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Technical Report

Fossil Fuel Power Plant Human-Machine Interface — CRT Displays

ISA-TR77.60.04 — Fossil Fuel Power Plant Human-Machine Interface — CRT Displays

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Preface

This preface, as well as all footnotes and annexes, is included for informational purposes only and is not part of ISA-TR77.60.04. The purpose of this Technical Report is to provide advice and guidance in the development of CRT Displays for use in conjunction with real-time Distributed Control Systems used in utility fossil-fired power plants with boilers of 200,000 lb/hr or greater capacity.

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Abstract

This report recognizes the substantial volumes of technical information already in existence on the topic of CRT display development. The intention of this Report is to provide a practical summary overview of the important considerations that apply to the development of effective CRT displays. It is hoped to be a handy reference to those design engineers and power-plant operators who are directly involved in display development.

Key words

Cathode Ray Tube (CRT) displays, coding conventions, color coding, CRT alarm management, CRT control applications, CRT display development, CRT display elements, CRT display organization, CRT display status, CRT display structure, CRT display types, CRT replacement guidelines, display access, Distributed Control Systems (DCS), format standards, fossil fuel power plant, human-machine interface, navigation designs (standard), operator entry techniques, real-time DCS, shape coding, size coding, typical color conventions for black background, work station ergonomics.

Contents

1 Scope

This technical report is provided for the benefit of design engineers and ultimately fossil-power-plant operators. By following this technical report, the developer of Cathode Ray Tube (CRT) displays will

a) provide clear and efficient communication between the user and the distributed control system;

b) accomplish display design based on the user's needs that are based on an assessment of planned control-operator functions to be performed; and

c) provide a display design to obtain timely access to required information and controls in a logical structure convenient to the user.

The display structure and organization, including access time to make appropriate control adjustments, should provide for operator response comparable to that of non-display-based, human-machine interface systems. To meet this requirement, the display structure must be developed using

a) clearly designed display accessing techniques;

b) a set of well-structured display relationships, predictable and familiar to the user;

c) standard display formats to increase speed of access to items within a display;

d) logical grouping of functions and tasks that minimize memorization of elements or results from previous displays; and

e) separation of overview graphics to simplify control graphics, preventing a "cluttering" of information and facilitating quicker display updates.

Input from plant operating personnel in all phases of CRT display development is critical to the development of effective displays. It is even recommended to have plant operating personnel build many of the graphics to ensure a sense of ownership by operations personnel.

This technical report will address the following issues relating to CRT display development:

Display structure	Display elements
Display access	Operator entry techniques
Display types	Control applications
Format standards	Alarm management
Display organization	Work station ergonomics
Coding conventions	

Recognizing the substantial volumes of technical reports on the topic of CRT display development, the intent of this report is to provide a summary/overview of the important considerations that apply in the development of effective CRT displays. For additional detailed guidance, please refer to Annex A — References.

2 Purpose

The purpose of this technical report is to provide advice and guidance in the development of CRT Displays for use in conjunction with real-time Distributed Control Systems (DCS) used in utility fossil-fired power plants with boilers of 200,000 lb/hr or greater capacity.

3 Display structure

Display structure establishes the relationship among displays and should reflect the relationships between functions and tasks to be performed through the CRT displays. A function/task analysis and goal assessment based on plant operating procedures is recommended to determine the goals and tasks to be accomplished.

Display structure provided with real-time distributed control systems is most commonly organized in a hierarchical structure. Displays are grouped according to levels of detail where each display serves as a menu to information above or below its level.

Using windowing techniques superimposes a sequential structure within the hierarchical structure, enabling the operator to access the requisite level of detail necessary to perform the required control functions (e.g., survey equipment status, get control help, select a transmitter, or call up a control face plate).

Three levels are typical of many fossil-plant CRT display structures as applied to the boiler/turbine and result in the following hierarchy:

Unit Control:	Unit overview. Unit master control provides the highest level monitoring and control of major process-control functions.
System Overview/ Summaries:	Overview graphics will be needed to help spot abnormal conditions, control mode summaries, plant status, and plant-process-variable summaries.
System Control:	Fuel, air, feedwater, condensate, etc. — the main controls for each supporting process
Equipment Control:	Mills, induced draft and forced draft fans, boiler feed, or condensate pumps, and associated control valves — the lowest level of control on specific equipment

Two additional CRT display structure organizing approaches are:

a) **sequential structure**, where movement from one display to the next is governed by a sequence. This technique is useful for procedural management of a plant such as a startup/shutdown sequence and is well applied when using pop-ups in a windowing environment; and

b) **spatial structure**, where the CRT display structure matches a mental map of the physical layout of the system/plant that the user has.

