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Recommended Practice

Human Engineering for Control Centers

ISA-RP60.3 — Human Engineering for Control Centers

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Preface

This preface is included for informational purposes and is not part of ISA-RP60.3.

This recommended practice has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static, but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms, and asks that they be addressed to the Secretary, Standards and Practices Board, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709, Telephone (919) 549-8411, e-mail: standards@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to U.S.A. users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, the Department will endeavor to introduce SI-acceptable metric units in all new and revised standards to the greatest extent possible. *The Metric Practice Guide*, which has been published by the Institute of Electrical and Electronics Engineers as ANSI/IEEE Std.268-1982, and future revisions will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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The information contained in the preface, footnotes, and appendices is included for information only and is not a part of the recommended practice.

The SP60 Committee is preparing a series of recommended practices on control centers. ISA-RP60.3 is the fourth of this series to be published. The published recommended practices and drafts in preparation are listed below.

RECOMMENDED PRACTICE SECTION	**TITLE**
dRP60.1	Control Center (C.C.) Facilities
dRP60.2	C.C. Design Guide and Terminology
RP60.3	Human Engineering for Control Centers
dRP60.4	Documentation for Control Centers
dRP60.5*	Control Center Graphic Displays
RP60.6	Nameplates, Labels and Tags for Control Centers
dRP60.7*	Control Center Construction
RP60.8	Electrical Guide for Control Centers (published 1978)
RP60.9	Piping Guide for Control Centers (published 1981)
dRP60.10*	Control Center Inspection and Testing
dRP60.11	Crating, Shipping and Handling for C.C.

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Contents

1 Scope

The intent of this recommended practice is to present design concepts which are compatible with the physical and mental capabilities of the control center operator while recognizing any of the operator's limitations.

The control center can be designed for efficient functioning of the man-machine system after one first defines the information the operator needs to control the process, and the controls to be provided.

This recommended practice is limited to those aspects of human engineering that will affect the layout of and the equipment selection for the control center. It is recognized that some of the human factors discussed in this document are also used in the design and manufacture of instruments.

2 Physical aspects

2.1 Static anthropometric data

In the dimensional design of a control center, one should consider the physical characteristics of the plant operators. The possible range in these characteristics is rather wide, but can be narrowed for a specific design if knowledge of such factors as age, sex, and physical qualities of the expected group is applied. Useful data may be obtained from the references listed in the bibliography for this recommended practice. It is important to note that in application of these data, one should not design the control center for average human characteristics but rather for the normally expected extremes of the subject group. Figures 1 and 2 and Tables 1 and 2 provide static anthropometric data taken from Military Standard (MIL. STD) 1472.

2.2 Dynamic anthropometric data

2.2.1 While the basic layout for a control center may be designed using static anthropometric data, it should be checked and refined using dynamic data. If this is done, the range to be covered by one operator can be described by physical reach and reasonable lateral movement. Included in the relevant dynamic information are the ranges of eye and head movement. If there is no head movement, the visual range is a cone whose angle is approximately 60°. However, discomfort results if the eye must be positioned off the standard line of sight. Therefore, head movement is used to accommodate or assist any scanning requirement. The result, then, is a control center whose dimensions and shape match the process and the operator. The standard profiles detailed in ISA-dRP60.7, "Control Center Construction," represent industry practice in the application of anthropometric data.

2.2.2 Displays should be arranged and positioned so that they are perpendicular to the line of sight when the eyes and head are in a comfortable position, and in any case should not be less than 45° from the normal line of sight. This is particularly important for displays which require constant attention.

The use of manually operated equipment located in positions which require frequent extreme physical movements, such as reaching, stooping, or squatting, will produce fatigue; thus, these locations should be avoided.

Consideration should be given to techniques or features in the control center which will help minimize fatigue when it is a requirement that the operator must stand most of the time. Arm rests or hand rails reduce upper back fatigue, and a foot rest or foot rail aids in easing lower back strain or fatigue.

