
Chapter 1. Scope

1.0 General scope

This standard specifies requirements and recommendations for user requirements and for the design and purchase of devices, such as input devices, electronic displays and furniture, that will be used while working with computers in a fixed, desktop environment. While this standard does not directly address the use or design of mobile devices, the requirements and recommendations herein may be helpful in designing, using and purchasing such equipment.

1.1 Conformance

The standard contains two classes of specifications: requirements and recommendations. Requirements are identified by a bold typeface "**shall**," whereas recommendations are indicated by a bold typeface "**should**".

The requirements and recommendations represent a consolidation and reduction to practice of the human factors engineering principles for the design and configuration of computer workstations and their components. The requirements and recommendations have been developed from accepted human factors and ergonomics research and established professional practices.

Conformance with this standard can be achieved at either the component level or the system level. "Component conformance" applies to specific devices used in computer workstations. This compliance level is intended to allow manufacturers of workstation components to meet the objectives of the standard apart from considerations involving the configuration of the installed computer workstation.

Evaluations of product conformance with this standard are intended to be performed by professionals who are familiar with and trained in the procedures and measurement techniques involved. To encourage consistency and comparability across conformance evaluations, assessment protocols are presented in each chapter.

Although a workstation and its individual components may comply with the standard when initially configured, the conformance requirements are intended to apply throughout the life cycle of a computer workstation. Systems integrators and evaluators should review installed workstations whenever components are added, modified, replaced, or removed.

NOTE: All normative dimensions in this standard are given in SI units (meter, kilogram, seconds). Dimensions given in US customary units such as inches, pounds, etc. are presented for advisory purposes only and are non-normative.

Chapter 2 Cited Standards

ANSI/BIFMA X5.1, General Purpose Office Chairs—Tests

ANSI/BIFMA X5.3, Vertical Files—Tests

ANSI/BIFMA X5.5, Desk Products—Tests

ANSI/BIFMA X5.9, Lateral Files—Tests.

Information Display Measurements Standard. (ICDM) International Committee for Display Metrology (2012).

ISO 24496:2017 Office furniture -- Office chairs – Methods for the determination of dimensions

Chapter 3 INPUT DEVICES

This chapter presents design specifications for alphanumeric keyboards and selected non-keyboard input devices used in computer workstations. These specifications, along with those in Chapter 5, Furniture, are intended for designers and manufacturers of input devices.

Purpose and Scope

The purpose of this chapter is to establish minimum design specifications for selected technologies used as primary and auxiliary user input devices at computer workstations in office settings. The scope of this chapter pertains to design features of alphanumeric keyboards, selected cursor control devices and direct touch input devices as listed below.

- Keyboards
- Mouse and puck devices
- Trackballs
- Joysticks
- Stylus and light pens
- Indirect (touch) input devices
- Direct touch input devices

The specifications presented in this chapter are intended to apply to devices used for producing, editing, and using text and graphics presented on the computer visual displays

Design Specifications

GENERAL SPECIFICATIONS

The following specifications apply to all input devices considered in this chapter and intended for an adult user population. Designers and manufacturers of specific input devices are referred to these general specifications and to the relevant specifications in Chapter 5, Furniture.
Input devices placed on a stable horizontal surface **should**

- Be stable (i.e., not wobble or stick) during normal operation

Likewise, integrated buttons and keys **should**

- Be stable (i.e., not wobble or stick) during normal operation

Activation of integrated buttons or keys **should not**

- Cause inadvertent movement of the input device (potentially leading to unintended inputs or errors)

Device instability (from slipping or rocking) and poor grip surfaces can adversely affect performance and lead to increased effort and errors. Smooth key and button action aids performance, reduces keying effort, and promotes user satisfaction. Button activation that requires users to alter their grip frequently can result in increased effort, unintentional cursor movement, and difficulty in simple object (target) acquisition (see Cushman & Rosenberg, 1991, Chapters 8 and 13).

Intentional Movements
Users should

- Be able to position input devices accurately and quickly without exerting excessive effort or force

However, the effort or force required to position the input device **should**

- Be sufficient to prevent the device from unintended drifting or changing of position

There must be a balance between the effort and force required for the user to position the device easily and the need for the device to remain stable at its intended position.

Grip Surface
The grip surfaces **should**

- Be sized, shaped, and textured to prevent slipping and unintended movements during normal operation

Input devices with buttons **should**

- Permit button activation without requiring alteration of the handgrip

Handedness
An input device designed for one-handed operation **should**

- Be operable with either hand

If the input device is designed for operation by a particular hand, then both left- and right-handed versions **should**

- Be available to users

Surface Reflectance
Specular reflectance of input device **s**urfaces that are visible during normal operation **should**

- Be 45% or less

Excessive reflectance of surfaces visible during normal operation can cause glare, which may lead to user discomfort and degraded visual performance (Sanders & McCormick, 1993, pp. 533–539).

Edges, Corners, and Surfaces

Hard surface edges and corners that come into contact with the user during normal operation **should**

- Have a radius of at least 2 mm (0.078 in.)

Radius is defined as the distance from the rounded surface to the center of the circle creating the arc. For surfaces that are not perfectly round or of constant radius, the minimum/smallest radius of the surface should be used. Flush-mounted features are excluded from this recommendation. Prolonged or frequent pressure and contact with sharp edges and corners can lead to discomfort, distraction, and degraded performance.

Button Placement

Thumb and finger-operated buttons on input devices **should**

- Be accessible during normal operation

and **should**

- Be activated with thumb/finger flexion, not extension

Hard-to-reach input device buttons or those that necessitate awkward or extreme thumb and/or finger motions can lead to fatigue and degraded performance.

Button Force and Displacement

For tasks involving frequent use of buttons on an input device, the maximum force needed to press and activate such buttons **shall**

- Be between 0.25 and 1.5 N (0.9 ounce-force–5.4 ounce-force)

Buttons **should**

- Have a displacement between 1.0 and 6.0 mm (0.04 in. to 0.24 in.)

Buttons **should**

- Support the resting weight of the thumb/finger in order to minimize accidental activation or the need to suspend the thumb or finger over the button in order to prevent accidental actuation

Although most research on the operation of small push buttons is associated with keying, typing, and keyboards, it is reasonable to generalize from this research to the use of push buttons on other input devices, especially when tasks involve frequent push-button operation. Consequently, this specification is supported by the literature and general consensus regarding minimum and maximum key-activation forces.

Button Feedback

Input device buttons **should**

- Provide feedback to users upon activation

Tactile or auditory feedback modes, or combinations of these feedback modes, are acceptable.

If auditory feedback is provided through software, it **should**

- Be user suppressible

A consistent research finding involving keying and push-button use is that feedback is essential during the acquisition of keying skill. Feedback aids in facilitating learning. Tactile feedback is suggested for high-volume or high-frequency button use and keying. Auditory and/or visual feedback as well as tactile feedback can be helpful during training (Cushman & Rosenberg, 1991).

Button Lock

A locking feature **should**

- Be provided for buttons on input devices that are used for tasks involving prolonged or continuous button depression

The button-lock feature is intended to relieve or reduce the necessity for continuous pressure by the finger to activate a button during specific task operations. This specification can be met through hardware or software controls.

Labels

Labels on input device controls **should**

- Be visually distinguishable and interpretable to users

Text-based labels **should**

- Be printed in a sans-serif font and in title case (i.e., uppercase first letter and remaining letters in lowercase)

Buttons, keys, and controls with full or partial function labels often lead to better performance than do unlabeled ones. Effective ways to label and group functions include borders, colors, fonts, labels, shape, size, shading, and spatial separation. If text labels are not feasible (e.g., because of space constraints), graphic symbols may be employed.

Control Dynamics

The control dynamics, such as control/display ratio, of non-keyboard input devices **should**

- Be user adjustable, within appropriate limits and if applicable to the device
- Be compatible with users' expectations for direction, speed, and location of movement through appropriate user references and examples

Control/display ratio (C/D ratio) is the relationship between movements of an input device and the associated movements of a visual indicator on a display screen. A low C/D ratio indicates that small device movements move the visual indicator rapidly across screen distance, whereas a high C/D ratio indicates that large device movements result in slow or small visual indicator movements. A user-adjustable C/D ratio is advantageous for accommodating user proficiency and task demands that require varying degrees of rapid, gross-distance movements and accurate, fine positioning.

KEYBOARDS

Keyboard rows are described by the codes "A," "B," "C," "D," and "E" (see Figure 3-1).

Row A is closest to the user; Row C is the center or home row. Some keyboards do not have a Row E. Additional rows of keys follow this same naming convention, for example, an additional row would be labeled as Row F, and so forth.

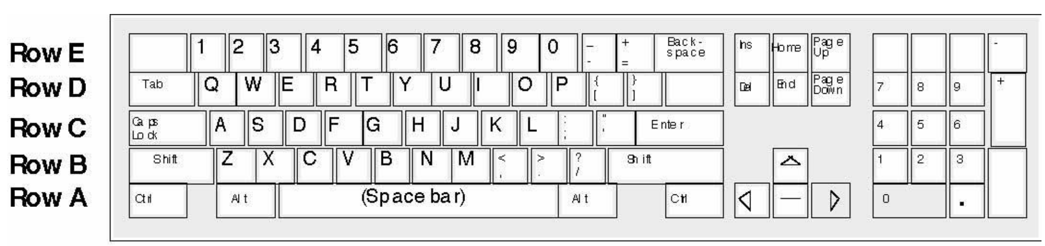

Figure 3-1. Row references for conventional keyboards.

Keyboard Layout

Alphabetic Keys

The alphabetic keys **should**

- Be grouped in the primary keying area

and function keys (the first row of keys beyond the alphanumeric portion of the keyboards) **should**

- Be located next to the primary keying area

Key grouping as shown in Figure 3-1 aids the logical organization of keyboards and facilitates the standardization of key layouts (Sanders & McCormick, 1993, p. 457). Standardization of key layouts is important and beneficial for users who need to transfer among computer workstations. Widely different layouts often involve a negative transfer of learning that can affect performance. In this regard, the QWERTY keyboard layout has been accepted as the de facto industry layout. QWERTY is the sequence of the letters on the left-hand side of the top row of alphabetic keys. However, research exists that supports the acceptability of other keyboard layouts (e.g., the Dvorak keyboard) for general text-entry tasks (Alden, Daniels, & Kanarick, 1972).

Numeric Keypads

In the design and manufacture of keyboards, numeric keypads **shall**

- Be provided when users' primary task involves numeric data entry

These keys **shall**

- Be grouped together

and, if integrated with the keyboard, **should**

- Be located to the side of the primary keying area

Either of the two numeric keypad layouts in Figure 3-2 is recommended. Keys with similar functions **should**

- Be grouped together

Usability studies on the layout of numeric keypads have supported both the telephone and calculator layouts (Conrad & Hull, 1968; Deininger, 1960; Lutz & Chapanis, 1955; Seibel, 1972).

The location of the keypad on the right-hand side of the primary keying area is conventional industry practice, although this location does not best accommodate left-handed users. Because key positions for the zero, double zero, triple zero, comma, decimal, and other such keys may be application dependent, alternative locations for such keys may influence performance.

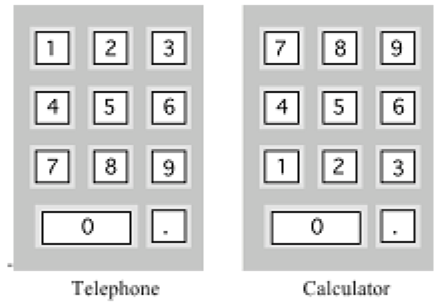

Figure 3-2. Numeric Keypad layouts.

Cursor Control

A two-dimensional cursor control (e.g., cursor keys, mouse, trackball) **shall**

- Be provided for text- and graphics-processing tasks

If cursor keys are provided, they **shall**

- Be arranged in a two-dimensional layout (four examples of possible layouts are illustrated in Figure 3-3) and

they should

- Be dedicated to cursor movement

If the cursor keys have collateral functions, their operational mode status **shall**

- Be clearly indicated

Additional keys placed near the cursor controls are acceptable provided that the overall layout of the cursor control keys is unchanged. There are two main patterns, the “Cross” and the ‘Inverted T.” Each has two variants that differ only by their location in the keyboard rows, as shown in Figure 3.3.