These techniques may be embedded as appropriate into a hierarchical display structure for the plant tasks to be managed.

4 Display access

Display access provides the means by which the user navigates through the display structure. Ease of navigation is critical to the effectiveness of CRT display structure. CRT display planning and design must take full advantage of operating system features for linking displays, including application software that enhances those features to provide a complete system of links and intelligent selection of targets. Some principle requirements for display access design are as follows:

a) Information provided must include selections based on goal/function/task analysis data with few user decisions. Critical information must be obtained within one or two selections. The system's response to the user must appear to be immediate or at least must provide some indication that processing is underway.

b) Information called up for each selection must be obvious to the user based on clear and consistent labeling and/or coding. Care must be taken to prevent labeling or graphics from overshadowing the pertinent process data.

c) Display access must be governed by consistent user actions to call-up windows/displays (e.g., touch screen, mouse, keyboard, or any combination of these).

d) Using access devices, such as a touch screen, mouse, trackball, or equivalent, that keep the user's eyes focused on data/action areas is preferred to using a keyboard, which only interfaces (see operator entry techniques). Touch screen targets should be adequately sized to ensure selection on the first attempt. Tab-key cursor control is not recommended.

4.1 Standard navigation designs

Various standard navigation designs for display access are available for displaying user options and defining user actions for display call-up. These methods are discussed as follows in accordance with their suitability for real-time system operation:

a) **Display targets** (Hot spots) provide immediate access to any form of pop-up that, in turn, can include menu selections or appropriate control face plates for operator actions. Because of its fast response system, this approach is very suitable for the real-time user.

b) **Maps/Menus** are a special form of display/pop-up by which a selected display can be called up by the user. These may include structured menu tables or menus coded by display elements (hot spots), which, in turn, can be used to make further selections. Consistency of symbolic representation and selection response is critical in using coded display elements.

c) **Context sensitive help** allows help and associated displays to be called up based on the current display or control face plate selected. These associated displays or pop-up windows can provide interlock, override, and/or permissive information for the associated device.

Prior to the widespread use and acceptance of touch screen and/or mouse-selected targets, command language, paging keys, and dedicated and variable function keys (in hardware) were commonly used as display access navigation aids. These approaches are less desirable today because they require the user to focus attention away from the CRT display.

5 Display types

Many display types are used in large data monitoring and/or control systems for power plant control, dispatch, or other applications. These display types may include overviews, system summaries, process systems (mimics), controls, component status, menus and submenus, control sequencing status, historical and trend information, alarms, diagnostics, line safety and tieline flow summaries, energy costs, database point details, maintenance and red-tag (out of service) functions, and help windows.

Display content and display organization are the two major elements that determine the display type. User functions (task analysis) should determine display content. Display organization must be logical to the intended user. Users with different responsibilities may need the same content to be organized according to the specific responsibility to be fulfilled. The display types provided should offer enough flexibility so that, when used in conjunction with the display system capabilities, a user's needs can be comfortably accommodated. For example, some operators may prefer to operate from process mimics, where others may prefer to work the control station face plates. The amount of detail on the screen at any moment in time should be at the discretion of the user.

Windowing capability provides a powerful means for obtaining selected details and support information on the main CRT screen without losing that main CRT screen information. Windowing

capability provides the capability for emphasizing the important control process information while de-emphasizing the less relevant support data, which is always available upon request.

In planning the CRT display types, it is important to consider various techniques to expedite display recognition that include

a) using display-type flexibility only in response to a specific user preference to minimize display types;

b) using consistent display formats and standard methods of exhibiting information to enhance user recognition; and

c) using display element standards such as symbols, colors, names, and abbreviations for all displays, as applicable, even if display content and organization varies according to the intended function.

6 Format standards

Consistency in the organization of each display type will enhance information recognition and will allow the system to perform in a generally predictable manner.