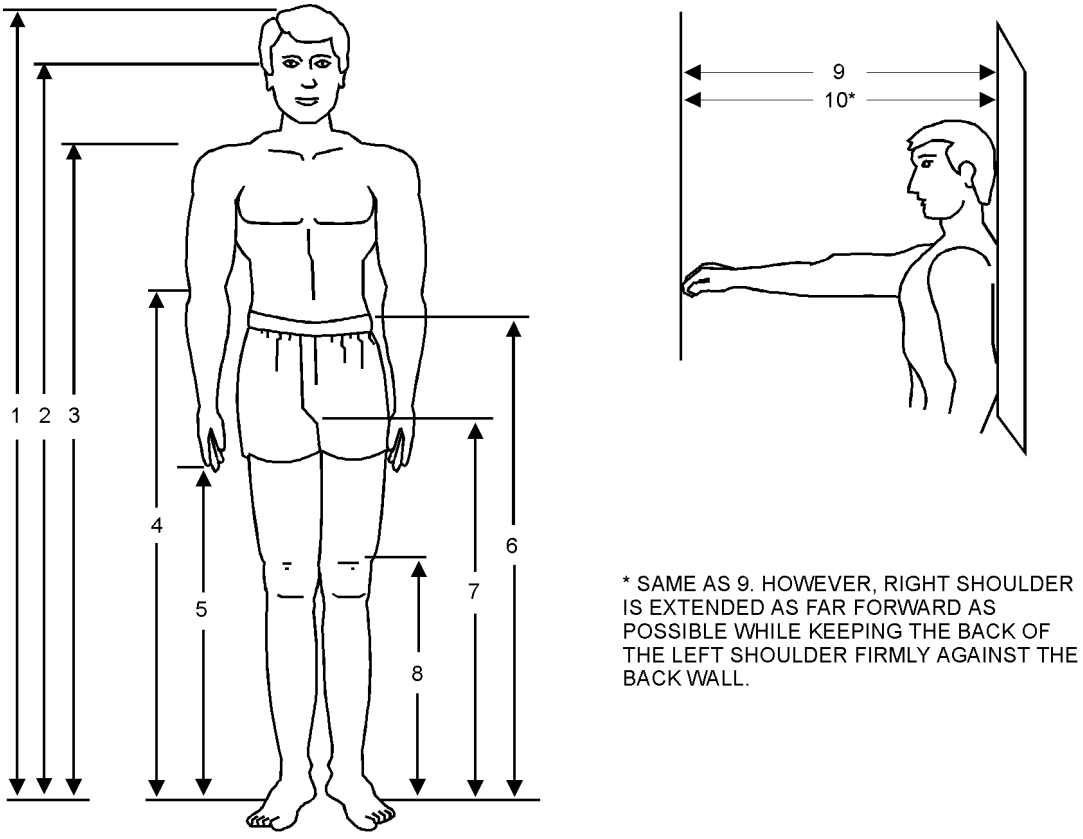

Figure 1 — Standing body dimensions

Table 1 — Standing body dimensions

	Percentile values in centimeters					
	5th percentile			95th percentile		
	Ground troops	Aviators	Women	Ground troops	Aviators	Women
Weight (kg)	55.5	60.4	46.4	91.6	96.0	74.5
Standing body dimensions						
1 Stature	162.8	164.2	152.4	185.6	187.7	174.1
2 Eye height (standing)	151.1	152.1	140.9	173.3	175.2	162.2
3 Shoulder (acromiale) height	133.6	133.3	123.0	154.2	154.8	143.7
4 Elbow (radiale) height	101.0	104.8	94.9	117.8	120.0	110.7
5 Fingertip (dactylion) height		61.5			73.2	
6 Waist height	96.6	97.6	93.1	115.2	115.1	110.3
7 Crotch height	76.3	74.7	68.1	91.8	92.0	83.9
8 Kneecap height	47.5	46.3	43.8	58.6	57.8	52.5
9 Functional reach	72.6	73.1	64.0	90.9	87.0	80.4
10 Functional reach, extended	84.2	82.3	73.5	101.2	97.3	92.7
	Percentile values in inches					
Weight (lb)	122.4	133.1	102.3	201.9	211.6	164.3
Standing body dimensions						
1 Stature	64.1	64.6	60.0	73.11	73.9	68.5
2 Eye height (standing)	59.5	59.9	55.5	68.2	69.0	63.9
3 Shoulder (acromiale) height	52.6	52.5	48.4	60.7	60.9	56.6
4 Elbow (radiale) height	39.8	41.3	37.4	46.4	47.2	43.6
5 Fingertip (dactylion) height		24.2			28.8	
6 Waist height	38.0	38.4	36.6	45.3	45.3	43.4
7 Crotch height	30.0	29.4	26.8	36.1	36.2	33.0
8 Kneecap height	18.7	18.4	17.2	23.1	22.8	20.7
9 Functional reach	28.6	28.8	25.2	35.8	34.3	31.7
10 Functional reach, extended	33.2	32.4	28.0	39.8	38.3	36.5