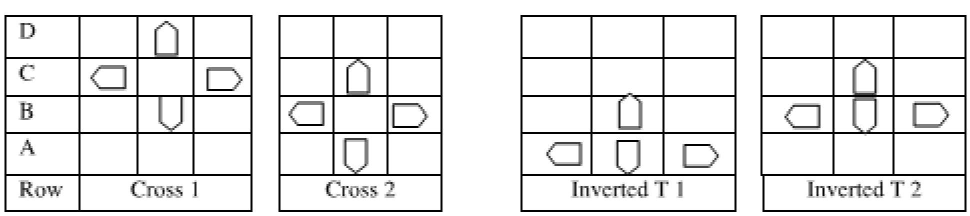

Figure 3-3. Cursor key layouts.

The usability of cursor keys is influenced by users’ expectations for spatial and/or positional compatibility with the direction of cursor movements. Emmons (1984) showed that the performance of inexperienced (novice) users was greater with a cross arrangement than with a box format. Reger, Snyder, and Epps (1987) showed that the inverted T was the most preferred of six common arrangements and that no significant performance or preference differences existed between the inverted-T and cross cursor control arrangements.

Editing keys (Insert, Delete, Home, End, PageUP, PageDown) **should**

- Be provided for keyboard navigation, control and editing purposes

These keys **should**

- Be arranged in a functional group

Keyboard Height, Slope, and Wrist/Palm Support

Keyboards, in combination with their supporting surface, chair, and other furniture, **shall**

- Permit users to attain the postural design criteria in the selected reference posture stated in Chapter 5, User Postures

The goal with keyboard height and slope designs/adjustments is to promote neutral postures in the wrist and forearm when using the device. Figures 3-4 and 3-5 illustrate keyboard tilt and keyboard height, respectively.

Consistent with these postural design criteria, the slope of conventional keyboards (rectangular keyboards with an alphanumeric and numeric keypad area and on which the home row of keys forms a straight line) **shall**

- Be between 0 and 15 degrees in its unadjusted position; and
- Should provide at least one positive slope setting between 0 and 15 degrees

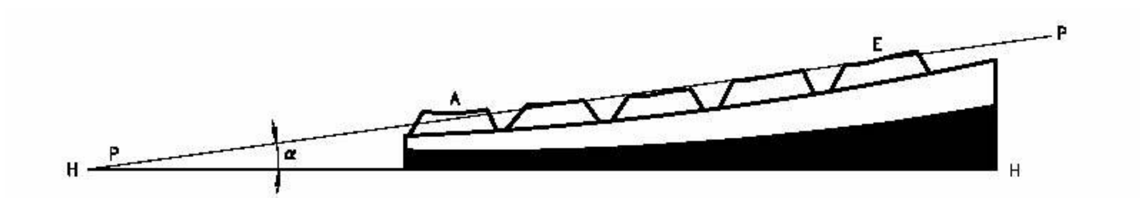

Figure 3-4. Illustration of keyboard slope. The slope is positive when the A row is lower than the D or E row, and negative when the A row is higher than D or E row. After ISO 9241, part 4 (ISO, 1998).

For contemporary or alternative keyboard designs that attempt to minimize the deviation of the hand and/or wrist from a neutral posture, the keyboard slope may extend beyond the stated positive slope range as well as include negative slopes in order to promote neutral wrist postures. The goal is to promote a neutral posture in both the flexion/extension and radial /ulnar planes and with regard to rotation of the forearm (pronation /supination). The American

Academy of Orthopedic surgeons defines neutral flexion/extension as the position where the horizontal plane created by the back of the hand is even and parallel with the horizontal plane created by the back of the forearm.

Keyboard height and slope are interrelated (see Chapter 5). Whereas slope adjustments up to 15 degrees have been incorporated into conventional keyboard designs, research has shown user preferences for even greater slopes (Burke, Muto, & Gutmann, 1984; Emmons & Hirsch, 1982; Miller & Suther, 1981).

Some keyboard designs, as illustrated in Figure 3-6, may use height, articulation, and tilt advantageously to aid in promoting neutral wrist posture (Hedge and Powers, 1995; Simoneau and Marklin, 2001)

If a height and/or slope adjustment mechanism is provided, there **shall**

- Be at least one adjustment that allows the keyboard to conform to the height specification

The preferred keyboard height is 30 mm or less and **should**

- Not exceed 35 mm (1.37 in.)

Keyboard height is the height measured from the table surface to the middle of the home row of the keyboard.

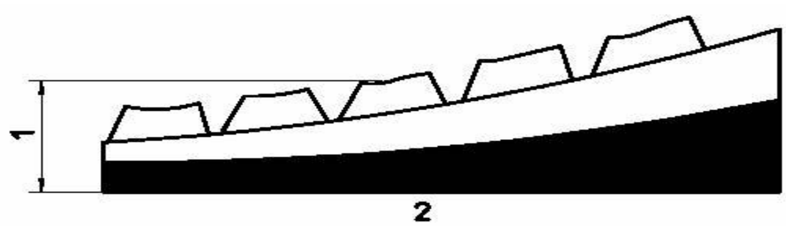

Figure 3-5. Keyboard height measured from the table surface to middle of home row of keyboard. From ISO 9241, part 4 (ISO, 1998).

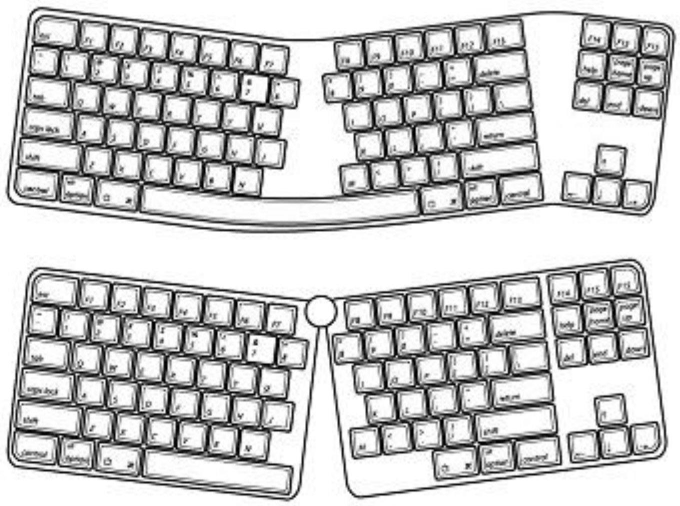

Figure 3-6. Keyboard slant (split) and tilt (gable). From Marklin, Simoneau, and Monroe (1999).

Profile

The keyboard rows **should**

- Be arranged in a dished (concave), stepped, sloped, or flat profile

Various keyboard profiles are considered acceptable (Cakir, Hart, & Stewart, 1980, pp. 125–126). Research examining stepped and sloped keyboard profiles found no notable differences in user performance (Kinkead & Gonzales, 1969). Other keyboard profiles may be possible, however they have not been studied with regard to acceptability.

Dual-State Keys

Dual-state (toggle) keys **should**

- Indicate their operational (functional) status

Dual-state keys include keys such as Caps Lock, Num Lock, Scroll Lock, and Function Lock. A common problem with dual-state keys or push buttons is visual identification of the position or state of the key. An effective solution is to provide a separate indicator light (see Cushman & Rosenberg, 1991, Chapter 8). Therefore, the preferred method for the status of dual-state keys is an indicator light.

When indicator lights are employed, they **should**

- Be imbedded in the key, located close to the associated keys or
- Be clearly labeled if not located close to the keys (e.g., Caps Lock icon)

An indicator panel for one or more dual-state keys is acceptable. Other means for indicating the status of dual-state keys may be effectively used such as showing the functional status on the receiver of a wireless keyboard or on the primary/main display.

Key Nomenclature

Nomenclature for the primary symbols on the alphabetic (i.e., A through Z) keys of the keyboard **shall**

- Be a minimum of 2.6 mm (0.10 inch) in height

and **should**

- Have a minimum contrast ratio between legend and key background of 3:1

Key nomenclature may be **darker or lighter** than the background.

The key nomenclature height recommendation is based on text- and display-related legibility research. Legibility is the rapid identification of single characters that may be presented in a non-contextual format. The threshold height for comfortable reading during a legibility task is in the range of 16 to 18 minutes of visual arc (0.267 deg. to 0.3 deg). A character height of 2.6 mm viewed from a distance of 560 mm would yield a symbol size of 16 minutes of visual arc.

Key Spacing

The centerline-to-centerline horizontal and vertical spacing between adjacent keys within the alphanumeric and numeric zones **shall**

- Be 19 mm +/– 1 mm (0.74 in. +/– 0.039 in.)

Function keys and infrequently used keys may be smaller. The specification for horizontal and vertical key spacing is supported by conventional practice. The key-spacing specifications apply to keys within a functional group but not to the separation between functional groups of keys, such as noncontiguous keys in a conventional or alternative keyboard design.

As shown in Figure 3-7, key spacing is the distance between corresponding points on two adjacent keys, measured horizontally (Sh) and vertically (Sv).

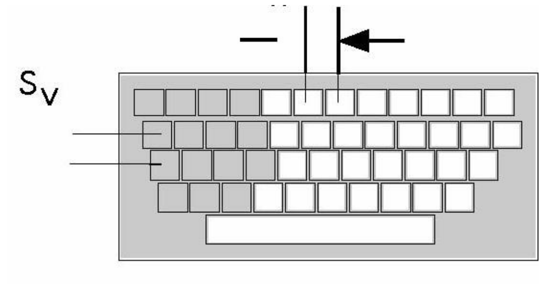

Figure 3-7. Illustration of key spacing.

Key Size and Shape
For alphabetic keys in the alphabetic key area, the horizontal strike surface **should**

- Be at least 12 mm (0.47 in.) wide

and the contact surface **should**

- Be concave to match the geometry of the tip of the finger and enhance coupling during the strike

Rectangular (square) strike surfaces on keys provide larger target areas than do circular strike surfaces for a given key spacing. Also, concave keys provide a good fit to fingertips (Cakir et al., 1980; Clare, 1976).

Key Rollover/Simultaneous Key Depression
Key rollover refers to the number of characters produced by simultaneous activation of keys. Keyboards **should**

- Have at least three-key rollover. An n-key rollover is recommended

Two-key rollover permits a second key to be depressed while one key is already down but will not produce a character until the first key is released. If the second key is released before the first key, the second key will be missed. If two keys are pressed simultaneously, all output is blocked. Three-key rollover will produce two characters accurately for two simultaneously depressed keys. Depression of a third key does not produce a character until one of the first two keys is released. In contrast, n-key rollover will produce any number of characters accurately no matter how many keystrokes overlap (Greenstein & Muto, 1988). N-key rollover is preferred to two-key and three-key rollover schemes (Davis, 1973; Gladman, 1976; Kallage, 1972).

Keying Feedback
Actuation of any key **shall**

- Be accompanied by tactile or auditory feedback, or both

If auditory feedback is provided, the sound **should**

- Occur at the same point in the displacement for all keys

If the auditory feedback is provided through software, the user **should**

- Be able to adjust the volume and turn it off

If tactile feedback is provided, the point of key activation (switch closure or make point) **should**

- Be marked by a distinguishable breakaway force

Tactile feedback for the key activation (snap point) can be implemented by increasing key force throughout the initial 40% of key displacement, then reducing key force over the next 20% of total displacement where the switch closure occurs, and again increasing key force over the remaining key displacement range.

Feedback is essential during the acquisition of keying skills; however, detailed specifications are difficult to establish because feedback effectiveness depends on feedback mode, user keying skill, task demands, and keyboard layout. Elimination of the breakaway force or the subsequent cushioning force can result in slower keying activity, higher error rates, and increased operator fatigue (see Cushman & Rosenberg, 1991, Chapter 8; Kinkead & Gonzales, 1969; Klemmer, 1971).

Key Repeat Rate

The default character repeat rate **should**

- Be approximately 10 characters per second after an initial delay of 500 ms following key activation

The character repeat rate **should**

- Be user adjustable

Key repeat allows the user to enter a character or command multiple times without needing to repeat keystrokes. Most conventional keyboards implement the key repeat function on all keys. The keyboard repeat rate may either be implemented in the hardware or software.