Each display must have a well-defined objective that is developed by considering (1) what will be done with the display (task analysis); (2) who will do it; and (3) when the display will be used. Similarly, the general format for the group of displays in a display type must have well-defined general objectives to guide its content and organization.

Standard display elements should be shown in a consistent location on all displays. These can include such things as display title, unit identification, time, date, and standard targets for hot spots/ menus.

The display title is most important since it helps the user recognize the display objective quickly and, thus, should be immediately visible to the user. Using human factors principles will help to assure visibility.

When standard format and, especially, standard layout are used, displays will tend to look alike. To avoid confusion and errors, it is equally important to make displays and layouts distinguishable from each other by using unique titling and possibly other coding techniques. For example, if multiple units can be accessed from a common console, the unit number must be clearly displayed along with the distinguishable color and/or shape coding; clearly evident format (symbol and color) and display background difference may also be used to differentiate between similar units on a common CRT.

The information provided by the CRT displays should be easily obtainable, meaningful, and discernible to the operator within a time frame compatible with control of critical components. The display system should enhance, not hinder, the operator's perspective of plant operation status.

7 Display organization

Human factors guidelines should be followed in the development of any display. These include guidelines for display content, organization, and coding with colors, symbols, etc. This clause provides guidelines for content and organization. The next clause will provide guidelines for coding.

a) General content and layout rules

1) Provide the necessary content, which should be sufficient to support the display objective.

2) Arrange content so it is not too dense.

   Crowded displays make it difficult to locate information. A rule of thumb is to provide a minimum of 25 to 40 percent blank space. For systems with limited numbers of CRTs, it may be necessary to increase display density in order to avoid excessive paging between displays. Effective display design will allow more information to be included on a single display without cluttering.

3) Show the most relevant data for the display objective (e.g., capability loss may be more important than resultant low flow).

4) Organize elements in the order they will be used (e.g., top to bottom, left to right) with the more frequently used elements shown with more prominence.

5) Facilitate ease of comparison by placing elements to be compared close to one another.

6) Match the level of abstraction with the display objective (i.e., summary overview displays will be more abstract while detailed process displays will be more concrete).

b) Emphasis of important items

1) Establish a focal point such as centering the title at the top of the display to serve as a starting point for viewing the display.

2) Place elements that have priority over others in prominent locations.

3) Avoid displaying alarm condition or status when alarm condition or status is not active (i.e., indicating lights that are off).

   It is permissible however to show normal equipment/device status as needed to monitor plant operations.

4) Avoid displaying secondary equipment if current status is satisfactory.

5) Display limit indications only when limit is reached or when knowledge of the limit is needed as part of improving plant performance.

c) User recognition

1) Follow the user's model (i.e., the way the user thinks about the system).

2) Take advantage of physical relationships known to the user, such as relative positions of plant equipment.

3) Maintain consistency between display design and existing displays and controls, especially if still in use, in conjunction with the distributed control system.

4) Take advantage of any existing conventions, particularly if they are well known and accepted, such as plant abbreviations, symbol standards, or color codes.

d) Grouping and labeling

1) Make the grouping immediately recognizable without reading data.

2) Use spacing rather than demarcation lines, which tend to add clutter.

3) Group data according to its functional relationship; alternately, it may be grouped according to its importance, frequency, sequence of use, location, or alphabetical or chronological order.

4) Make grouping consistent for all displays of a specific type.

5) Label all data (except when information can be easily inferred from the display).

6) Make labels short, unique, and distinctive.

7) Establish labeling conventions for size, location, and case (upper or lower).

Size should be consistent unless there is a hierarchical standard. Locate data labels consistently with respect to data—preferably to the left or alternately above the data.

NOTE — Upper/lower case is most readable. Please do not use all upper case.

8) Avoid using solids for bordering, which can add complexity.

9) Place data values of importance in a bright color (white, yellow, or cyan) to make them appear more noticeable.

10) Place less important data values as low as 1/2 intensity.