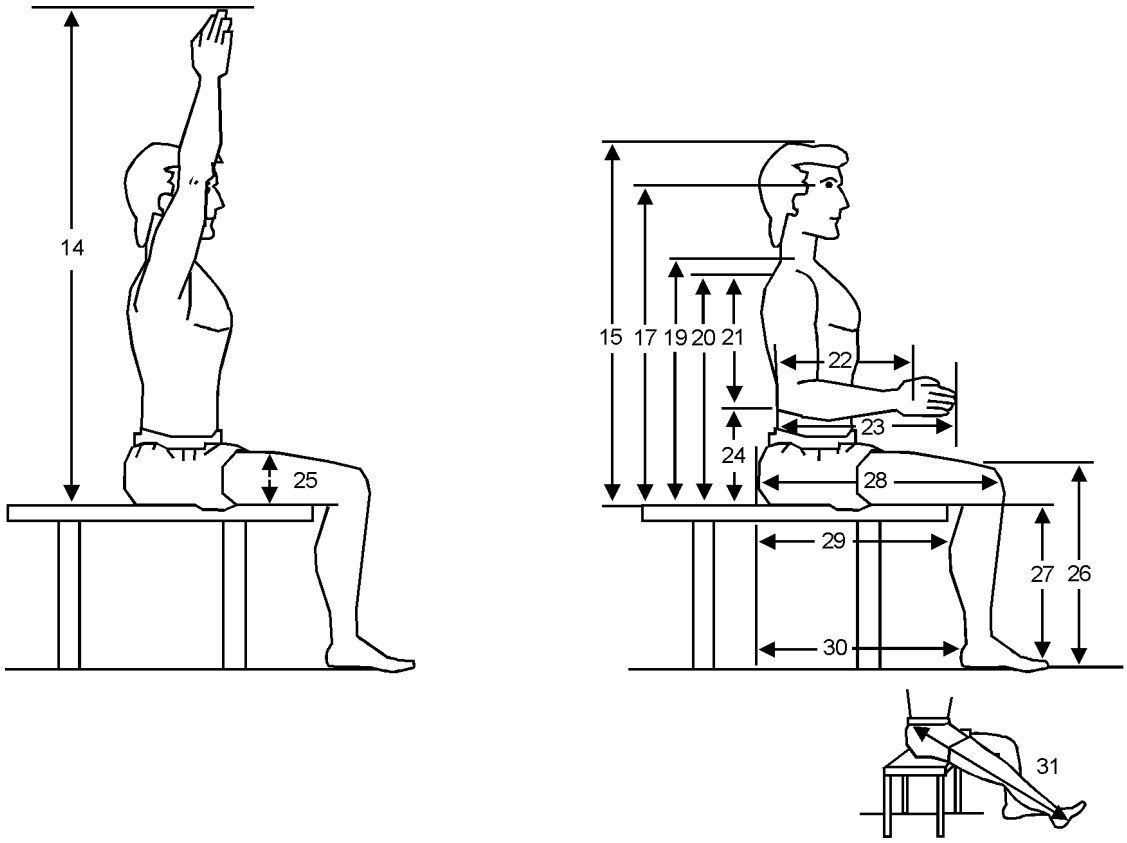

Figure 2 — Seated body dimensions

Table 2 — Seated body dimensions

	Percentile values in centimeters					
	5th percentile			95th percentile		
	Ground troops	Aviators	Women	Ground troops	Aviators	Women
Seated body dimensions						
14 Vertical arm reach, sitting	128.6	134.0	117.4	147.8	153.2	139.4
15 Sitting height, erect	83.5	85.7	79.0	96.9	98.6	90.9
16 Sitting height, relaxed	81.5	83.6	77.5	94.8	96.5	89.7
17 Eye height, sitting erect	72.0	73.6	67.7	84.6	86.1	79.1
18 Eye height, sitting relaxed	70.0	71.6	66.2	82.5	84.0	77.9
19 Mid-shoulder height	56.6	58.3	53.7	67.7	69.2	62.5
20 Shoulder height, sitting	54.2	54.6	49.9	65.4	65.9	60.3
21 Shoulder-elbow length	33.3	33.2	30.8	40.2	39.7	36.6
22 Elbow-grip length	31.7	32.6	29.6	38.3	37.9	35.4
23 Elbow-fingertip length	43.8	44.7	40.0	52.0	51.7	47.5
24 Elbow rest height	17.5	18.7	16.1	28.0	29.5	26.9
25 Thigh clearance height		12.4	10.4		18.8	17.5
26 Knee height, sitting	49.7	48.9	46.9	60.2	59.9	55.5
27 Popliteal height	39.7	38.4	38.0	50.0	47.7	45.7
28 Buttock-kneel length	54.9	55.9	53.1	65.8	65.5	63.2
29 Buttock-popliteal length	45.8	44.9	43.4	54.5	54.6	52.6
30 Buttock-heel length		46.7			56.4	
31 Functional leg length	110.6	103.9	99.6	127.7	120.4	118.6
	Percentile values in inches					
Seated body dimensions						
14 Vertical arm reach, sitting	50.6	52.8	46.2	58.2	60.3	54.9