Home Row Locator

The home row keys (Row “C” as in Figure 3-1) **should**

- Contain at least one tactile feature to assist users in positioning their fingers on the keyboard

Current industry practice is to use a small raised bar, a dimple, or some other shape on the key cap. A tactile indicator on the home row keys, typically the F and J keys in the alphanumeric area and 5 on the numeric keypad, provides a reference landmark for users to orient their hands and fingers over the home row and the keyboard (Gladman, 1976, p. 149). A tactile indicator on the "5" key in the numeric keypad can also be used as a reference landmark for users to orient their hands and fingers over the numeric keypad.

Keyboard Wrist/Palm Rest

The intent of wrist rest is to promote more neutral postures in the wrist. For keyboards with integrated or attachable wrist rests/palm supports for the proximal portion of the palm, the rest or supports **should**

- Be matched to the width, height, and shape of the front edge and slope of the keyboard

Matching the width, height, and shape of the rest or supports to the front edge of the keyboard provides a smooth transition from the surface of the rest or support surface to that of the keyboard. Sharp corners and/or small radius edges that create pressure points should be avoided. Differences in width, height, and shape between the rest or support and the keyboard may be cumbersome, constrain the user, or limit access to the keyboard. Some users prefer to use wrist rests with keyboards. However, some rests may inhibit motion of the wrist during typing. Thus, a wrist rest is considered an optional feature.

Mice

A mouse (Figure 3-9) is a hand-operated input device typically used for two-dimensional cursor-positioning and object-selecting tasks. The mouse often resembles a palm-sized, contoured block with one or more thumb- and/or finger-operated buttons. The mouse is moved over a surface in order to move a cursor on the screen. Refer to sections 3.2.1.4–3.2.1.8 for general design considerations.

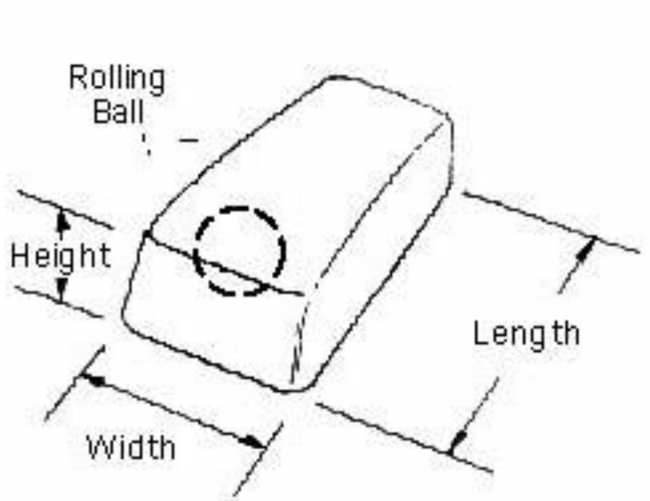

Figure 3-8. Illustration of a mouse. Note, many mice use an optical motion sensor rather than a ball.

Shape and Size

The shape and size of a mouse **shall**

- Allow single-handed operation

Users can comfortably grip rectangular-shaped mice that are between 40 and 70 mm wide, between 70 and 120 mm long, and between 25 and 40 mm high (Goy, 1988; U.S. Department of Defense, 1989). Overly form-fitting mouse designs should be avoided because they can result in continual and prolonged contact between the device and the skin's surface, reducing the ability of the skin to breathe and resulting in hand perspiration. Overly form-fitting mouse designs offered in just one size rarely work well for a wide variety of hand sizes.

Motion Sensor

The motion sensor **should**

- Be located toward the front of the input device, under the fingertips, not the palm

This specification is intended to facilitate fine-positioning accuracy with the device through greater sensitivity in fingertip-driven and/or wrist-based movements. Locating the rolling ball or motion sensor underneath the fingertips increases the apparent moment of inertia as the device is pivoted from the elbow or the heel of the hand (Verplank & Oliver, 1989). This assists hand movements involved in fine positioning because the forward location conveys the motion of the hand more accurately. The design of mice that use a mechanical ball and encoder system to sense movement should facilitate easy removal and cleaning of the ball and encoder. The ball and encoder should be made of materials that do not easily attract and accumulate dust and/or dirt.

TRACKBALLS

A trackball (Figure 3-11) is a hand-operated or finger-operated input device that is used typically for cursor movement and object selection tasks. Trackballs generally are mounted into a horizontal surface (desk or keyboard) or are built into their own module. These devices can include finger-operated and thumb-operated buttons located near the ball. Users' rotations of the trackball cause movements of the cursor on the screen. Trackballs can be rotated in any direction to generate any combination of x and y control.

Figure 3-9. Illustration of a trackball.

Diameter

As shown in Figure 3-12, the diameter of a desktop-mounted trackball **should**

- Be between 50 and 150 mm (1.97 in. and 5.9 in.)

The exposed surface of the trackball **should**

- Be between 100 and 140 degrees

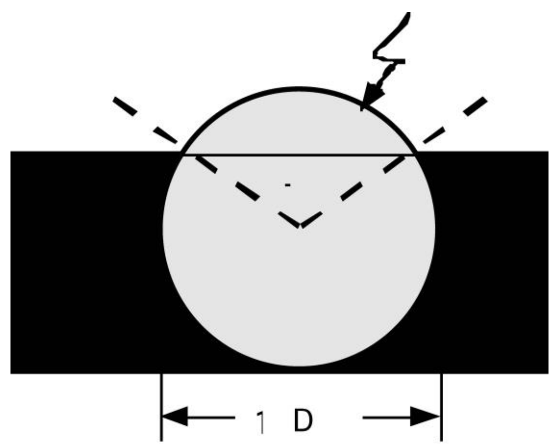

Figure 3-10. Exposed surface and diameter of trackball.

This specification is based on conventional practice (U.S. Department of Defense, 1989). Task-related factors to consider when selecting an appropriate trackball include types of motions and cursor movements, level of precision required, and space constraints.

Resistance
Resistance **should**

- Be less than 1.0 N (0.22 pounds force) and preferably less than 0.3 N (0.66 pounds force)

This specification is based on conventional practice (U.S. Department of Defense, 1989). It is intended to enable users to apply a minimum amount of force to move the trackball accurately. Some amount of resistance is necessary to dampen the ball.

Joysticks
A joystick (Figure 3-13) is a finger-or hand-operated device used for two-dimensional tracking tasks and complex perceptual/motor tasks. It also may be used for pointing and selection tasks, if precision is not critical. Joysticks consist of a handle for the main control interface, and these devices may contain one or more buttons on the handle top or device housing (Arnaut & Greenstein, 1988, p. 101; Cushman & Rosenburg, 1991, p. 196).

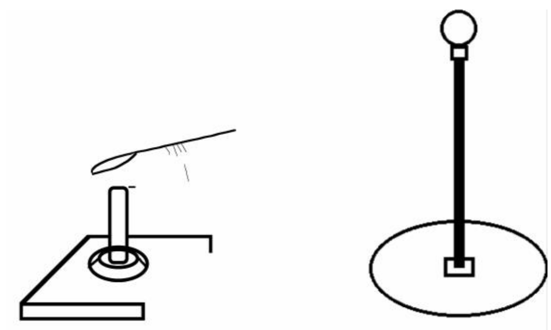

Figure 3-11. Finger-operated (left) and hand-operated (right) joysticks.

Handle Size
The handle of a finger-operated joystick **should**

- Be between 6.5 and 16.0 mm (0.26 and 0.63 in.) in diameter and
- Be between 25 and 150 mm (0.98 and 5.9 in.) long

The grip surface of a hand-operated joystick **should**

- Be less than 50 mm (1.97 in.) in diameter and
- Be 110 to 180 mm (4.3 to 7.1 in.) long

The handle size specifications are based on basic anthropometric considerations and conventional practice (Arnaut & Greenstein, 1988; U.S. Department of Defense, 1989).

Force
The force to displace the cursor with a hand- or finger-operated joystick **should**

- Be at least 4.5 N (1.01 pound force)

A force joystick (isometric) responds to pressure on the joystick to move the cursor or visual indicator. For joysticks with a handle diameter of between 9 and 10 mm, a full-scale force of approximately 9.0 to 15.0 N tends to work best for graphics tasks. A minimum force of 4.5 N is recommended (Doran, 1989).

Displacement

For displacement (isotonic) joysticks, the angular displacement from the rest position **should not**

- Exceed 45 degrees

The angular displacement specification is based on conventional practice (U.S. Department of Defense, 1989). Angular displacements beyond 45 degrees require a greater range of motion and involve more demanding hand and wrist postures.

Tablets

Tablets are flat, slate-like panels that can be used for cursor movement and object selection tasks. Typically, a tablet is configured with a puck or stylus to provide the user with an electronic digitizing surface. Many tablet systems consist of opaque overlays, which provide graphics used for the cursor movement and for button activation.

Surface

The active area of a tablet or touch-sensitive surface **should**

- Be flat, smooth, and free from warping or surface imperfections

Uneven surfaces and surface abnormalities can create an unstable work situation, interfering with a puck, a stylus, and the user's finger. Such conditions can lead to an increase in errors, effort, and fatigue.

Styli

Styli are handheld input devices used for object selection, cursor movement, and freehand drawing tasks. They have a pencil-like shape and may contain one or more finger-operated buttons. Typically, styli are used with a tablet-like device (e.g., tablet computer, visual display, or pressure-sensitive tables),

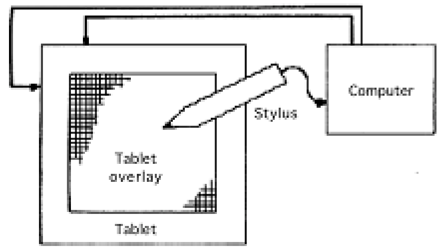

Figure 3-12. Illustrations of stylus.

Surface
The exterior surface of the stylus **should**

- be slip resistant

The exterior grip surface of a stylus or light pen is a key design component in the stability and effort involved during its use. A stylus that is comfortable to hold and easy to grip will aid in an operator's effectiveness.

Button Shape
Barrel-mounted buttons on a stylus **should**

- Be shaped for comfort and not cause excessive pressure points

Barrel-mounted buttons or switches on a stylus are typically used to make selections or provide additional functionality. Button or switch designs that have sharp edges or corners or create an excessive pressure point can rapidly lead to discomfort or distraction and can potentially degrade performance.

Diameter
The diameter of a stylus **should**

- Be between 7.0 and 20.0 mm (0.28 and 0.79 in.)

The barrel size of the stylus can affect the operator's comfort, grip, and overall effectiveness. This specification is based on conventional practice and is intended to enable the user to comfortably grip the barrel of the stylus (U.S. Department of Defense, 1989).

Length
The length of a stylus **should**

- Be between 120 and 180 mm (4.7 and 7.1 in.)

The length and balance of a stylus can affect the operator's effectiveness. This specification is based on basic anthropometric considerations and conventional practice. It is intended to provide users with an adequate stylus length to improve overall effectiveness (U.S. Department of Defense, 1989).

Pucks

A puck (Figure 3-15) is similar in shape to a mouse but typically is used in conjunction with a digitizing surface (e.g., tablet) for encoding graphics in drawing tasks and for selecting objects. A puck typically consists of a reticule window that allows users to align the device accurately. Refer to sections 3.2.1.4–3.2.1.8 for general design considerations.

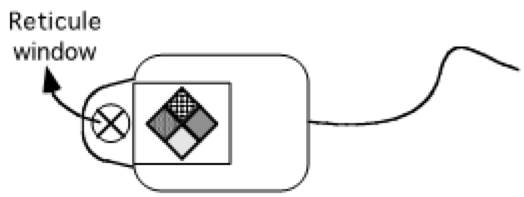

Figure 3-15. Illustration of a puck.

Shape and Size

The shape and size of a puck **shall**

- Allow single-handed operation

Users can comfortably grip rectangular-shaped puck devices that are between 40 and 70 mm wide, between 70 and 120 mm long, and between 5 and 40 mm high (Goy, 1988; U.S. Department of Defense, 1989).