NOTE — Many of the preceding principles may at times be in conflict; trade-offs may be necessary based on what has the greater impact on performance.

e) Display aesthetics

The display's visual appeal should be considered after all of the more important issues of content, organization, and coding guidelines have been addressed. The display should be aesthetically pleasing to view. Spacing and balance among the elements can greatly affect the aesthetics of a display.

f) Graphic labels

Include the graphic name and any special coding symbols to help engineers find graphic source files and special notes, which help to configure the graphic. These labels should be dark so as to not clutter the graphic.

g) Hierarchical displays

The display system should provide the capability to descend primarily to three levels of hierarchy suggested as follows: the first level is monitoring display; the second level is control display; and the third level is diagnostic display. These displays should depict information to the operator depending on the function being performed during various stages of plant operation and control; i.e., monitoring, control, or diagnosis.

8 Coding conventions

Coding can provide a concise, efficient way to communicate with the operator. Proper use of coding techniques will significantly increase display intelligibility. Several basic coding principles are given and are followed by guidelines for each type of coding.

8.1 General coding principles

a) Establish coding conventions to keep coding constant across the display set. Primary coding should emphasize pattern over color or labels.

b) Code to natural expectations (e.g., a larger pump symbol for a larger pump).

c) Use codes known by user (e.g., plant color coding, abbreviations, drawing symbol standards).

d) Use obvious codes (e.g., up arrow symbol for increase, PR for print).

e) Provide definitions for special uncommonly used codes (e.g., color definition should be displayed in the appropriate color).

f) Avoid overuse of codes. The user's mind should not be so cluttered with what it has to interpret that the user cannot focus on the job.

g) Provide a help screen to "decode," wherever codes are used.

8.2 Color coding[1]

Color coding has two general uses:

1. The implementor should be aware that potential users may have difficulty or lack the ability to distinguish between specific colors or many colors. Color, therefore, should not be the sole distinguishing factor on critical indicators such as alarms, valve positions, pump start/stop, etc. Redundant indicators should be considered on those items, such as color plus shape change or color plus label.

a) To convey meaning

While 11 colors are distinguishable for an optimum design, no more than four or five colors should be used.

NOTE — As the number of colors increases, the relative effectiveness of the color codes decreases.

b) To distinguish one item from another

Since the eyes are quite sensitive to color differences, the limitation of four or five optimum colors per (see 8.2 [a]) does not apply when colors are used to distinguish items; i.e., subtle shade differences can be used to create an illusion of depth to distinguish items while minimizing clutter.

8.2.1 Additional color coding guidelines

a) Establish a color code standard.

Match computer color coding with color coding outside the distributed control system that is familiar to the user.

b) Consider color coding as a redundant form of coding.

Displays should be reviewed as if there were no color present in order to test if the display's meaning is conveyed (e.g., breaker open/closed). Using this approach will minimize problems of color distortion or color blindness.

c) Use bright colors (e.g., yellow or light green) to highlight such items as dynamic data or dynamic symbols; use dark colors (e.g., red or indigo) to repress such items as static symbols.

d) Avoid dark red or dark blue for symbols or alphanumerics.

These colors exhibit low brightness when used against a dark screen background.

e) Use a dark screen background.

Coding of display elements in bright colors will achieve better contrast against a dark background (e.g., overall screen background should match ambient conditions; 25 to 50 percent gray is best. Specific items can use darker backgrounds to enhance contrast such as numerical data in yellow on a black background and a green bar chart fill on a black background; a gray overall background helps mask glare).

f) Use a different background for windows to distinguish them from the main screen and ensure that the background provides good contrast with the established color code (e.g., light gray for pop-up).

The following example is representative of how color coding may be applied. Using red and green colors for Alternate 1 follows traditional utility industry practice. Alternate 2 is suggested where difficulty is encountered with red/green differentiation by the user. Shape coding is extremely important when using Alternate 2.

Unit Identifier Color — Color should be carefully chosen, so that each unit is readily distinguishable from the other units.

Numerical Values (Process Point Values)

	Alternate 1	Alternate 2
No alarm —	yellow or green or white	cyan, white
Alarm - Unacknowledged —	red flashing	yellow flashing
Alarm - Acknowledged —	red not flashing	yellow not flashing
Device Status —	See the Table below.	

