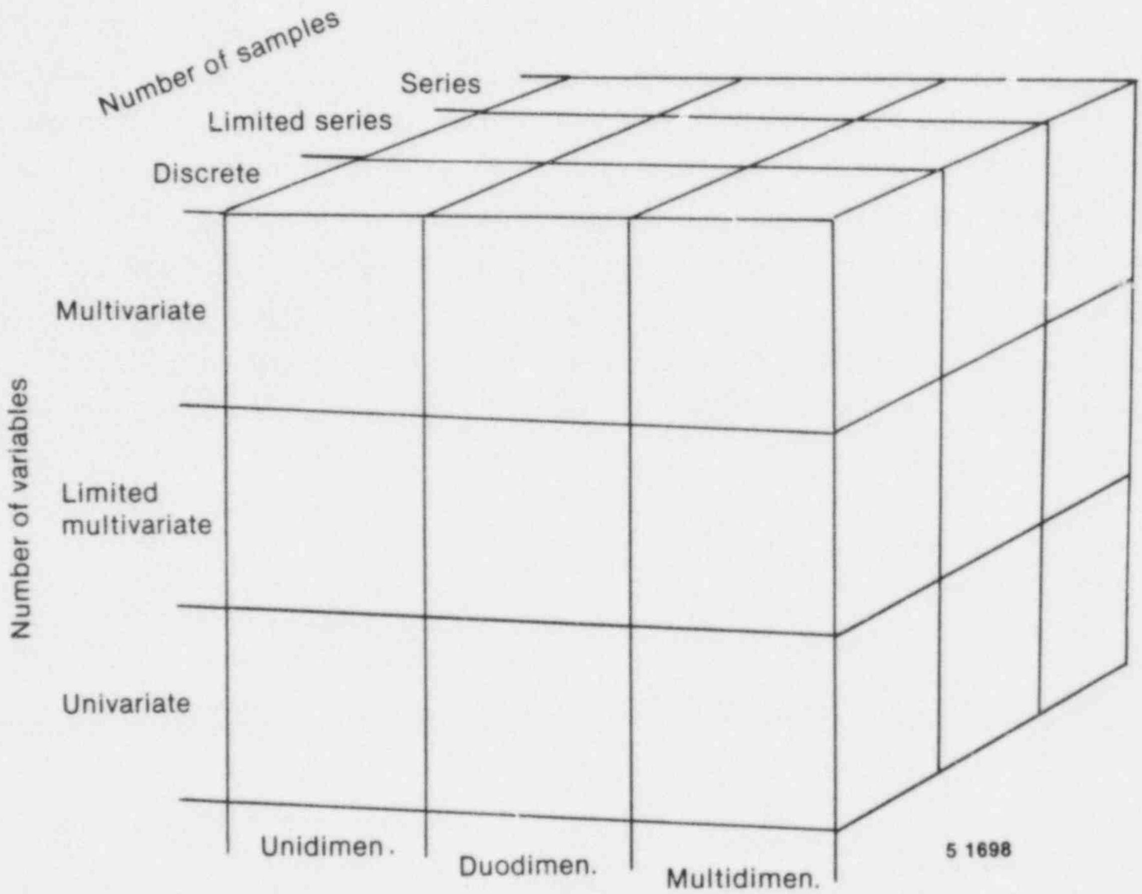


Figure B-1. Data type classification scheme.

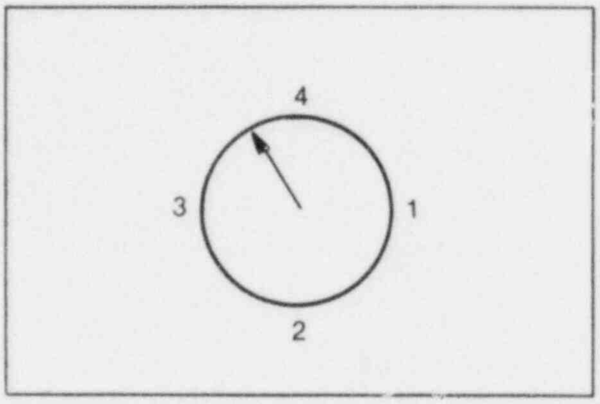
and only one sample. A pressure-temperature plot of redundant measurement channels over time would be labeled Duodimensional (°F - PSIG), Limited Multivariate (Channel A, Channel B, etc.), and Series (points plotted for each minute over the last hour).