15 Sitting height, erect	32.9	33.7	31.1	38.2	38.8	35.8
16 Sitting height, relaxed	32.1	32.9	30.5	37.3	38.0	35.3
17 Eye height, sitting erect	28.3	30.0	26.6	33.3	33.9	31.2
18 Eye height, sitting relaxed	27.6	28.2	26.1	32.5	33.1	30.7
19 Mid-shoulder height	22.3	23.0	21.2	26.7	27.3	24.6
20 Shoulder height, sitting	21.3	21.5	19.6	25.7	25.9	23.7
21 Shoulder-elbow length	13.1	13.1	12.1	15.8	15.6	14.4
22 Elbow-grip length	12.5	12.8	11.6	15.1	14.9	14.0
23 Elbow-fingertip length	17.3	17.6	15.7	20.5	20.4	18.7
24 Elbow rest height	6.9	7.4	6.4	11.0	11.6	10.6
25 Thigh clearance height		4.9	4.1		7.4	6.9
26 Knee height, sitting	19.6	19.3	18.5	23.7	23.6	21.8
27 Popliteal height	15.6	15.1	15.0	19.7	18.8	18.0
28 Buttock-knee length	21.6	22.0	20.9	25.9	25.8	24.9
29 Buttock-popliteal length	17.9	17.7	17.1	21.5	21.5	20.7
30 Buttock-heel length		18.4			22.2	
31 Functional leg length	43.5	40.9	39.2	50.3	47.4	46.7

3 Psychological aspects

3.1 General

3.1.1 This section deals with how an operator distinguishes, comprehends, and reacts to the information displayed in a control center. Measurement and control systems may contain thousands of devices representing functions or bits of information displayed, each potentially requiring operator actions. Considering the tremendous quantity of information confronting the operator, a high level of mental concentration is demanded.