	Valve	**Circuit Breaker**	**Motors**	**Electrical Lines**
Operating State	OPEN	CLOSED	ON	ENERGIZED
Alternate 1 Color	Red	Red	Red	Red
Alternate 2 Color	Red or Green	Red or Green	Red or Green	Orange
Operating State	CLOSED	OPEN	OFF	DE-ENERGIZED
Alternate 1 Color	Green	Green	Green	Red
Alternate 2 Color	Green	Green	Green	Brown or Dark Orange

Process flow lines (See mimics in the display elements, Section 9.)

For convenience, refer to Annex B for the suggested typical color conventions for black background from EPRI TR 101378. (See Annex A for full reference.)

8.3 Size coding

Size coding is used to emphasize items (e.g., use a larger pump symbol for a large pump). Use a small number of sizes (i.e., small, medium, or large).

8.4 Shape coding

Shapes are quick and easy to recognize independent of any color coding. Shapes are especially effective for identifying components and their operational status. Guidelines include the following:

a) Use shapes consistently for the same equipment or to convey the same meaning. Simple shapes should reflect equipment shape as much as possible.

b) Establish a "shapes" library, using standard symbols familiar to the user.

c) Make shapes clearly distinct; 10 to 15 are easily distinguished.

d) Use space to ensure legibility of alphanumeric when used in conjunction with a shape (e.g., label inside shape).

8.5 Highlighting

Highlighting is a means of coding to catch the user's attention and should be limited to two or three items on one display to be effective. Some methods include

a) **reverse video:** effective for alarms to overcome low perceived brightness of red;

b) **increased brightness:** e.g., increase color intensity or use a brighter color; and

c) **flashing:** while extremely useful in attracting attention, it must not be overused. It should be reserved for alarms or possible target detection in a high density display. Flashing should be user suppressible.

8.6 Location coding

This coding takes two forms:

a) **Display template** — where typical information is in a consistent location such as titles, function-select targets, or priority information; and

b) **User model mimic** — where display items are located according to the user's model (mimic) of a process system of equipment, or the user's model based on a PID flow diagram.

8.7 Alphanumeric codes and abbreviations

Alphanumeric codes, while providing the greatest flexibility in conveying a message to the operator, require more time to read and interpret than other codes. Guidelines are as follows:

a) Make abbreviations consistent and distinctive.

b) Establish abbreviation standards to be followed for all displays.

c) Use codes (alphanumeric or otherwise) that have meaning to the user. Avoid arbitrary codes.

d) Make abbreviations and codes consistent with labeling conventions on equipment in the plant.

e) Place numbers and/or letters together (e.g., DC2 is better than D2C; B12 is better than 1B2).

f) Avoid pairing (e.g., 1 and L, 0 and O, 2 and Z).

g) Establish a convention for consistent use of upper- and lower-case letters.

h) Use space to ensure legibility of symbols (shapes) with words.

i) Avoid symbols, underscores, and over-reliance on abbreviations, since they require time to be deciphered by the user.

j) Make a help screen available on any screen by using alphanumeric codes and an abbreviation, explaining what they mean.

9 Display elements

Display elements consist of letters, numbers, shapes, and/or colors. In developing the best display elements, it is important to determine the best coding method to convey the required information and to select the best display element to communicate that information.

A number of typical display elements are described with guidelines as to their design and use in suitable applications.

a) **Numerical value** is a digital read out of the parameter's value, using digital numbers where precision (i.e., the exact value) is needed. It requires a label or symbol to identify its meaning, including units of measure.

b) **Analog indicator (bar chart or meter)** shows the relative value of a parameter, using a continuous change in size or position of a shape.

This element is best applied where qualitative information is to be conveyed (e.g., direction of movement, relationship among values, and rate of change [inferred]). While bar chart is preferred for comparison readings, user familiarity with meter (pointer and scale) may dictate use of the latter. Pointers may be combined with a bar to show alarm limits or with numerical values, if comparison and precision are needed. Do not include more scale markings than the precision of the display can support.

c) **Digital indicator** is used to display a device status that can have one of two or more discrete states.

Each state must be easily distinguishable. States are displayed with labeling (such as ON/OFF), supplemented with color coding (red or green), and possibly enhanced with shape coding (breaker open or closed). Labeling or coding is critical since misinterpretation by the user would infer the opposite of the intended message. Avoid using color alone as a means of conveying device status.

d) **Mimic (process or system display)** is a symbolic picture reflecting the user model of a process, including relationships among variables.