When dealing with a system that has many variables, one has to define terms carefully and be consistent in classification. The system state could be viewed as being comprised of all the individual input variables; in that case, it should be classified as Multivariate. Alternately, one could take a holistic approach and say that the system's state is Univariate--treating the entire system as a single point. In the latter case, comparison of different systems would then constitute the Multivariate situation. Dimensionality must also be treated carefully. If a system has a number of different units but the data are normalized, the system should correctly be unclassified as Unidimensional.

TABLE B-1. DISPLAY FORMAT SUMMARY FOR ANALOG DISPLAY (MOVING POINTER)

NAME: Moving Pointer — I. D. #: 63

DESCRIPTION: A display with a single moving line fixed at one end. The angle of inclination determines the current value.



5 1699

INPUT DATA TYPE:

- Unidimensional
- Univariate
- Discrete

USE CATEGORY:

- Approximate value
- Pattern recognition

SPECIFIC USES: Historically used to indicate values, such as a time clock.

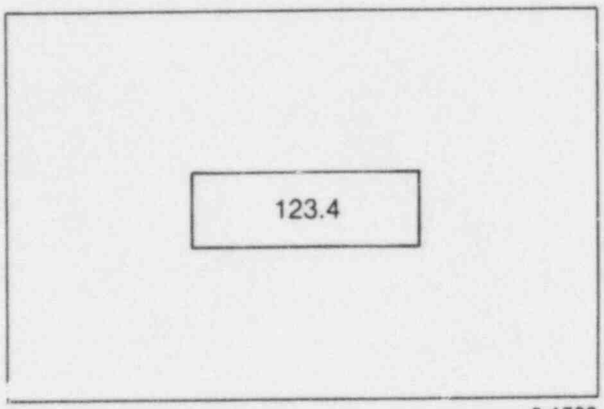
COMMENTS: Good pattern recognition.

TABLE B-2. DISPLAY FORMAT SUMMARY FOR DIGITAL READOUT

NAME: Digital Readout

I. D. #: 62

DESCRIPTION: A numeric display indicating the current value of the variable.



5 1700

INPUT DATA TYPE:

Unidimensional
Univariate
Discrete

USE CATEGORY:

Quantitative

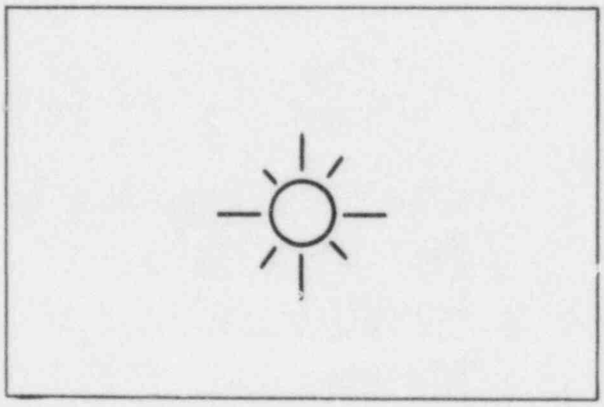
SPECIFIC USES: When very precise reading of a value is required.

COMMENTS: None.

TABLE B-3. DISPLAY FORMAT SUMMARY FOR BINARY INDICATOR

NAME: Binary Indicator I. D. #: 64

DESCRIPTION: A simple indicator, such as a lamp, that lights when a certain limit of the variable has been exceeded, or vice versa.



5 1701

INPUT DATA TYPE:	USE CATEGORY:
Unidimensional	Status and Warning
Univariate	Pattern recognition.
Discrete	

SPECIFIC USES: For annunciation of a limit violation.