Touchpads

Touchpads are small, touch sensitive tablets typically found in notebook computers. They use relative mode for cursor control. Most of the touchpads can operate in absolute mode (for handwriting input or drawing). Scrolling can be initiated using special gesture or special section of the touchpad. Touchpads are typically equipped with separate buttons (similarly to left and right mouse buttons). Alternatively tap gesture on the surface of the touchpad can be used for selection task. In latest generation of touchpads buttons are integrated into clickable touch-sensitive surface.

Touch sensitive panels

Touch-sensitive panels are finger-operated devices used primarily for object-and button-selection tasks; however, they can also be used for cursor movement and drawing tasks. A touch-sensitive panel consists of an overlay or empty frame mounted over the visual display screen. In typical applications, users press a finger or pointing device on the screen to signal a location to the computer. Users also may drag their finger or pointing device on the screen for object movement and drawing tasks.

Minimum Touch Area
Touch areas (soft keys) **should**

- Be at least 9.5 mm (0.4 in.) wide and 9.5 mm (0.4 in.) high

If the touch screen and the image plane of the screen are separated, the dimensions of the touch areas **should**

- Be increased to avoid user performance degradation attributable to parallax problems

The optimum touch-sensitive area depends on the application and required accuracy. Touch areas greater than 22 mm square do not improve performance (Beaton & Weiman, 1984; Beringer & Peterson, 1985; Weisner, 1988).

Dead Space
The dead space surrounding each touch area **should**

- Be at least 3.2 mm (0.13 in.)

Dead spaces (Figure 3-16) minimize accidental activation of keys, especially when parallax is present or when touch areas are small (Beringer & Peterson, 1985; Martin, 1988; Usher & Ilett, 1986). Smaller dimensions for the dead space can be used when error-preventing algorithms are used to encode the touch-area activations.

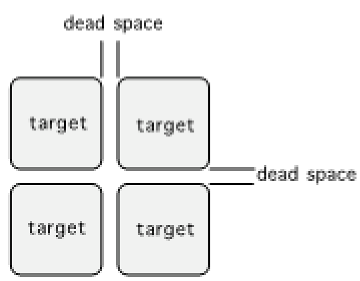

Figure 3-13. Touch panel dead space.

Target Tracking
During a select-and-drag operation, the object or cursor being moved **should**

- Track the finger, both temporally and spatially

Real-time tracking provides the user with direct feedback on target status and position.

Metrics

DEVICE STABILITY

Observe the input device during normal, expected use. Determine whether or not it slips or rocks during use. The input device should be installed as per design instructions.

To assess the stability of input device keys, observe the input device in normal, expected use. Determine whether or not the keys wobble or stick.

NUMERIC KEYPAD LAYOUT

Determine if a numeric keypad is provided as appropriate for users. Verify that the keys on the numeric keypad are arranged in one of the patterns shown in Figure 3-2.

CURSOR CONTROL

Determine whether a two-dimensional cursor control is provided for users, as is appropriate. If cursor control keys are provided, verify that the keys are arranged in one of the two patterns shown in Figure 3-3.

KEYBOARD HEIGHT AND SLOPE

Verify that the keyboard, when installed as directed, does not cause the user to violate the postural guidelines described in chapter 8. Verify that the slope of the keyboard is between 0 and 15 degrees. The slope of the keyboard is determined by the angle between the plane of the support surface and the plane passing through the centers of the keys, or other equivalent and corresponding points of keys, in the rows containing Q and Z in the QWERTY layout.

KEY SPACING

Vertical and horizontal key spacing is measured from key centers as shown in Figure 3.7.

KEY FORCE

Key force is the maximum force necessary to the “snap” point measured in the geometric center of the key top strike area along the same axis as the key travel.

KEY DISPLACEMENT

Key displacement is measured in the axis of the key travel.

KEYING FEEDBACK

Verify by observation that key actuation is accompanied by either tactile or auditory feedback.

SHAPE AND SIZE

Verify by observation that the mouse or puck can be operated with one hand.

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VIEWING CHARACTERISTICS

Display Viewing Distance

The minimum design viewing distance **should** be 40 cm.

The *display viewing distance* is the distance between the nasal bridge in any reference posture (see Figure 1) and the center of the screen image area. The display viewing distances discussed below can be applied to cases of single and multiple monitor configurations. They should not be confused with the *design viewing distance*. The *design viewing distance* is a viewing distance, specified by the manufacturer, at which all the requirements of this standard can be met.

Work with the displays available in 1988-1991 found that viewers considered a 50-cm distance too close for typical computer workstation tasks (Jaschinski-Kruza, 1988, 1990, 1991) and that greater visual fatigue was associated with a 50-cm viewing distance than with a 100-cm viewing distance (Jaschinski-Kruza, 1990). More recent work (Jaschinski, Heuer, & Kylian, 1998; Psihogios, Sommerich, Mirka, & Moon, 2001; Sommerich, Joines, & Psihogios, 2001) has shown that most users prefer viewing distances from 75 to 83 cm (when text size is large enough to meet the 16 arcmin requirement; discussed in 7.2.6.1 Character Height). Viewing distances closer than a typical viewer's resting focus, which is typically about 67 cm but varies from 29 to 192 cm in the reference population (Andre & Owens, 1999; Leibowitz & Owens, 1978), require greater effort for accommodation and convergence than do further distances (Collins, O'Meara, & Scott, 1975; Fisher 1977). Thus, the preferred viewing distance of a typical user is likely to exceed 40 cm. This assumes normal or corrected-to-normal vision and an age less than 40 years, because many viewers older than 40 are unable to accommodate to a display 40 cm away without spectacles or other optical assistance (Charness et al., 2008; Turner, 1958).

NOTE: This recommendation is for desktop displays. ISO 9241-303 suggests a 30 cm design viewing distance, which may be more common for hand held displays on mobile devices.

Multiple Displays

When viewing two or more displays the distance from the users' eyes to the center of each screen **should** be equal.

The primary display **should** be positioned directly in front (no head rotation) of the user with the other screen(s) set off to the left and/or right. The primary display is the display viewed most frequently when multiple displays are present.

As with single displays, multiple displays **should** be positioned between 50 and 100 cm from the eyes.

Research suggests that repeatedly rotating the head/neck left and right may lead to upper back muscle strain and discomfort (Camilleri et al., 2010). Perhaps due to the effects of head rotation, viewers of multiple displays tend to position the screens a little higher than a single screen.

Viewing Angle

Viewing angle is the angle in the vertical plane between the horizontal line of sight and a defined visual target, see example below. The entire visual area of a visual display terminal workstation **should** be located between 0° (eye level) and 50° below eye level when the user assumes the upright sitting, declined sitting, or standing reference posture. For users without presbyopia the center of the visual display screen(s) **should** be located 10° to 20° below eye level. For users who have presbyopia and vision correction with multifocal lenses the center of the display **should** be located 15° to 40° below eye level.

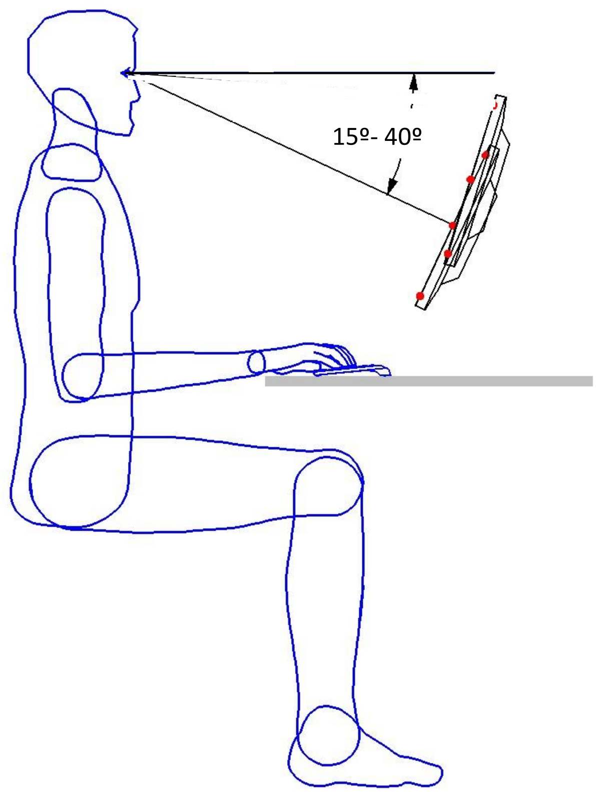

Figure 1 Viewing angles. In this diagram two display positions are represented. The viewing angle to the top of the higher screen is -15° and the viewing angle to the center of the lower screen is -40°

Several field studies have reported that computer users position the center of the display as low as 40° below the horizontal line of sight (Allie et al., 2009, 2010; Jaschinski et al., 1999).

For multiple display set-ups, the results of Camilleri's research suggest that rotating the neck to view two or more displays placed side-by-side, while looking downward, may tax the musculature more than when viewing a single display (Camilleri et al., 2010). Given these findings, when viewing two or more displays, the center of the screen should be positioned from 5 to 10° below the horizontal line of sight.

Display Tilt Angle

Tilt angle is the angle of the display at its center relative to vertical. Differences between the users' viewing angle and the display tilt angle may cause blurring of images presented on some screens (Burgess-Limerick et al., 1998). To minimize any such blurring the angle of the surface of the display should be perpendicular to a line from the eye to the center of the display. In order to accommodate computer users, including those who wear multifocal lenses, the display **shall** have the capability to tilt from +10° to -35° (positive tilt is defined as the top of the display closer to the user than the bottom, and negative tilt as the bottom of the display closer than the top.

Note 1: this recommendation does not apply to displays designed for touch interaction with the user. Research results indicate that more than 40° of rearward tilt will be necessary to accommodate users with touch interactive displays (Shin and Zhu, 2012).

Note 2: ISO 9241-303 specifies that the display should permit the user to view the screen with a gaze angle from 0 to 40º and a head-tilt angle from 0 to 25º

SPATIAL CHARACTERISTICS

As contemporary displays most often consist of discrete picture elements (pixels), the properties of these elements, such as their size, density, and number, determine the spatial characteristics of the display.

Pixel Grid Modulation, Fill Factor, and Pixel Pitch

Pixel grid modulation is the difference between the maximum and minimum luminance along a white display row, divided by the sum of maximum and minimum luminance (i.e., the contrast across display rows). For displays having a pixel density of fewer than 30 pixels per degree of visual angle at the design viewing distance, the pixel grid modulation **shall** not exceed 0.4 for monochrome and 0.7 for multicolor displays when all pixels are at maximum luminance. Compliance is established by the procedures specified in section 7.1 of the SID IDMS standard (2012).

The *fill factor* is the surface available to present information (the pixel area) divided by the total display area. For flat-panel displays having a pixel density of fewer than 30 pixels per degree of visual angle at the design viewing distance, the fill factor **shall** be at least 0.3 and **should** be at least 0.5. Compliance is established by the procedures specified in section 7.4 of the SID IDMS standard (2012).

Pixel pitch, the distance between adjacent pixels from center to center, is determined by the design viewing distance (Section 7.2.2.1), the height of characters in number of pixels (Section 7.2.6.5), and the height of characters in visual angle (Section 7.2.6.1). For example, if the design viewing distance is 50 cm, the pixel pitch must be 0.25 mm for characters 16 arc minutes high and 0.35 mm for characters 22 arc minutes high. Pixel pitch and the pixel grid modulation jointly determine the minimum pixel size for displays. Pixel pitch **shall** be specified by the manufacturer.

Pixel and Subpixel Faults

The supplier shall specify $Class_{pixel}$ of the display. The electronic display **should** be free of pixel and subpixel faults, as defined in ISO 9241-307 (ISO, 2008), for example section 5.2.

Compliance is established by the procedures specified in section 7.6 of the SID IDMS standard (2012).

TEMPORAL QUALITY

Response Time

Response time is the time required for luminance changes to go from 10% to 90% of the luminance change.

The response time **shall** be 20 ms or less to allow the transition between black and white and **should** be less than the duration of a single frame.

Longer response times can reduce the contrast of rapidly changing images, especially those that move, and leave afterimages and visible trails behind moving objects (Holcombe, 2009).

Compliance is established by the procedures specified in section 10.2 of the SID IDMS standard (2012).