3.1.2 Psychological aspects are thought processes which are difficult to measure but which must be considered in any control center design. The importance of these aspects increases rapidly with the complexity of the process and the quantity of the control center instrumentation. Psychological aspects also affect the selection and arrangement of the display devices.

3.1.3 Too often, control centers are designed without considering the principles of human engineering design. To the casual observer, the resulting control center may be an impressive display of lights and instruments. To the operator who must live with such a presentation, it can become bewildering. Operator confusion can lead to costly operational mistakes.

3.1.4 The operator can be considered a system — complete with sensory inputs, data processing capability (including information storage and processing), and responsive outputs. The following sections show how human beings fit this information processing system analogy. This information should help the designer incorporate good human engineering concepts into the control center design.

3.2 Information sensing (inputs)

3.2.1 Visual inputs

Visual inputs provide 80 to 90 percent of the information required to operate a control center. The operator interprets:

1) Color, and changes of color;

2) Position, and change of position (dials and switch handles);

3) Patterns, and changes of pattern, e.g., on cathode ray tube (CRT) displays;

4) Digital values;

5) Nameplate data.

3.2.2 Auditory inputs

Auditory input makes up the remaining 10 to 20 percent of the information required to operate a control center. This input reinforces the visual information by adding sounds from attention-getting devices such as horns, sirens, and other audible devices.

3.3 Information storage

Memory is the information storage unit which makes it possible to integrate previous experience with present activity. The ability to perform the job's requirements depends on how well the operator can process the information presented and relate this to previously stored information.

3.4 Information processing

The way in which the information is presented determines the operator's ability to recognize, comprehend, and react to a situation. It is evident that the operator can be overloaded with information, which leads to inefficiency and inaccuracy. The ability to recognize, comprehend, and react correctly to a situation is usually determined by the manner and speed with which information is presented. Information theory may be used as a tool to measure the optimum combination of display type and speed to avoid the operator's becoming overloaded and confused. For more information, refer to McCormick, *Human Factors Engineering*, Chapter 5 (see Section 5).

4 General design

4.1 Objective

4.1.1 This section will describe specific features and techniques that should be used in the design and layout of a control center, implementing the human engineering factors treated in Sections 2 and 3. Not all of the following recommendations will apply to every application. The designer should include only those features that are compatible with the overall design requirements of the control center and facility, taking into consideration hardware availability, cost, and delivery time.

4.1.2 Information display devices include analog indicators, recorders, indicating lights, backlighted nameplates, annunciator windows, digital displays, CRT displays, projection screens, and printers or typers. Control devices include selector switches, pushbutton switches, keyboards, and analog control stations (manual/automatic, manual loading, setpoint, and other types).

4.1.3 The use of computers to process data and generate displays should be considered where large amounts of data and/or complex operating data must be monitored and controlled. The computer can assist the operator in performing the necessary control functions. A computer can operate display devices such as CRTs, indicating lights, projection screens, digital displays, analog indicators, and printers or typers.

4.2 Implementation guidelines

4.2.1 Equipment arrangement

Control devices should be located on the control center in the same general sequence that the operator will follow in any of the operations of systems or subsystems, or located in the same relative positions that the actual equipment is located. The same concept may be applied to the location of individual sections of a control center. Consideration should also be given to prominent location of emergency shutdown systems.

Those devices which are interrelated or are used to determine the operating condition and status of a system or subsystem may be grouped together.

To assist the operator in identifying and locating a particular group of devices, space may be left between adjacent groups, different colors may be used, or groups may be outlined with tape or painted stripe.

Consistent criteria should be used for the relative location of specific status conditions where multiple status display devices are used.

Mounting the devices within graphic sections on the control center can result in easier identification by the operator.

Use consistent criteria for the location of nameplates in relation to their devices.