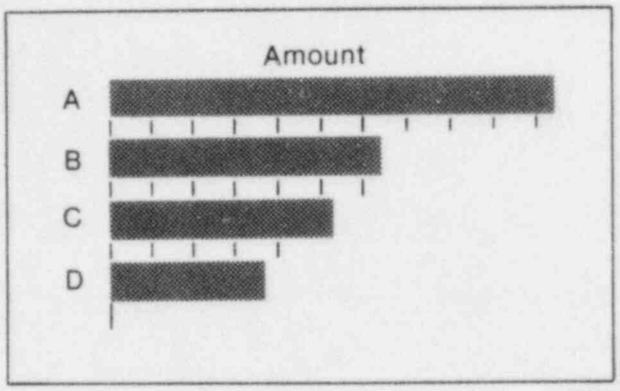
COMMENTS: None.

REFERENCES: None.

TABLE B-4. DISPLAY FORMAT SUMMARY FOR SIMPLE BAR CHART

NAME: Simple Bar Chart I. D. #: 12

DESCRIPTION: Horizontally oriented rectangles or bars emanating from a vertical line. The horizontal axis indicates values of the independent variable; the length of the bar is determined by the value or amount of each item.



5 1702

INPUT DATA TYPE:

Unidimensional
Univariate
Discrete

USE CATEGORY:

Approximate value

SPECIFIC USES: Compares the magnitude of items as of a specified time on a single scale.

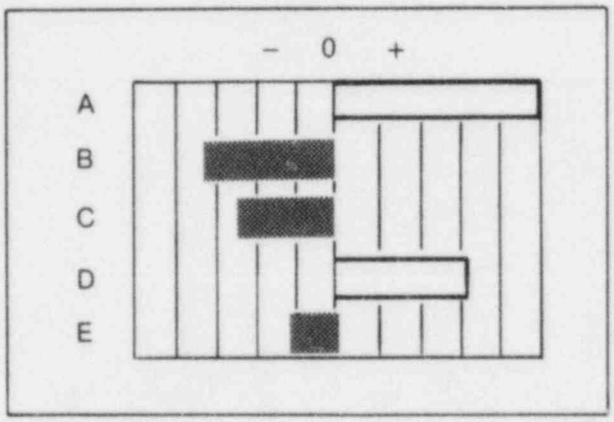
COMMENTS: Item sequence could be in the following orders:

- o numerical
- o alphabetic
- o progressive
- o qualitative
- o chronological

TABLE B-5. DISPLAY FORMAT SUMMARY FOR DEVIATION BAR CHART

NAME: Deviation Bar Chart I. D. #: 18

DESCRIPTION: Each item has a bar extending either to the right or left of a common vertical baseline to indicate the deviation from some "normal" value.



5 1703

INPUT DATA TYPE:

Unidimensional
Univariate
Discrete

USE CATEGORY:

Deviation

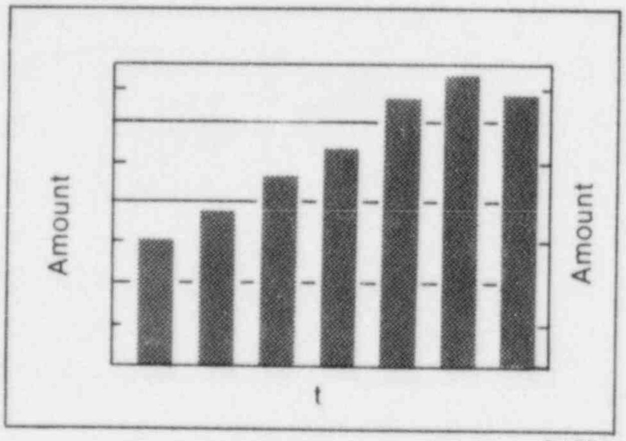
SPECIFIC USES: Presentation of positive/negative data for a number of items.

COMMENTS: None.