Flicker

The frames of displays with short response times **should** be
refreshed at a rate that exceeds the value defined by the following equations:

$$CFF = m + n\{\ln[T(f)]\}; \text{ where} \qquad (7\text{-}1)$$

$$m = 14.62 - 7.89/\{1 + \exp[-(D - 42.3)/5.55]\}; \text{ and} \quad (7\text{-}2)$$

$$n = 11.33\{1 - \exp[-(0.735 + D/46.3)]\}. \quad (7\text{-}3)$$

T(f) is the amplitude of the fundamental temporal frequency, f, of the display, measured in Trolands; and D is display size in degrees of visual angle.

The Troland value, T, is obtained by multiplying luminance by the area of the pupil of the eye:

$$T = \pi(d/2)^2 L_\Omega, \quad (7\text{-}4)$$

where d is the diameter of the pupil of the eye in mm, and L_Ω is the mean luminance of the display in cd/m^2, without reflected light or with the reflected light subtracted from the measured value (see SID IDMS standard [2012], section 11.2). Measurement of L_Ω is described in the SID IDMS standard (2012), section 5.3.

The diameter of the pupil of the eye, d, of a typical observer can be estimated from the empirical equation (Moon & Spencer, 1944):

$$d = 5 - 3\tanh[0.4\log(L_T + 1)], \quad (7\text{-}5)$$

where L_T is the mean luminance of the display in cd m^{-2}, including any reflected light. Note, however, that under any given set of conditions there are large individual differences in pupil size among different individuals and even in a given individual at different times, and that pupil size tends to diminish with increasing age (Wyszecki & Stiles, 1982).

NOTE 1: It is important to note that the flicker tolerances reported here are based on the 1994 Moon and Spencer formula for estimating pupil diameter. More recent studies (Watson and Yellott, 2012) have suggested different results; as this information is developed, flicker specifications may need to change.

The fundamental temporal frequency of a display, f, is normally equal to the rate at which it is refreshed, but it can be measured according to the procedure described in the SID IDMS standard (2012), section 10.5. Alternatively, if the temporal response of display luminance follows an exponential curve with known time constant, α (in sec), then the amplitude of the fundamental temporal frequency is given (Farrell, Benson, & Haynie, 1987) by the equation:

$$T(f) = 2T/[1 + (\alpha 2\pi f)^2]^{0.5} \quad (7\text{-}6)$$

The response time, α, can be measured according to the procedure described in the SID IDMS standard (2012), section 10.2.

Equation 7-1 estimates the minimum refresh rate at which no more than 10% of users report seeing flicker (Farrell et al., 1987). Equations 7-2 and 7-3 are empirical descriptions of the results of varying display size (Eriksson & Backstrom, 1987). Although the data cover only the range from 10 to 70 degrees, both functions appear to approach an asymptote at the largest display sizes.

Flicker causes modest yet reliable increases in subjective reports of visual fatigue, increased task difficulty (Harwood & Foley, 1987), and reduced visual acuity (Murch, 1983).

Compliance is established by the measurements described above and by application of equation 7-1 to the results.

It is important to note that this information is largely based on Cathode Ray Tube (CRT) displays. More recent research on flicker and Solid State Lighting (SSL) systems at the Lighting Research Center at Rensselaer Polytechnic Institute has suggested that there are two types of flicker, direct and indirect, that are of concern with regard to solid state lighting and potentially of concern with regard to displays. Direct and indirect flicker may have effects on individuals' comfort and performance.

Direct and indirect flicker

Direct flicker is defined as the ability to directly perceive the frequency of modulation when it is relatively low (<80 Hz). The indirect perception of flicker is a stroboscopic effect created by the interaction of the light source with moving objects.

A metric of direct flicker detectability has been suggested by a group of researchers at Rennselaer (Alliance for Solid State Illumination Technologies, 2015). Similarly, a metric of the perceptibility and acceptability of indirect flicker has also been proposed (Alliance for Solid State Illumination Technologies, 2012). These expanded definitions of flicker should be carefully considered in future revisions of this standard.

COLOR AND LUMINANCE

Luminance Range

The display **shall** be capable of producing a luminance of at least 35 cdm^{-2}, and it **should** be capable of producing least 100 cd/m^2.

Users often prefer high display luminance (e.g., 100 cd/m^2 or greater), particularly under high ambient illumination. Moreover, reading speed and accuracy increase with increasing luminance, and legibility decreases below 35 cd/m^2 (Blackwell, 1946; Chung, Mansfield, & Legge, 1998; Giddings, 1972; Legge, Parish, Luebker, & Wurm, 1990; Legge, Pelli, Rubin, & Schleske, 1985; Legge, Rubin, & Luebker, 1987; Strasburger, Harvey, & Rentschler, 1991), as does color discrimination (Legge et al., 1990; Pokorny & Smith, 1986).

Compliance is established by the procedures specified in section 6.1 of IEC 62341-6-1 (2017) with medium APL image loading.

Luminance Nonuniformity

Luminance nonuniformity is the ratio of the maximum display luminance to the minimum when each is averaged over a 1º area at the design viewing distance.

The ratio of maximum luminance to minimum luminance of a display intended to be uniform shall be 1.7 to 1 or less.

Compliance is established by the procedures specified in section 8.1 of the SID IDMS standard (2012).

Luminance Contrast and Reflections

Luminance contrast ratio is defined here as the maximum luminance divided by the minimum luminance.

The display **shall** exhibit a contrast ratio of at least 3 under all office illumination conditions.

If the 3 to 1 ratio cannot be met, change the location or orientation of the display so that it does not face windows or other sources of bright light.

Visibility improves with increasing up to a contrast ratio of 3, above which it rapidly levels off (Legge et al., 1987; Legge et al., 1990; Strasburger et al., 1991). Luminance contrast is required because purely chromatic contrasts have poor visibility (Anderson, Mullen, & Hess, 1991; Chen & Yu, 1996; Legge et al., 1987; Legge et al., 1990; Mullen, 1985; Sekiguchi, Williams, & Brainard, 1993). Aside from this low sensitivity of the visual system to isoluminant stimuli, the failure of isoluminant contrast to drive accommodation (Switkes, Bradley, & Schor, 1990; Wolfe & Owens, 1981) can further reduce retinal contrast, depending on the distance of the display relative to the distance of the observer’s resting accommodation (Andre & Owens, 1999;

Leibowitz & Owens, 1978). Note also that 8%–10% of males of European ancestry have difficulty discriminating reds from greens (Pokorny & Smith, 1986). Note also that as workers age, they require more contrast, approaching a factor of 3 at age 65, to produce a given visibility (Blackwell & Blackwell, 1971).

Excessive reflections from the display reduce display contrast and therefore legibility, and users object to them (Kubota, 1994; Kubota & Takahashi, 1989; Pawlak & Roll, 1990). Note that reflection of light from any source by an ordinary polished glass surface creates a virtual image with a luminance anywhere from 4% to 100% of that of the source itself, depending on the angle of incidence. Possible sources of reflected light include the sun, at $10^{9.5}$ cd/m^2; filaments of tungsten sources, at $10^{6.3}$ cd/m^2; fluorescent tubes, at $10^{4.2}$ cd/m^2; blue sky, at $10^{3.4}$ cd/m^2, and white office walls or desktops, at $10^{2.1}$ cd/m^2 (Makous, 1998). Hence, even reflections from the walls can be excessive, and direct reflections from almost any source are likely to be excessive. The best solution is often careful planning of the environment, including use of task lighting.

Compliance is established for a minimum contrast ratio of 3 by the procedures specified in section 11.9 of the SID IDMS standard (2012). In the absence of glare, the contrast ratio is completely determined by the illumination levels on the display for the workplace where the display is being used. When glare can be observed in the visual field, the procedure specified in section 11.9 of the SID IDMS standard (2012) is modified by using the procedure in section 11.7.3 to include a glare directional source, like of one of the sources mentioned in the above paragraph.

Color Uniformity

The chromaticity differences of a color, Δ(u'v'), at different locations on the display that is intended to be uniform **should** be no greater than 0.03 and no greater than 0.02 within any area subtending less than 40° of visual angle

The ability of the eye to detect chromaticity differences decreases with increasing separation of targets (Sharpe & Wyszecki, 1976).

Compliance is established by the procedures specified in section 8.1 of the SID IDMS standard (2012).

INFORMATION FORMAT

Character Height

The height of a character is typically specified by the height of the lower-case *x* character. The minimal *x* height in body text should be 16 arcmin. Comfortable, efficient reading requires minimally 22’ of arc (Chung et al., 1998; Giddings, 1972; Legge et al., 1985; Legge et al., 1987; Legge et al., 1990; Strasburger et al., 1991). However, character size should be below 30’ of arc to avoid slowing down reading by reducing the number of characters that can be viewed foveally during a fixation (Arditi, Knoblauch, & Grunwald, 1990; Legge et al., 1987).

Character height should be greater on a computer screen with poorer screen resolution. Users with presbyopia (i. e., those older than 40) and those with poor visual acuity (20/70 or poorer) require larger character height. Young children just beginning to learn reading should use larger character height.

The height of characters with less than ideal contrast relative to the background should be larger. With the minimal contrast ratio of 3, character height should be 30’ of arc or larger (Chen & Yu, 1996; Legge et al., 1990; Sekiguchi et al., 1993).

Where speed of recognition is unimportant, such as footnotes and subscripts and superscripts, character height can be as low as 12’ of arc; warnings and other essential information require larger characters to ensure accurate and speedy recognition.

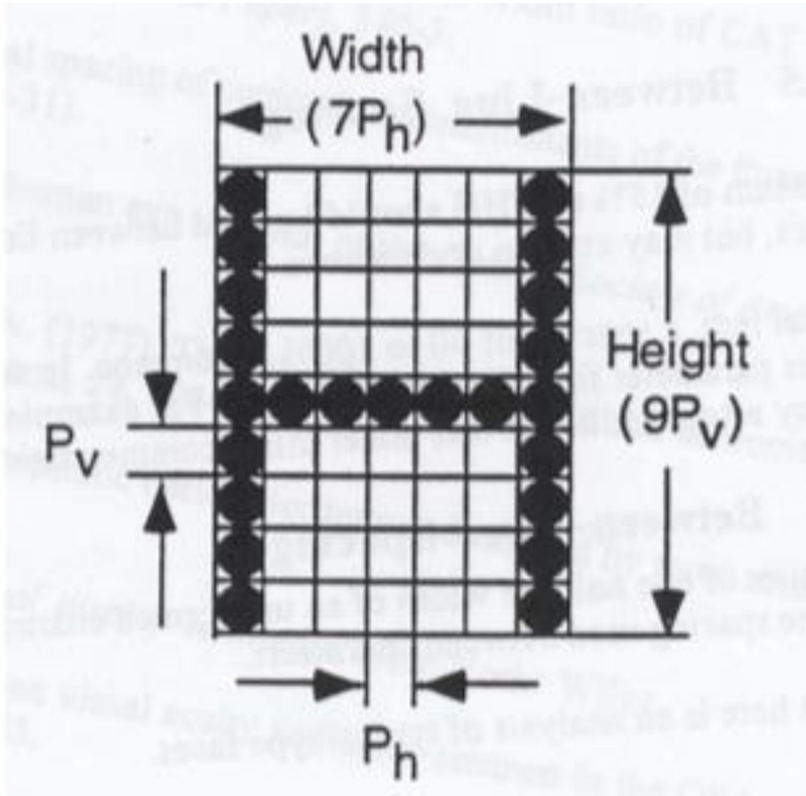

Figure 2. Dimensions of characters. The height and width of characters are defined by this figure. Squares represent pixels. P_v and P_h represent the vertical and horizontal dimensions of a pixel respectively.

Character Width-to-Height Ratio

Character width-to-height ratio is based on the lower-case letter x and upper-case letter *H* without serifs. The range of width-to-height ratio ("Width"/"Height" in Figure 7-4) shall be from 0.5:1 to 1:1 and, for optimal legibility and readability, should be from 0.6:1 to 0.9:1. These ratios are based on a character width of at least 4 pixels for lower-case letters and 5 pixels for upper-case letters.