Layouts for duplicate units should be identical to improve operator proficiency as long as there is proper unit identification. Arrangements utilizing reverse or mirror images in the design of control centers for duplicate units should be avoided.

4.2.2 Accessibility

Control devices should be mounted on sections of the control center that are within the normal reach of the operator when the operator is in normal position, either standing or sitting.

Control devices should be mounted on the control center with sufficient clearance, so that the operator can conveniently operate them without interference from other devices or adjacent control center surfaces. Consideration should also be given to:

1) Plant conditions that might require gloves
2) The size or strength of an operator's hand
3) Hindrances due to safety clothing
4) Other operational hindrances

Frequently adjusted controls and often-referenced visual indicators should be located at the most convenient elevation. The height is related to the operator's normal position of standing or sitting. ISA-dRP60.7, "Control Center Construction," shows a typical profile, with an operator's average standing or sitting line of elevation. These typical profiles are based on the physical aspects outlined in Section 2.

Space should be provided for convenient storage of and access to operating checklists and instructions.

4.2.3 Pattern recognition

Pattern recognition and symmetry may be used to aid the operator in the detection of abnormal conditions. Mounting several edgewise indicators adjacent to each other is one way to use this technique.

The direction of motion of the pointers for all indicators should be established and used consistently. Common practice is for the pointer to move from the bottom of the scale to the top, from left to right or clockwise as the displayed variable increases in value.

The direction of operation of control switches and selector switches should be chosen consistently for the functions that they perform. For example, all equipment starting functions on a particular control center may be performed when the switch handle is turned in a clockwise direction and stopped when the switch handle is turned in the counterclockwise direction. For another example, valves may open when the switch handle is turned in the clockwise direction, close when turned in the counterclockwise direction, and stop when in a neutral, or center position.

4.2.4 Shape or type

The use of particular types of display or control devices in the control center facility should be standardized to increase the operator's efficiency and possibly improve the aesthetic appearance of the control center.

A specific size or shape of switch handle should be used as a means to identify a specific function; this will increase operator accuracy during emergencies.

The type of switch handle that will be most comfortable and convenient for the operator to use for the particular application should be selected. For the smaller-sized selector switches, use of "bat lever knobs" and "gloved hand operators" reduces the strain on the operator's hand. This is particularly true with spring return switches, for which the operator may be required to hold the switch in the momentary position for relatively long periods of time.

Where illuminated pushbuttons are used, select an arrangement or type of pushbutton that does not produce large amounts of heat and cause the pushbutton to become hot to the touch.

4.2.5 Visibility and readability

Locate the display devices on the control center above the associated controls so that no part of the operator's body will obstruct the view of the related display devices during operation of the controls.

Mount those devices that have hinged doors or sections, such as recorders, so that operation or observation is not blocked from critical displays or control devices when these doors or sections are swung out from their normal operating positions.

When selecting a minimum size for the letters, numbers, and symbols on legends, scales, engraved nameplates, and other displays, take into consideration the distance from which the device will be read by the operator in the normal operating position; also consider the significance of the device. See ISA-RP60.6, "Nameplates, Labels and Tags for Control Centers," for recommended letter sizes.

Abbreviations should be avoided, but may be used when necessary. Consistent terminology and abbreviations should be used.

Requirements for the resolution of readings may determine the length of scales and the type and size of indicators and recorders.

Those devices which have graduated scales and require reading by the operator should be mounted on a section of the control center that is within the line of sight of the operator when in the normal operating position (standing or sitting) at the control center.

Glare on the surface of the display device may be reduced by:

1) Use of antiglare glass or materials for the windows of display devices;

2) Use of hoods that extend over the top of the display device — especially for CRTs, digital displays, and projection screens;

3) Proper selection of the mounting angle for the display device in relation to both the operator and the source of reflection;

4) Use of adjustable lighting intensity in the area of the control center;

5) Use of indirect or diffused lighting. Glare on the surfaces of the control centers and nameplates should be minimized through the proper selection of surface finish.