TABLE B-6. DISPLAY FORMAT SUMMARY FOR SIMPLE COLUMN CHART

NAME: Simple Column Chart | I. D. #: 21

DESCRIPTION: This abscissa of this chart has a small number of values while the ordinate has a greater number. Vertically oriented rectangles indicate the value of the independent variable by the length of the rectangle from a common horizontal baseline.



5 1704

INPUT DATA TYPE:

- Unidimensional
- Univariate
- Limited Series

USE CATEGORY:

- Approximate value

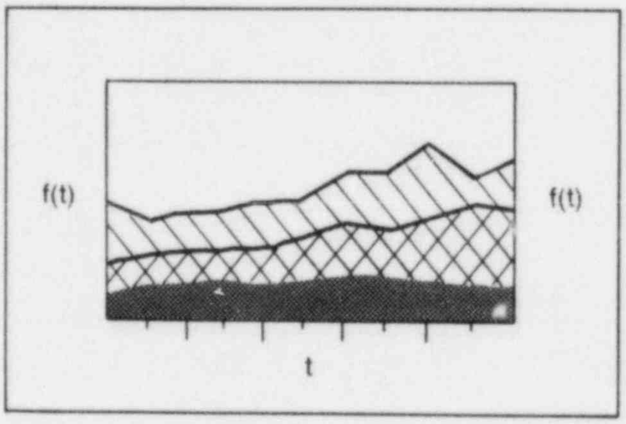
SPECIFIC USES: Depicting a small number of numerical values within a series, usually time. It can provide greater emphasis in portraying amounts in a single series.

COMMENTS: None.

TABLE B-7. DISPLAY FORMAT SUMMARY FOR MULTIPLE SURFACE/BAND CHART

NAME: Multiple Surface/Band Chart | I. D. #: 8

DESCRIPTION: Similar to a Simple Surface Chart but contains a series of bands or strata depicting the components of a total series. Each value is added to the previous value, i.e., it is cumulative. The right side of the chart must be closed at the maximum abscissa value.



5 1705

INPUT DATA TYPE:

- Unidimensional
- Limited Multivariate
- Series

USE CATEGORY:

- Approximate value
- Prediction
- Pattern recognition

SPECIFIC USES:

- o All of Simple Surface Chart
- o When a general cumulative picture of components of a total series is to be shown.

Not to be used:

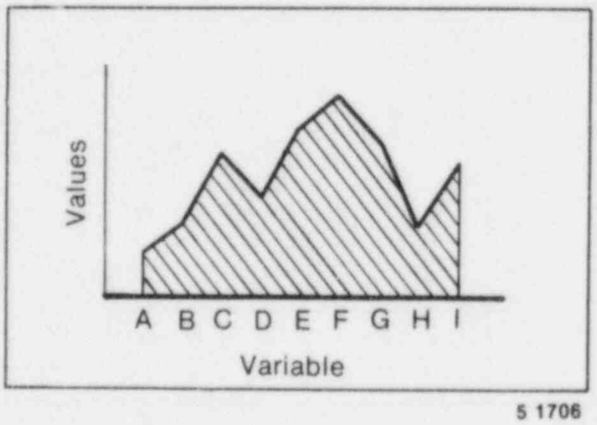
- o When changes in the movement of a series are abrupt.
- o Where accurate reading of a component is of paramount importance.

COMMENTS: Also called a subdivided surface chart.
All the components must be related to the total.
The sequence of bands should begin with the component of least movement.

TABLE B-8. DISPLAY FORMAT SUMMARY FOR LINEAR PROFILE

NAME: Linear Profile — I. D. #: 40

DESCRIPTION: Polygonal line that connects the various heights corresponding to the values of the variables arranged along a baseline.



INPUT DATA TYPE:

- Multidimensional
- Multivariate
- Discrete

USE CATEGORY:

- Approximate value
- Pattern recognition

SPECIFIC USES: To show the nature of a relationship between variables.