To avoid misrepresentation and potential resultant confusion, care must be taken to conform the mimic to the user model. Guidelines are as follows:

1) Conform abstract symbols to common electrical or mechanical symbol conventions wherever possible.

2) Minimize details based on goal/function/task analysis data to present the required content and to avoid clutter.

3) Provide labeling inside symbols, if possible.

4) Locate data in conjunction with symbols consistently (e.g., locate pump amps below the pump symbols).

5) Locate data for mimic lines and symbols as near as possible to the corresponding line or symbol to which it relates.

6) Distinguish dynamic display symbols from non-dynamic symbols that are used statically for coherence of the mimic.

The user must recognize that the symbol is providing status information.

7) Use redundant coding of dynamic symbols wherever possible (e.g., with red/green valve, OPEN/CLOSED label, or distinguishable open or closed valve to show the valve state).

8) Use dynamic mimic flow lines to show the operation of the process when significant to understanding process operations.

Presence of flow or pressure in lines can be shown both with color coding or symbolically by showing a hollow (empty) or filled-in (full) area between two parallel lines. Mimics can be arranged to show flowing fluid by alternating the contents of the filled pipe.

9) Use dynamic electrical line mimics to show charged and uncharged lines. Presence of power can be shown both with color coding and symbolically by showing the open or closed breaker.

10) Make touch-screen or mouse targets distinguishable as to the kind of information accessed.

Targets that call up controls should be coded to be distinguishable from targets that call up other displays. Similarly, analog control call-up targets should be distinguishable from digital or binary control call-up. All targets must be identified; e.g., a three-dimensional effect is useful to infer the "button" metaphor. Non-targets must not have a similar appearance.

e) **Plots or graphs** show a parameter/parameter plot and are useful for diagnostic purposes such as marking normal-versus-abnormal operating regions.

f) **Trend** shows the history of one or more variables including rate of change and approach to limits. Guidelines are as follows:

1) Use consistent trend layouts throughout the display system.

2) Trend multiple variables only when they are related or needed for comparison to each other.

3) Provide labels for all trended variables in a consistent location.

4) Code the label that corresponds to the particular trend by color or other means for multiple variable trends.

5) Provide proper labeling such as trend variable range and time scale.

g) **Tables and lists** are used to show large amounts of information and must be well organized and coded to minimize the time to read or interpret. Guidelines are as follows:

1) Label rows on the left, columns at the top.

2) Align lists of data vertically with labels on the left and left-justified. The corresponding numeric data should be on the right and justified to the decimal, or if no decimal, right-justified.

3) Group data of more than 3 to 5 items with spacing.

h) **Text**, while being very flexible, is probably the least desirable display item since it is slow to read and interpret.

Text should generally be limited to labels and brief messages (such as help messages). Color suggestions are as follows:

1) Dark colored text (red, blue, black, etc.) should have a light background.

2) Light colored text (white, green, yellow, etc.) should have a dark background.

i) **Standardized display element combination** allows the combination of basic display elements into a custom display element that fits the specific need of the user. It should be standardized to be useful and is recommended because it addresses specific user needs. Some typical examples are as follows:

1) **Control station** is a combination of labels, bar graphs, meter pointers, numeric values, digital indicators, and push-button hot spots (selection target) arranged as a standard symbol familiar to the user.

2) **Selection target** is a combination of shapes and labels to create standard symbols for display call-up selection or control selection, etc.

3) **Trend/Indicator** is discussed in Clause 9, f.

j) **Integrated display** uses several display elements on one screen to communicate clearly and quickly a variety of data.

10 Operator entry techniques

Operator entry techniques allow the operator to enter commands or other information on the distributed control system. Common input devices used today are touch screen, mouse (or track ball), and keyboard. Using on-screen entry techniques (mouse or touch screen) keep the operator's eyes focused on the data and, thereby, minimize operator errors in making single-selection commands. This method is preferred over keyboard or special-function panel entries.

The system response to operator entries should be positive, obvious, and natural. No response (lack of system response to the input received) is not allowed. System response time should appear to be instantaneous (less than 2 seconds). If response time exceeds 2 seconds, instanta-

neous feedback should show that (a) the process is underway, and (b) the process will take an estimated length of time to complete.