The width-to-height ratio shall be adapted to different character formats and viewing conditions and should be optimal: .78:1 for continuous reading of lower-case Latin alphanumeric characters and .71:1 for uppercase letters and numerals. Subscripts, superscripts and the numerals in fractions should have an .82:1 ratio.

The width-to-height ratio should increase for viewing from a horizontal angle. The increase should be proportional, with a 0.7:1 to 1.3:1 ratio when viewing from a 40-degree angle. In the unusual condition of increased vertical viewing angle, similar consideration in increasing height-to-width ratio should be given.

Legibility is sometimes sacrificed to some extent for esthetics, conservation of space, or other practical considerations (Benson & Farrell, 1988; Soar, 1955). This can be remedied by using larger inter-letter spacing or character size.

For the purpose of identifying individual characters, the same ratios shall be maintained but a smaller character size can be used. Anti-aliasing fonts require a larger character size to permit a similar rate of letter and word recognition.

Stroke Width

The stroke width of characters (a multiple of "P_h" and "P_v" in Figure 2) shall be from 10% to 16% of the minimal character height, and at least one pixel width (see Figure 2). Wider strokes are better for black text on white background than for the opposite polarity (Berger, 1944; Grether & Baker, 1972; Kuntz & Sleight, 1950; Shapiro, 1951; Uhlaner, 1941). If a display provides positive and negative polarities, it shall meet all the requirements of section 7.2.6 for each image polarity.

Stroke width should be increased when anti-aliasing rendering, such as cleartype font, are used to maintain the structural integrity of individual characters.

Spacing Between Characters

The spacing between characters, S_c, without serifs shall be at least equal to the stroke width (e.g., for adjacent *i*'s) and shall be 25% (for narrower character format) to 60% (for wider format) of the width of uppercase letters (see Figure 3). The spacing between characters with serifs shall be at least 20% of H width (and at least one pixel) between the two strokes of adjacent letters (see Figures 2 and 3).

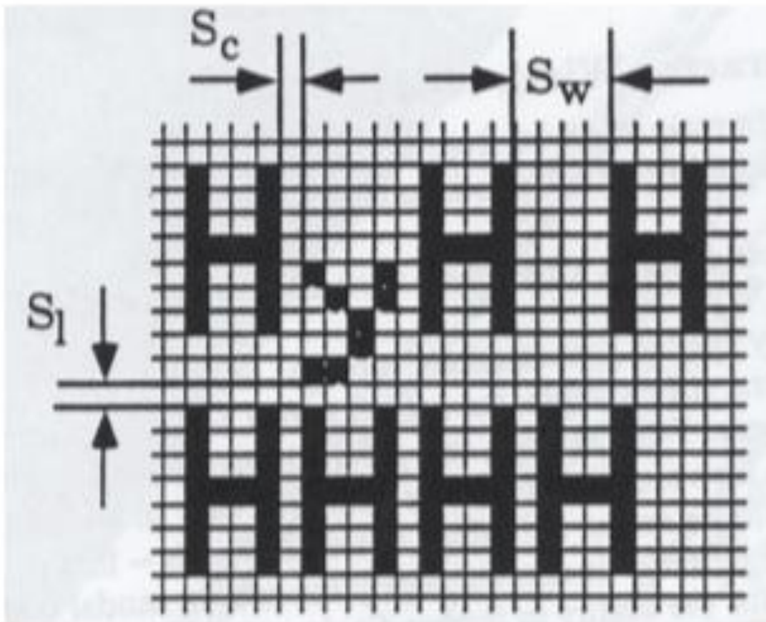

Figure 3. Spacing between characters (S_c), lines (S_l), and words (S_w). Squares represent pixels.

This recommendation concerns both the effects of crowding (Arditi et al., 1990; Chung, Levi, & Legge, 2001; Leat, Li, & Epp, 1999; Martelli, Majaj, & Pelli, 2005; Pelli, Palomares, & Majaj, 2004; Strasburger et al., 1991) and degraded legibility caused by excessive spacing.

Spacing should be increased for angled viewing and for anti-aliasing rendering, as both reducing the actual physical distance between the adjacent edges of letters.

Spacing Between Words

The spacing between words (S_w in Figure 3) shall exceed the spacing between characters (S_c in Figure 3) and should be at least 50% of the width of an uppercase letter *H* without serifs (see Figure 2).

Spacing Between Lines

The space between lines of text (S_l in Figure 7-5), including diacritics, should be at least 15% (and at least one pixel) of H height between any strokes of vertically neighboring lines of letters (see Figure 7-4). Users with partial vision or ocular difficulties in maintain eye fixation require larger spacing of 25% to 30%.

Compliance

Compliance for Character Height, Sizes of Colored Characters, Character Width-to-Height, Stroke Width, Character Format, Spacing Between Characters, Spacing Between Lines, and Spacing Between Words sections is established by inspection of the display under sufficient magnification to resolve individual pixels.

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Chapter 5 Workstation furniture

Introduction

The specifications presented in this chapter are product-centered, and should be used for product design, requirements, and selection purposes by furniture designers, manufacturers, specifiers, and end users.

This chapter presents design specifications for chairs, tables, and accessories used in computer workstations. The furniture specifications are based on anthropometric considerations associated with four basic, whole-body reference postures: upright sitting, reclined sitting, declined sitting, and standing. (See Figure 1)

This chapter also presents specifications and guidance to employers and the individuals that employers designate to configure computer workstations and the immediately surrounding workplace environment for the individual user. In addition to furniture, these workstations consist of input devices and visual displays that conform with component specifications stated elsewhere in the standard (i.e., Chapter 3, Input Devices; and Chapter 4, Visual Displays).

Purpose

The purpose of this chapter is (1) to establish design specifications for computer workstations that support and enhance operator performance during text-, data-, and graphics-processing tasks, and (2) to provide specifications and guidance to individuals who have responsibilities for acquiring, installing, and integrating computer workstations.

Anthropometry

The scope of this chapter covers design features for computer work surfaces, monitor and input-device support surfaces, chairs, and supports for users' feet, wrists, hands, and forearms.

The anthropometric data are based on the Society of Automotive Engineers' CAESAR anthropometric database[1,2] and are weighted to match the demographics of the 2011-2014 NHANES[3] anthropometric survey. Additionally, as there were fewer individuals in the extremes, or "tails" of the CAESAR data than desired, such as individuals with high Body Mass Indices (BMI), the "tails" of the CAESAR data were supplemented with data from the University of Michigan Transportation Research Institute (UMTRI) with appropriate statistical methods.

Virtual Fit Test Tool
The Virtual Fit Test Tool (VFT) is a user-friendly tool that facilitates estimates of multi-variate anthropometric accommodation.

A multivariate technique is required, as specifying 90th percentile values for each dimension (the approach taken in previous versions of this standard) will not generally accommodate 90 percent of all individuals on all dimensions concurrently, as demonstrated with modern statistical models.

The VFT solves this problem, directly indicating the estimated proportion of the intended users (United States of America civilians) that are concurrently accommodated on all dimensions entered in the tool. The VFT was used to develop the required product dimensions given in this chapter.

NOTE: The terms “User,” “Operator,” and “Worker” are used interchangeably in this chapter.

Conformance
A required dimension is indicated by a **shal**l statement. Dimensions predicated on a **should** statement are not requirements and do not affect conformance with this standard. Conformance with the required dimensional specifications will accommodate 90 percent of the intended users, unless otherwise noted.

A product or system conforms to this standard when it meets all the pertinent requirements or **shall** statements. **Should** statements do not affect conformance.

Dimensional specifications for workstation components
To conform to this standard, the required dimensions of a product or product system **shall**

> Concurrently accommodate at least 90 percent of the intended users on all required dimensions.

It may not be possible, or even desirable, for a single product to accommodate 90 percent of all intended users concurrently on multiple dimensions. In such cases, a system of two or more related products, e.g. a “small” model chair and a “standard” model chair, that jointly accommodate 90 percent of all intended users, is deemed to conform with this standard as a system.

Design Specifications

Whole-body Postures

This standard recognizes that computer workstation users frequently change their working postures to maintain comfort and productivity. Four whole-body reference postures are used in this standard to represent a range of whole-body postures observed at computer workstations (see Figure 1).

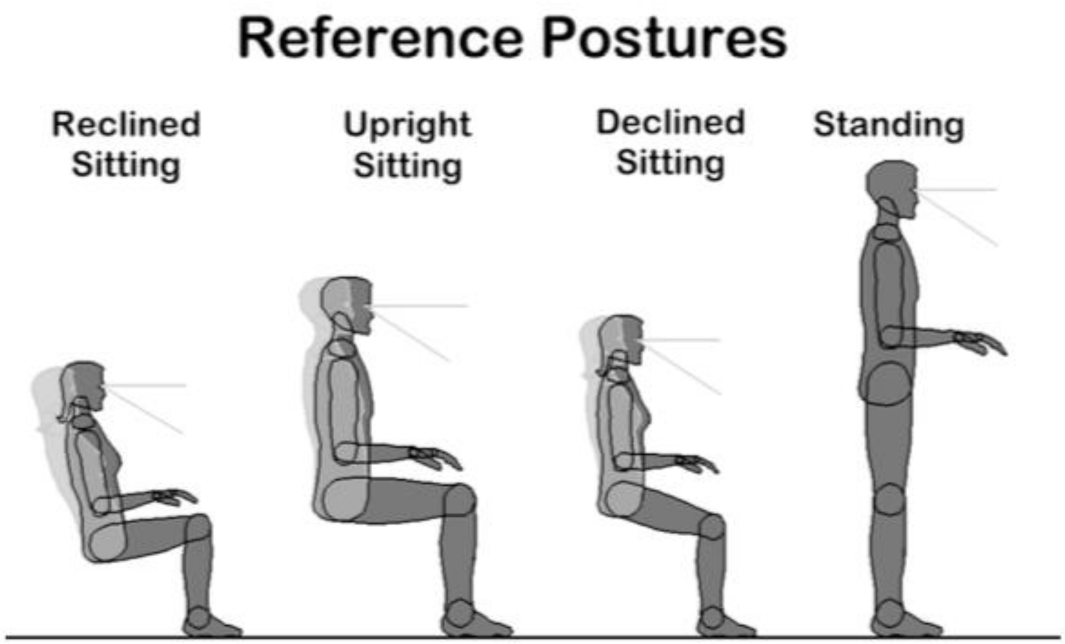

Figure 1. Whole-body reference postures for computer workstation users.

The four whole-body reference postures are characterized as follows:

> **Reclined sitting.** In the reclined sitting posture, the user's torso and neck recline between 105 and 120 degrees relative to horizontal.

Upright sitting. In the upright sitting posture, the user's torso and neck are approximately vertical and in-line (between 90 and 105 degrees to the horizontal), the thighs are approximately horizontal, and the lower legs vertical.

Declined sitting. In the declined sitting posture, the user's thighs are inclined below the horizontal, the torso is vertical or slightly reclined behind the vertical, and the angle between the thighs and the torso is greater than 90 degrees.

Standing. In the standing posture, the user's legs, torso, neck, and head are approximately in-line and vertical.

Users require frequent movement and postural changes to achieve and maintain comfort and productivity [4,5]. The four reference postures are intended to illustrate the diversity of body positions observed at computer workstations. Because these reference postures are intended as examples of human postures, variations in actual postures observed during work sessions can be expected. However, not all postures may be equally comfortable or applicable to all tasks.

User Postures

The installed workstation **shall** allow users to adopt postures within the following reference postural design criteria for body segments:

Elbow angles between 70 and 135 degrees[6,7,8,9] See Figure 2 for an illustration of the range of acceptable elbow angles.

Shoulder abduction angles less than 20 degrees[10,11]. See Figure 3 for an illustration of the range of acceptable elbow angles.

Shoulder flexion angles less than 25 degrees[12]. See Figure 4 for an illustration of the range of acceptable shoulder flexion angles.

Wrist flexion and extension angles less than 30 degrees[13,14]. See Figure 5 for an illustration of the range of acceptable wrist angles.

Torso-to-thigh angles equal to or greater than 90 degrees[15] See Figure 6 for an illustration of the range of acceptable torso-to-thigh angles.