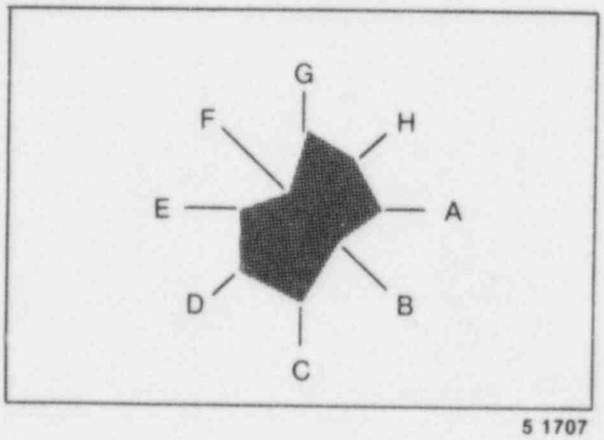
COMMENTS: Better done with a Simple Bar Chart.

TABLE B-9. DISPLAY FORMAT SUMMARY FOR CIRCULAR PROFILE

NAME: Circular Profile

I. D. #: 41

DESCRIPTION: Variation of the linear profile in which the polygonal line connects points located on equally spaced rays, where the distance from the center represents the value for each of the variables. Each ray may have different units.



INPUT DATA TYPE:

Multidimensional
Multivariate
Discrete

USE CATEGORY:

Approximate value
Deviation
Normal
Range
Pattern recognition

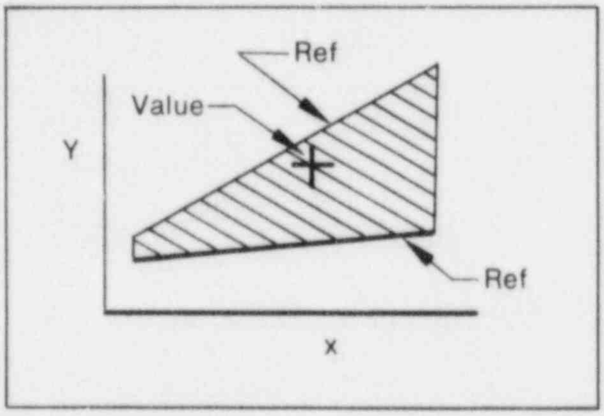
SPECIFIC USES: To show the nature of a relationship between variables not having the same units.

COMMENTS: Also called Polar Plots, Star Diagrams and Multivariate Polygons.
Good mnemonic character.
High dimensionality

TABLE B-10. DISPLAY FORMAT SUMMARY FOR A SINGLE VALUE LINE CHART

NAME: Single Value Line Chart I. D. #: 65

DESCRIPTION: A Line Chart whose time series is fixed as background data. A moving point indicator displays the current value of the parameter in relation to the fixed reference line.



5 1708

INPUT DATA TYPE:

- Duodimensional
- Univariate
- Discrete

USE CATEGORY:

- Approximate value
- Deviation
- Normal
- Prediction

SPECIFIC USES: To indicate a value in reference to a time series.

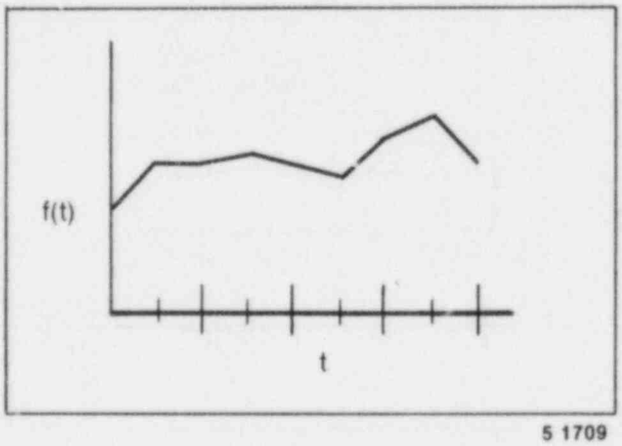
COMMENTS: None.

REFERENCES: None.

TABLE B-11. DISPLAY FORMAT SUMMARY FOR TIME HISTORY (ARITHMETIC LINE) CHART

NAME: Arithmetic Line Chart (2D) I. D. #: 1

DESCRIPTION: Chart with two orthogonal axes. The horizontal axis (abscissa) usually indicates time while the vertical axis (ordinate) indicates values that are a function of the abscissa. Successive data points are connected by a straight line.