Touch-screen, mouse, and keyboard entry techniques are as follows:

a) Touch screen

One advantage of a touch screen, as compared to using a mouse, is the automatic movement of the cursor to the selected location. The disadvantage*s* are that significantly larger targets are required to be "hit" consistently and that fingerprint smudges can affect screen legibility, especially when glare is a problem. Guidelines are as follows:

1) Provide well-marked target areas.

2) Provide consistent target locations on standard displays.

3) Provide differentiation among targets to make them easily distinguishable for the function performed (e.g., call-up of full screen displays versus window details versus control selection).

4) Provide a minimum of 3/4" x 3/4" target area for all critical functions. Smaller areas may be accepted if immediate and accurate response is not required.

5) Highlight the user selection when selection is made.

6) Provide all consoles (sit down/stand up) with suitable arm rests, making arm extension to the screen minimal, and precise target selection easier to achieve.

7) Use multiple touch actions for control (recommended) to avoid the problem of accidental touch.

b) Mouse (or track ball)

An advantage of using a mouse, as compared to a touch screen, is that targets can be smaller because selection is more precise. One disadvantage is that the location of the cursor must be known by the user, which may require more time to reach the target. The mouse/track ball action is more secure since it requires more deliberate actions. The mouse is suitable for both stand-up and sit-down consoles with a suitable tabletop area provided.

c) Keyboard

Keyboards are means to provide standard and variable function keys as well as multiple key data entry as required for entering numeric values or messages.

Complete QWERTY (standard) Keyboards are needed to support the engineering/configuration functions. A reduced special purpose keyboard may be provided for operator functions. Keyboard action is the most secure form of operator entry since it minimizes the incidence of unintended activation errors. General guidelines for operator keyboard entry functions are as follows:

1) Provide a logical arrangement for function keys.

2) Group function keys when many function keys are used.

3) Provide entry fields with a cursor showing location of the next keyed entry for multiple-key entry.

4) Provide means of distinguishing multiple-key entry fields from non-keyed current data, so that current data is not confused with the multiple-key entry.

5) Locate edit fields (used to edit current data) below or to the right of the data to be edited or at a consistent prompt location.

6) Highlight data being entered to help ensure the correct value is being entered.

d) Pushbutton Panels

Backlight, display-access key panels are useful for rapid one-key access to displays.

11 Control applications

Distributed control systems that control plant process or dispatch systems must have a quality CRT display design. Guidelines for standard control-station display-element development and for control design of an optimum user interaction are provided.

a) **Standard control station**: A standard control station display element is recommended for control applications. Guidelines are as follows:

1) Provide consistent target functions including the way targets are presented across all control stations.

2) Standardize keyboard interaction if utilized. Different keys should be provided for different functions to avoid operator errors.

3) Provide consistent location of basic display elements that comprise the control station (e.g., labels, bar graphs, meter pointers, numeric values, digital indicators).

b) Guidelines for optimum user interaction

1) Provide display coding to highlight which items can be selected to be controlled by the operator; what control is currently active; and what is not controllable. This differentiation is critical for mimics where some devices are not controlled.

2) Provide clear indication of control states:

a) Is item automatically controlled?

b) Is manual control inhibited?

c) What is the current operating mode (auto, manual, local control, etc.) of plant areas/units, loops, or equipment?

3) Follow a consistent loop-operating philosophy for control of an analog process variable or a digital state of equipment. This should include

   a) a well-defined act for selecting a control (A two-step operation should be provided for any significant control action including a means of deselection.);

   b) a feedback that the control is active;

   c) a second act of adjusting the active control selected;

   d) a feedback from the actual control device being controlled (not just a verification of the demand signal);

   e) a means to invoke context-sensitive help if control action is not allowed (e.g., an interlock) for a selected device; and

   f) a cancel selection target or button to clear the currently selected object.

4) Perform analog control adjustments in either of two ways: (a) select and enter a target value that has an acceptable slew rate built into the firmware, which drives the change; or (b) have raise/lower keys on a keyboard or displayed on a screen view and have them accessed with either a cursor or touch screen. Ability for multiple speed selection reaction is helpful.