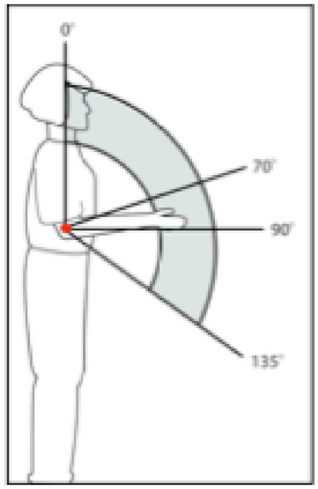

Figure 2. User reference postures, elbow angles.

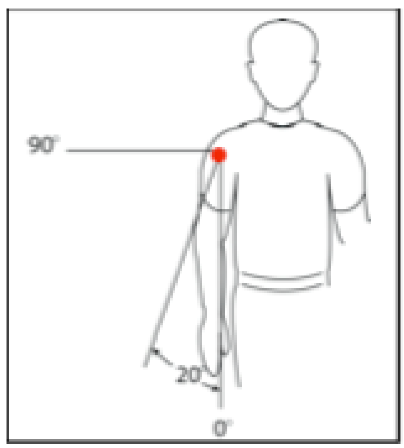

Figure 3. Acceptable range of shoulder abduction angles

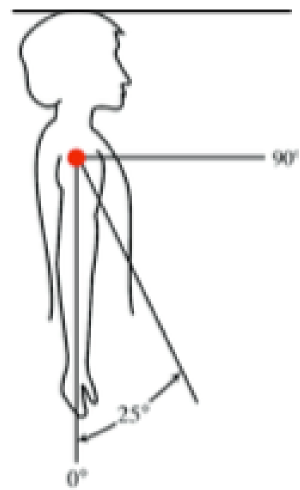

Figure 4. Acceptable range of shoulder flexion angles

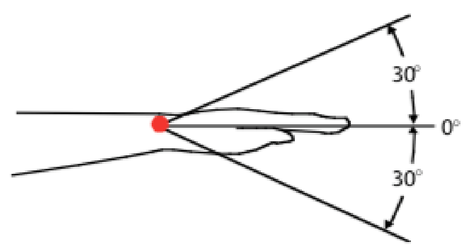

Figure 5. Acceptable range of wrist flexion and extension angles

Figure 6. Acceptable range of torso to thigh angles

Definitions

Lean support –a type of support in which some of the body weight is supported by leaning against a contoured edge or vertical support. Minimal body weight is supported by the lean support, the rest is on the feet, which are always on the floor.

Perch – a type of seating support with a full seat, no back, and which supports most user weight on the seat but with some supported by the feet, which can be on the floor or on rings or rungs attached to the perch.

Stool – a tall chair with a full seat and back in which all the user's weight is supported by the stool. A stool may include arm rests, foot rings or foot rails and various styles of bases.

Prop – a type of seating support with a full seat, typically no arms, but feet are always in contact with the floor and the seat may pivot and or free float. Normally attached to a flat base that feet stay in contact with during use.

Installation and Configuration of Computer Workstations

The installation and configuration of computer workstations involves several key considerations:

Employers **should**

> Ensure that individual hardware components, such as work surfaces and chairs, conform to the required design specifications stated elsewhere in this standard.

Employers **should**

> Ensure that the configured workstation is properly adjusted to fit users individually.
>
> Ensure that users are informed about the proper use and adjustment of the workstation components.

NOTE: an employer is defined as the individual or organization responsible for the proper workstation set up. Typically, the employer will contract with facility designers, interior designer, facility managers, installers, system integrators, in-house health and safety professionals, ergonomists, etc., to provide the necessary workstation initial design, set up, adjustments, and maintenance to assure compliance with this standard.

Some users have body dimensions that lie outside the design ranges used in the equipment specifications of this standard. In such cases, the principles and specifications of this chapter may be of benefit in guiding the configuration of workstations to suit those individuals' needs.

Dimensional Measurements

To determine dimensional compliance, portions of this standard that refer to seating-related measurements should use a standard chair measuring device (CMD) as specified by ISO 24496, Chair Measuring Method[16].

Adjustment Controls in the Workstation

Controls used for the adjustment of workstation components **shall not**

Intrude into the leg and foot clearance spaces when not in use

Interfere with users' typical work activities or pose hazards during use

Adjustment controls **should**

Be usable by users while in the relevant reference postures

Some user groups may have special requirements regarding adjustment controls. Considerations for these user groups include:

- Inadvertent activation of controls while tactilely locating and identifying the control or controls,
- Ability to use two hands for control activation,
- Limits on the ability to exert force, or the ability to grasp, pinch, or twist the wrist,
- Ability to discern the status of locking or toggle controls through touch or sound

Adjustable Surface

Adjustable workstation surfaces **shall**

Use a fail-safe mechanism to prevent inadvertent movement

Use a control locking mechanism to prevent inadvertent operation

Pinch Points
Pinch points, in which fingers, arms, and legs can be caught between movable surfaces or parts, **shall**

Be avoided by means of design or guarding

The recommended hierarchy of procedures to avoid pinch points is to

- Design to eliminate the hazard,
- Guard against the hazard,
- Provide warning labels and instructions to users for safe operation

Radii of Edges
All work surface edges directly in front of the user **shall**

Have radii of at least 3 mm

Other edges of the work surface with which the user may contact **shall**

Have radii of at least 2 mm

Device Cabling
Cables that connect to devices in the workstation **should**

Be placed to avoid interference with the operation of workstation components

Be placed to avoid creating hazards for people or equipment in the workstation

Clothing and Movement Allowances
Anthropometric measurements are taken with participants wearing tight fabrics and no shoes to obtain accurate surface anthropometry distances and values. To correct for individuals wearing expected clothing layers and shoes for indoor office work, an allowance is added to the anthropometric dimensions. The allowances in this standard are for clothing, shoe height, and movement needed to shift postures.

Dimensional Specifications for Workstation Components
To conform to this standard, the required dimensions of a product or product system **shall**

Concurrently accommodate at least 90 percent of the intended male and female users on all required dimensions.

It may not be possible, or even desirable, for a single product to accommodate 90 percent of all intended users concurrently on multiple dimensions. In such cases, a system of two or more related products, e.g. a “small” model chair and a “standard” model chair, that jointly accommodate 90 percent of all intended users, conform with this standard as a system.

Work Surfaces

This section contains specifications for work surfaces used with the four reference postures.

Definitions for Work Surfaces

Support Surfaces

- Primary work surface: The main surface where the worker will be performing most computer-related tasks.
- Display (or monitor) support: A surface or another device used to support a monitor or display at a workstation.
- Input-device support surface: A surface such as a desk top or keyboard tray used to support input devices such as keyboard, mouse, etc.

Work Zones

A work zone is an area on the work surface within which where the worker can access various input devices and tools.

- Primary work zone: The area nearest the worker where it is easiest to reach and move while in a seated or standing posture

- Secondary work zone: The area beyond the primary work zone that requires some effort to reach and move while in a seated or standing posture

- Tertiary work zone: The area beyond the secondary work zone that requires the most effort to reach and move while in a seated or standing posture

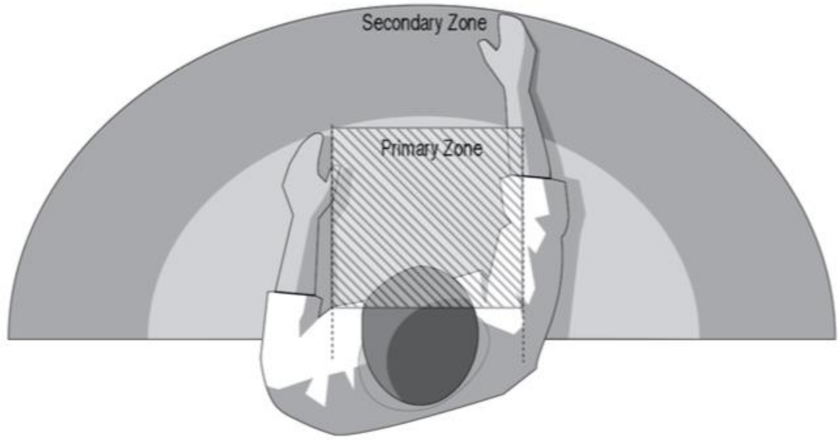

Figure 9. Recommended primary, secondary, and tertiary (outside the secondary) horizontal work zones.

Operator Clearances Under the Work Surface

Seated Clearances

Operator clearance spaces under all working surfaces (i.e., primary work surface, display support surface, input-device support surface) **shall**

> Accommodate the upright seated posture and at least one of the other two seated reference working postures.

The following dimensions define the required clearances for the intended users when seated. The limits of the height adjustability range at the forward edge of the work surface is based on thigh clearance. The limits of the height adjustability range at the level of the knee is based on height of the knee while seated. The width requirement is based on female hip breadth.

Figure 7 illustrates the clearance space.

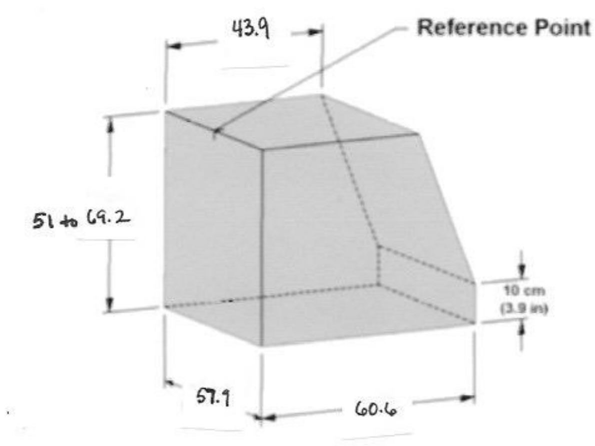

Figure 7 Illustration of the Clearance Space. The reference point faces the user. (to be redrawn)

To accommodate at least 90 percent of the intended users, the clearance space **shall** be:

Adjustable between 48 and 66.2 cm (20.1 and 26.1 in) in height at the edge of the work surface closest to the operator, or between 51 cm and 69.2 cm (20.7 in to 27.8 in) with a 3-cm heel allowance added to the greater height

At least 53 cm (21.2 in) wide, or 57.9 cm (22.8) wide including a 4.9 cm clothing and movement allowance

At least 39.4 cm (15.5 in) deep at the level of the knee, or 43.9 cm (17.3 in.) deep at the level of the knee with a 4.5 cm clearance allowance

At least 56.1 cm deep at foot level and 10 cm)3.9 in) above the floor, or 60.6 cm deep with a 4.5 cm clearance allowance.

The installed work surface **should not**

Hinder the foot, leg, or knee in positions not included in the four reference postures.

Standing Clearances
Clearance for users' feet under a standing work surface **should**

Be at least

10 cm (3.9 in.) in height

51 cm (20.1 in.) in width

10 cm (3.9 in.) in depth.

Primary Work Surface

The primary work surface top **should**

Be at least 68.1 cm (26.8 in.) wide,

Accommodate the user postural design criteria described in User Postures.

The most commonly used objects **should**

Be placed in the primary work zone.

The depth of the primary work surface **should**

Allow a viewing distance of at least 50 cm (19.7 in.)

Allow positioning of the monitor so that the angle between the horizontal level of the eyes and the center of the screen ranges between 15 and 25 degrees

Allow positioning of the entire viewing area (e.g., including the keyboard) in 60 degrees below horizontal eye level.

NOTE: Multi-focal lens wearers may prefer to place the center of the screen at the lower end of the recommended range, or slightly lower.

Electronic Display Support

The monitor support surface manufacturer **shall**

Specify the size and weight of monitor that can be accommodated by the support surface

Specify the range of adjustment if the support surface is adjustable.

The monitor support surface **should**

Be designed to allow placement of the viewing area of the screen at a minimum viewing distance of 50 cm (19.7 in)

Be stable during use

Not interfere with the user’s ability to adjust the height, tilt, and rotation of the monitor.

NOTE: The maximum viewing distance is one that allows alphanumeric characters rendered on the screen (in their primary or default font) to subtend at least 16 arc minutes of visual angle, for example, 2.3 mm at 50 cm viewing distance (0.1 in. at 19.7 in). This character size facilitates legibility; many individuals find that a character height of 20 to 22 arc minutes improves readability.