4.2.6 Illumination

Consider the use of internal illumination for indicators and recorders either (1) to increase readability, or (2) to call the operator's attention to an off-normal variable (by having the illumination flash or otherwise change from the continuously lighted condition).

Variation of light intensity and flash frequency can be used to draw the operator's attention to a display device.

Higher flash rates can be used in identifying more important devices.

When selecting indicating lights, backlighted nameplates, CRT displays, digital displays, and projection screens, consider the light intensity of the device, the lighting levels in the control center facility, and the effects of deterioration of the brightness of the device with age.

Some devices, such as CRT displays, have an adjustment for brightness. Status light power supplies may be designed to provide different intensities. See ISA-dRP60.1, "Control Center Facilities," for the recommended lighting levels inside the control room.

4.2.7 Color coding

The establishment of a color coding system can assist in the identification of those devices that are associated with a particular system, subsystem, function, or piece or type of equipment. Nameplates, bezels, control center surfaces, graphic materials, switch rings, and switch actuators can be provided in different colors.

Use a consistent color designation scheme for all indicating lights and backlighted displays in the control room. Each color should designate a specific status condition or priority.

Color coding the indicating scale backgrounds by group or function can result in easier identification by the operator.

Contrasting colors for the background, lettering, and pointers of indicators and recorders should aid in their readability. Care should be taken in the selection of color for background and lettering of backlighted devices so that they will be readable in both the illuminated and extinguished state, if this is the desired effect.

4.2.8 Auditory techniques

Audible devices are frequently used with display devices (such as annunciator windows, CRT displays, and printers or typers) to alert the operator to a condition that requires attention. Audible devices may also be used to direct attention to a particular control center or piece of equipment. Types of audible devices include: horns, bells, buzzers, sirens, gongs, chimes, klaxons, and pre-programmed verbal messages.

Audible devices should be chosen so that each device has a distinct and recognizable sound. This can be accomplished by use of different types of devices, tone sequences, pulse frequencies, and by varying the pitch of each signal. All devices in the control room, including telephones, should be considered.

Each audible device should have the capability of being adjusted for loudness so that the device can be heard, at the operator's location, over the background noise while at the same time not being offensively loud.

4.2.9 Safety considerations

In critical applications such as emergency shutdown and trip functions, either guarded or protected pushbuttons or dual operation devices should be used to minimize inadvertent actuation.

Removable handles and key-operated switches may he used to prevent unauthorized operation.

"Panic Buttons" for emergency trip actuations should use mushroom head type pushbuttons or other readily operated devices. They should not be located where they could be accidentally actuated.

4.3 Maintenance

4.3.1 Each device should be located and mounted on the control center so that it is readily identified and accessible for maintenance, testing, or calibration without loss of operability. Provisions for easy removal of each device should be included. Interference from other devices, framing, reinforcing members, and surfaces of the control center, or from adjacent wiring, tubing, and piping should be taken into consideration during the design and layout.

4.3.2 Internal surfaces of the control center should be colored a flat white to improve visibility during maintenance.

4.3.3 Reduce to the maximum extent possible the interference with the functions of the operator during the performance of maintenance, testing, or calibration of the control center devices. This may be done by mounting the devices so that they can be quickly removed, and by locating auxiliary devices away from the immediate operating area. Locate the test and calibration connections so that they do not interfere with operations.

4.3.4 A means should be provided for readily identifying faulty display devices on the control center. This can be done by providing:

1) A lamp test feature and/or dual lamps

2) A dim-bright operating feature

3) An upscale or downscale burnout

4) A live zero

5) An out-of-service indication for critical items

6) Three displays or channels—to avoid the ambiguity of dual indications in critical services

4.3.5 A means should be provided for disconnecting the power source to the devices mounted on the control center. This may be done by the use of circuit breakers, disconnect switches, or individual plugs and receptacles.

4.3.6 If custom changes have been made to standard equipment in order to provide desired human engineering features, a complete documentation of these changes should be maintained.

5 Bibliography

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