5) Design displays for sequential automatic control functions to include displays/windows that

   a) list all sequence steps and start/run permissives;

   b)indicate the current sequence step;

   c) indicate the target sequence step;

   d) indicate steps satisfied;

   e) indicate steps unsatisfied;

   f) list inhibits present that prevent further progress;

   g) display elapsed time for any time-based holds;

   h) include controls to start/stop the sequence; and

   i) provide direct feedback indicating completion of failure to complete a selected command.

6) Never allow an item to be controlled but not observed (e.g., if a setpoint raise key is active, the setpoint must be displayed).

12 Alarm management

An effective alarm management system built within the distributed control system and supplemented by user application software is an essential part of an effective CRT display system for process control. The following are a number of minimum requirements that should be considered:

a) Alarm attention

Call attention to a new alarm regardless of the display in use. This can be accomplished by a standard alarm code in the same place on all screens or in a display area dedicated to incoming alarms (alarm screen or sub-screen); or by an alarm bell that sounds; or a combination of these. New alarms need to be distinguished from acknowledged alarms.

b) Alarm filtering

Provide alarm filtering to inhibit nuisance alarms, such as alarms related to equipment out of service, based on goal/function/task analysis data.

c) Alarm recognition

Establish standard display techniques to show process variables, equipment, or control loops, etc., in alarm. These may be supplemented by alarm summaries in display format for both current and historical alarms.

d) Alarm resolution

Show priority of alarms by using color and other techniques (for color-blind operators). Provide a standard methodology for alarm acknowledgment, including clear indication of alarm acknowledgment and/or return to normal status.

e) Alarm diagnosis / Response support

Using logic-driven (or expert system-driven) indicators or windows to identify the root cause of the upset situation or to help the operator resolve the problem is highly recommended.

f) Sequence of event (first-out) processing

Provide for major process-upset conditions.

13 Work station ergonomics

The physical design (numbers of CRTs, CRT placement, etc.) must support the intended (single- or multi-unit) operation and must be coordinated with the CRT display design based on a task analysis of functions to be performed. Task analysis must consider various individuals using the work station during all plant operating conditions. The CRT display hardware used by operators must be designed and arranged to conform to the physical requirements of Human Factors' guidelines for distance angles and anthropometrics, etc.; e.g., seating, work surface, and seat support must accommodate operator size from small- through large-framed operators, both male and female; touch screens must be within the operator's reach; a mouse may be needed if physical arrangements require the CRTs to be too far away; and symbol and letter height must be adjusted for the expected viewing distance.

As large screen technology improves (by both projection or other techniques), the use of semi-permanent displays for monitoring the overall plant performance (as was formerly provided by the dedicated operator control board and control desk instrumentation) will minimize the need to ascend the display hierarchy from control level 2 to monitoring level 1 displays.

14 CRT replacement guidelines

CRTs wear out over time; they get dim and lose focus. All systems must support replacing CRTs with standard video format. Users should plan on replacing CRTs at a minimum of five-year intervals.

Annex A — References

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ANSI/HFS 100-1988 American National Standard for Human Factors Engineering of Visual Display Terminal Work Stations — The Human Factors Society, Inc.

Available from: ANSI
11 West 42nd Street
New York, NY 10036 Tel. (212) 642-4900]

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P.O. Box 12277
Research Triangle Park, NC 27709 Tel. (919) 990-9200

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Annex B — Typical color conventions for black background

The following table is printed with permission from the Electric Power Research Institute and is found in EPRI TR-101378, *Guidelines for Designing Displays for DCS Retrofit Projects*, January 1993, Figure 6-1 (see Annex A — References).

Typical color conventions for black background

Color	Use
Black	display background
	auto/manual station background
Magenta	reserved color for target icons used for control stations, windows, trends, and display links
Light Green	text, tag names, engineering units
	status: off, not running, open circuit, closed MOV
Bright Green	data: normal data
Flashing Light Green	circuit breaker tripped
Light Orange	status: remote control, MOV traveling
	data: intermediate high/low limit (no alarm)
Light Red	status: on, running, closed circuit, open MOV, permissive satisfied
	data: high or low alarm (acknowledged)
Flashing Bright Red	data: high or low alarm (unacknowledged)
Bright Orange	status: permissive not satisfied
	data: bad data
White	data: manually fixed data
Cyan	symbol building
Most Blues	symbol building, selected bar chart background, flow path, fluid paths
Blue	flow paths, fluid paths

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