INPUT DATA TYPE:

- Unidimensional
- Univariate
- Series

USE CATEGORY:

- Approximate value
- Prediction
- Pattern recognition

SPECIFIC USES:

- o For a series where there are many successive values to be portrayed
- o For close reading and interpolation
- o When emphasis should be on movement rather than on actual amounts.

TABLE B-11. (continued)

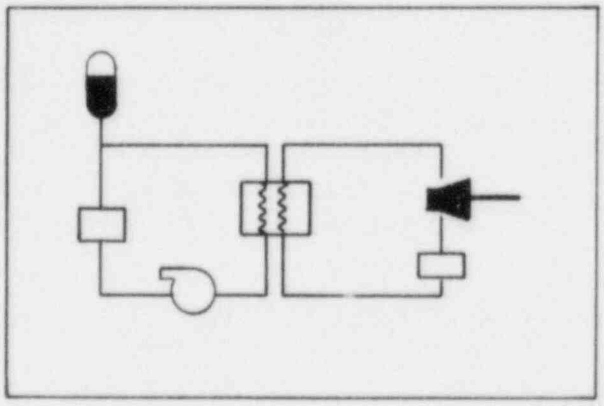
Not to be used for:

- o When there are relatively few plotted values in the series
- o When emphasis should be on changes in amounts rather than on movement
- o To emphasize differences between values or amounts on different
- o When movement of data is extremely violent or irregular
- o When presentation is for popular appeal.

TABLE B-12. DISPLAY FORMAT SUMMARY FOR MIMIC DIAGRAMS

NAME: Mimic Diagrams | I. D. #: 59

DESCRIPTION: Alphanumeric and graphic representations of data related to a system in caricature form.



5 1710

INPUT DATA TYPE:

- Multidimensional
- Multivariate
- Discrete

USE CATEGORY:

- Quantitative

SPECIFIC USES: When describing physical processes having variables with dissimilar units.

COMMENTS: Used extensively in process control.
A map is a mimic of a geographic entity.

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any): NUREG/CR-4227 EGG-2388

2. TITLE AND SUBTITLE: Human Engineering Guidelines for the Evaluation and Assessment of Visual Display Units

3. LEAVE BLANK

4. DATE REPORT COMPLETED: MONTH June YEAR 1985

5. AUTHOR(S): W. E. Gilmore

6. DATE REPORT ISSUED: MONTH July YEAR 1985

7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code): EG&G Idaho, Inc. Idaho Falls, ID 83415

8. PROJECT/TASK/WORK UNIT NUMBER

9. FIN OR GRANT NUMBER: A6308

10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code): Division of Risk Analysis and Operations, Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission, Washington, D.C. 20555

11a. TYPE OF REPORT

b. PERIOD COVERED (Inclusive dates)

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

This report provides the Nuclear Regulatory Commission with a single source that documents known guidelines for conducting formal Human Factors evaluations of Visual Display Units (VDUs). The handbook is a "cookbook" of acceptance guidelines for the reviewer faced with the task of evaluating VDUs already designed or planned for service in the control room. The areas addressed are visual displays, controls, control/display integration, and workplace layout. Guidelines relevant to each of those areas are presented. The existence of supporting research is also indicated for each guideline. A comment section and Method for Assessment section are provided for each set of guidelines.

14. DOCUMENT ANALYSIS – a. KEYWORDS/DESCRIPTORS: CRT Displays; Human Engineering Display Design Evaluation; Computer Operator Aides

b. IDENTIFIERS/OPEN-ENDED TERMS

15. AVAILABILITY STATEMENT: Unlimited

16. SECURITY CLASSIFICATION: (This page) Unclassified; (This report) Unclassified

17. NUMBER OF PAGES

18. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FOURTH CLASS MAIL
POSTAGE & FEES PAID
USNRC
WASH. D.C.
PERMIT No. G 67