Input-Device Support Surfaces

Input-device support surfaces may be designed for use while seated only, standing only, or while seated or standing. Input-device support surfaces shall comply with the clearance requirements specified in section Operator Clearances Under the Work Surface.

General Specifications for Sit, Stand, or Sit/Stand Input Device Support Surfaces

If height and tilt adjustable, the input-device support surface designed for both sitting and standing work postures **shall**

Adjust in tilt in some portion of the range between -45 and +20 degrees, including 0 degrees, to facilitate user postures as described in Figure 2.

The input device **should**

Be placed within the recommended space for input devices.

The lateral boundaries of the input device space are swept out by the user's forearm-hand length when the included elbow angle varies between 70 and 135 degrees, as is shown in Figure 2. The shoulders are relaxed, the upper arm is approximately vertical, and the elbows are held loosely against the torso with no more than 20 degrees' abduction. For seated working positions, the lower limit of the elbow angle is determined by thigh clearance. A plan view of the recommended space is illustrated in Figure 8.

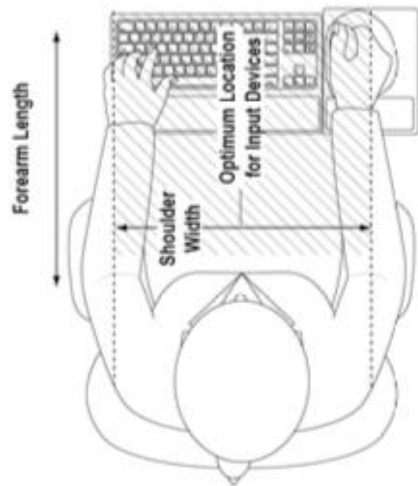

Figure 8. Plan view of the recommended space for placement for input devices

If detachable, such as a keyboard tray, the input-device support surface, **should**

Be marked to specify the range of adjustment for height and tilt.

For sit/stand work, the input device support surface **shall**

Accommodate at least one of the seated reference postures in addition to the standing reference posture without requiring the user to violate the user postural criteria described in User Postures.

The manufacturer of an input-device support surface **shall**

Provide information regarding the range of height adjustment

Provide information regarding tilt adjustments.

All detachable input-device support surfaces (e.g. keyboard trays) **should**

Adjust fore and aft in the horizontal plane

Adjust side-to-side within the optimal area for input devices

Tilt.

Sit-Only Working Postures

If tilt adjustable, the tilt adjustment of the input device support surface for sitting only working postures **should**

> Provide tilt adjustment to include the range between –15 degrees and +20 degrees, including 0 degrees in order to conform with the user postural guidelines specified in section 4.2.
>
> NOTE: tilting the input device support surface more than 15 degrees below horizontal may interfere with clearance for the user's thighs.

The installed input-device support surface designed for only sitting working postures **shall**

> Be adjustable in height by various means such as manual, electric, or automatic.
>
> Have a surface height adjustment that includes at least the range of 55.4 cm to 73.9 cm (21.8 to 29.1 in.) as measured from the floor to the top of the surface, or 58.4 cm to 76.9 cm (21.8 to 30.3 in) with a 3-cm shoe height allowance.

Stand-Only Working Postures
A non-tilting installed input-device support surface designed for standing only working postures **shall**

> Have a surface height adjustment that includes at least the range of 91.4 cm and 117.7 cm (36.0 and 46.3 in.) as measured from the floor to the top edge nearest the user,
>
> or 94.4 cm to 120.7 cm (36.0 to 47.5 in) with a 3-cm shoe height allowance.

If tilt adjustable, the tilt adjustment for standing only working postures **should**

> Allow tilt adjustment that includes the range between –45 degrees and +20 degrees as described in Figure 2.

Standing Clearances
Clearance for users' feet under a standing work surface **should**

> be at least
>
> > 10 cm (3.9 in.) in height
> >
> > 51 cm (20.1 in.) in width
> >
> > 10 cm (3.9 in.) in depth.

Sit/Stand Working Postures

The installed input-device support surface designed for both sitting and standing working postures **shall**

> Adjust in height between 55.4 cm and 117.7 cm (21.8 and 46.3 in.) as measured from the floor to the surface at the top edge of the surface,
>
> Or 58.4 cm and 120.7 cm (21.8 to 47.5 in) with a 3-cm shoe height allowance.

Stand-Biased Workstations

A stand-biased input device support surface is set at a fixed height to encourage standing while working. A seating device such as a tall chair (stool) or other device may be used to allow the user to support his or her weight while working and to alternate between standing and supported postures.

Any seating device used at a stand-biased workstation **shall**

> Have sufficient friction to prevent sliding on the floor during ingress or egress

When working at a stand-biased workstation, and to conform with the User Postures, the support **should**

> Support the user so that their elbow height is no more than 50.8 mm (2 in) above or below the work surface.

A stand biased workstation **should**

> Provide support to both feet while sitting, or to one foot while standing.

The foot support **should** be

> 15 cm to 25 cm high (5.9 in to 9.8 in) and 15cm to 25 cm (5.9 in to 9.8 in) in depth.

Display Support Device

Display support devices are used to support the computer display and allow the user to adjust the location of the monitor relative to their seated or standing position.

The display support device **shall**

> Allow users to adjust the line-of-sight (viewing) distance between their eye point and the) surface of the viewable display area
>
> Allow users to adjust the tilt and rotation angle between their eye point and the surface of the viewable display area.

The display support device **should**

All the users to adjust the position of the display to the left or right of center, as necessary.

The monitor support device **should**

Allow users with normal visual capabilities to adjust the line-of-sight (viewing) distance between their eyes and the front (first) surface of the viewable display area within the range of 50 to 100 cm (19.7 to 39.4 in).

Display Viewing Angle

The center of the electronic display screen **should**

Be located 15 to 25 degrees below horizontal eye level.

NOTE: Multi-focal lens wearers often prefer angles low in the range specified or slightly lower.

During work periods, visual display screens **should not**

Be located more than 35 degrees off to the side of the user's center line while the user is facing straight ahead.

The entire visual area of a computer workstation, including items other than the display such as the keyboard, **should**

Be located between 0 degrees (horizontal eye height) and 60 degrees below eye height when users assume the upright sitting, reclined sitting, declined sitting, or standing reference postures.

Document Holders

Adjustable document holders allow users to read and/or transcribe hard-copy materials without assuming awkward postures[17]. Placing the hard-copy materials at a distance and angle from the user similar to those used for the display minimizes changes in visual accommodation and vergence, thereby reducing visual effort.

Document holders **should**

Allow placement of materials adjacent to the monitor and at approximately the same height, distance, and angle relative to the user's eyes as the display

Be stable when loaded with the intended materials.

Forearm supports

For tasks requiring prolonged use or precise control of input devices, supports **should**

Be provided for the user's forearms

Facilitate user postures of the wrist and arm postural design criteria specified in the User Postures section of this document.

The shape and firmness of the support **should**

Be designed to distribute forces evenly over the contact area.

Footrests

Footrests **shall**

Be provided when the range of adjustment of the chair, work surface, or both, does not permit the person's feet to be supported on the floor.

To provide support for placement of feet, a footrest for seated work **should**

Be at least 51 cm (20.1 in.) wide and 20 cm (7.9 in.) deep

Be height-adjustable up to 22 cm (8.7 in.) and may be adjustable in angle (pitch).

Seating

The furniture specifier or designer **should**

Verify that the chair can be adjusted to provide clearance under the work surface

Provide information to the user as to the recommended use and adjustment of the chair.

The chair **shall**

Have a height adjustable seat height

Allow the user to recline the backrest

Allow adjustment of the amount of force required to recline the to match the user's requirements.

NOTE: User adjustment is defined as any method of adjusting the force required to recline. This can be accomplished either with manual devices (levers, knobs, adjustments, etc.) or automatically as users of different weights sit in the chair.

Seat Height

The minimum range of seat height adjustment **shall**

Be adjustable by the user over a minimum range of 11.4 cm (4.5 in.) within the recommended range of 33.8 to 47.8 cm (13.3 to 18.8 in.), or in the range of

36.8 cm to 50.8 cm (13.3 to 20 in), including a 3-cm heel allowance.

Seat Pan Depth and Front Edge

The seat pan **should**

Have a waterfall or rounded front edge.

The seat depth **shall**

Be no greater in depth than 42 cm (16.5 in) if nonadjustable

Include a depth of 42 cm (16.5 in.) if adjustable.

Seat Pan Width

The seat pan **shall**

Be at least 53 cm wide (20.9 in), or 53.4 cm (21 in) with a 0.4 cm clothing allowance.

Seat Pan Tilt Angle

The seat pan tilt angle **shall**

Have a user-adjustable range of at least 4 degrees, which includes a reclined position of 3 degrees

NOTE: User adjustment is defined as any method of activating the movement of the seat pan/backrest. This can be accomplished either with manual devices (levers, knobs, adjustments, etc.) or by movement of the body.

Seat Pan–Backrest Angle

If the backrest is adjustable, it **shall**

Have an adjustment range of 15 degrees or more within the range of 90 degrees and 120 degrees relative to the seat pan.

If the backrest recline angle exceeds 120 degrees from the horizontal, the backrest **should**

Have a headrest, preferably user adjustable.

Backrest Height and Width

The backrest of the chair used to support the workstation user **shall**

Not constrain the user's torso to a position forward of vertical

Allow adjustment of the angle between the backrest and seat pan to an angle of 90 degrees or greater.

The top of the backrest **should**

Be at least 45 cm (17.7 in.) above the compressed seat height.

The width of the backrest **should**

Be at least 36 cm (14.2 in) in the lumbar zone.

The position of the center of the lumbar support area of the backrest **should**

Be located between 15 and 25 cm (5.9 and 9.8 in) above the compressed seat height. fixed.

Armrests

This standard does not require that chairs include armrests.

The clearance between armrests **should**

Be at least 53 cm (20.9 in.) in width between the inside edges of the armrests, or 53.4 cm (21 in) with a 0.4 cm clothing allowance.

Adjustable armrests **should**

Adjust in height from 19.2 to 29 cm (7.6 to 11.4 in.) above the compressed seat pan height

Be adjustable by the user (for example, pivot or otherwise move)

Clearance between armrests should include a width of 530 mm (20.9 in), or 53.4 cm (21 in) with a 0.4 cm clothing allowance.

Fixed-height armrests **should**

Be between 19.2 and 29 cm (7.6 to 11.4 in.) above the compressed seat pan height.

Armrests **should**

Provide sufficient clearance to allow the user to sit or stand without interference

Not cause the user to violate any of the postural guidelines specified in the User Postures section

Be designed to distribute forces evenly over the contact area

Not create excessive pressure points

Not irritate or abrade the skin

Allow adjustment of the clearance width between the armrests

Be detachable from the chair if necessary to fit the workplace.

Casters
Casters on the chair used to support the workstation user **should**

Be appropriate for the type of flooring at the workstation.

Seating Dimensional Measurements
Measurements of seating dimensions **shall** use a standard chair measuring device (CMD) as referenced by

ISO 24496:2017, Office furniture -- Office chairs – Methods for the determination of dimensions
Product Stability and Measurement

Stability and Durability
Workstation furniture **shall**

Be stable and durable in typical usage conditions

Meet the current applicable requirements of:

- ANSI/BIFMA X5.1, General Purpose Office Chairs—Tests
- ANSI/BIFMA X5.3, Vertical Files—Tests
- ANSI/BIFMA X5.5, Desk Products—Tests
- ANSI/BIFMA X5.9, Lateral Files—Tests.

Adjustable Surfaces
Adjustable workstation surfaces **shall**

Use a fail-safe mechanism to prevent inadvertent movement

Use a control locking mechanism to prevent inadvertent operation.

Pinch Points
Pinch points, in which fingers, arms, and legs can be caught between movable surfaces or parts, **shall**

Be avoided by means of design or guarding.

The recommended hierarchy of procedures to avoid pinch points is to

- Design to eliminate the hazard,
- Guard against the hazard,
- Provide warning labels and instructions to users for safe operation.

Device Cabling
Cables that connect to devices in the workstation **should**

Be placed to avoid interference with the operation of workstation components

Be placed to avoid creating hazards for people or equipment in the workstation

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