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Human Factors Engineering of Computer Workstations



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FOREWORD

This standard contains hardware design specifications that are based on accepted human factors engineering research and experience for computer workstations, their associated furniture, and the end user's workplace environment. This standard was developed by the Human Factors and Ergonomics Society (HFES), using the rules and procedures of the American National Standards Institute (ANSI).

This edition is the first revision of ANSI/HFES100-1988, *American National Standard for Human Factors Engineering of Visual Display Terminal Workstations*. This edition of the standard incorporates several extensions based on technology advancements and increased human factors knowledge to the technical areas discussed in ANSI/HFES100-1988.

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1 PURPOSE

This technical standard specifies acceptable applications of human factors engineering principles and practices to the design and configuration of the human-hardware interfaces in computer workstations.

For the purposes of this standard, the term *computer workstation* refers to an operator-machine system consisting of a computing unit and, more important, several associated hardware components that form interfaces with the users of the system. The user interfaces addressed by this standard are input devices, output devices, and furniture. Because the application of human factors engineering principles and practices requires the consideration of specific end-user situational constraints, this standard also considers the configuration of the installed workstation components and the ambient environment immediately surrounding the computer workstation.

This standard applies to computer workstations used regularly in office workplaces by users with normal perceptual and cognitive capabilities for text-, data-, and simple graphics-processing tasks. It is specifically intended for moderate to intensive computer users. The specifications in this standard are not intended to apply to the diverse uses of computers beyond the office workplace application stated above. Although generalizations of some specifications contained in this standard to other applications may be reasonable and justifiable, it must be recognized that such generalizations exceed the scope of this standard. For example, health and safety considerations for users of computer workstations are beyond the intended purposes and stated scope of this standard.

Implementation of this standard and the assessment of conformance with this standard should be performed by trained and knowledgeable human factors engineers and ergonomists. These professionals may have technical responsibilities, in whole or in part, for the design, installation, and inspection of computer workstations and their associated components.

Many specifications contained in this technical standard are presented in a quantitative manner; that is, as numbers representing acceptable design limits. Such specifications are based on accepted empirical data and established human factors engineering principles and practices. Users of these specifications should follow acceptable human factors engineering practice when tailoring the specifications contained in this standard to particular computer workstations and user populations.

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.

2 GENERAL SCOPE

This standard covers operator-machine interface issues associated with computer workstations used regularly in offices (i.e., intentionally built indoor office workplaces) for text-, data-, and simple graphics-processing tasks. This standard applies to computer workstations for a wide range of users; in general the physical dimensions and force requirements are designed to accommodate at least 90 percent of the North American population.

User Diversity¹

“In general, the design specifications for the computer workstation components are intended to be equitable; that is, the design accommodates people with diverse abilities.”

However, users may vary in their ability to perceive information that is statically presented or dynamically supplied by the computer workstation, in their ability to understand how to use the product, and in their ability to operate the product. Some users may need to use assistive devices with their computer workstation components. For example, a user with tremor or limited eye-hand coordination might need a special keyboard with increased spacing between the keys.

In some instances, the most practical or feasible means of achieving accommodation of diverse users may be through the use of software intended to be used with the workstation component, such as device drivers, rather than through the physical properties of the device. For example, it may be more practical to adjust key repeat rate via software controls than to build variable activation delays into a key switch circuit.

Because of the very nature of diversity, it is difficult and perhaps even contradictory to attempt to specify a unique set of design criteria that will accommodate all users. For example, a user with very limited strength may require that keys on an input device respond almost instantaneously to a light touch, yet a user with an intentional tremor may require that the keys respond only to a sustained high level of force. At present the research literature does not suffice to answer these accommodation questions, at least at a level sufficient to allow specification.

Similarly, the current state of knowledge does not allow us to determine if there is a single set of design criteria that will result in a computer workstation component suitable for all possible users. However, it is possible to provide designers with some general principles regarding features of computer workstation components that will support accommodation.

General Guidelines

Perception

Computer workstation components, either separately or in combination with supporting software, should facilitate diverse users' ability to perceive statically or dynamically displayed information such as

- Key labels
- Key locations
- Feedback from operation of the device
- Status of toggle keys, for example, number lock and capital lock

¹ The Human Factors and Ergonomics Society wishes to acknowledge the kind permission of the International Standards Organization to use this material related to user diversity.

Operation

Computer workstation components, either separately or in combination with supporting software, should facilitate diverse users' ability to operate the device by

- Not limiting the ability to use alternate methods of carrying out the device functions, for example, assistive technologies
- Minimizing the likelihood of accidental activation
- Supporting error recovery
- Support varying rates of user-provided input, for example, keying rate

Understanding

Computer workstation components, either separately or in combination with supporting software, should facilitate diverse users' ability to

“Apprehend the manner or method of using the device.”

Finally, the United States Federal Government has established accessibility criteria to be used when purchasing computer workstation components. These criteria are described in Section 508 of the US Rehabilitation Act. Similarly, the International Standards Organization (ISO) has developed a Draft International Standard (ISO 9241-20), which addresses accessibility of computer workstations. At the time of this revision, there are no known conflicts between the accessibility content of these documents (Section 508 and ISO 9241-20) and the content of this document.

Because the form and functionality of computer workstations recognized in this standard vary substantially, the standard presents specifications for a generic workstation and for specific user-interface components (i.e., input devices, visual displays, and furniture) used in that workstation. These specifications are contained in four subsequent chapters:

- Chapter 5, Installed Systems
- Chapter 6, Input Devices
- Chapter 7, Visual Displays
- Chapter 8, Furniture

General scope statements for each of these chapters are presented below. The individual chapters contain detailed scope statements, which discuss assumptions and limitations of the specifications contained therein.

Chapter 5, Installed Systems, addresses human factors specifications for configurations of installed and functioning workstations and for their immediately surrounding ambient environments. These specifications provide guidance to system integrators and apply to the effects of computer workstations on ambient conditions in designed indoor office environments used for the regular conduct of computer-based tasks. The specific work issues considered in this chapter include

- Layout of computer components
- Lighting
- Acoustical noise
- Temperature
- Ventilation

- Equipment emissions
- Mechanical vibrations
- Electrical interference

Chapter 6, Input Devices, identifies human factors specifications for keyboards and auxiliary input devices used in computer workstations. This standard does not address the design of typewriters or handheld computer-based devices. The specific input devices considered in this chapter include

- Keyboards
- Mouse and puck devices
- Trackballs
- Joysticks
- Stylus and light pens
- Tablets and overlays
- Touch-sensitive screens

Chapter 7, Visual Displays, provides specifications for visual display monitors used in computer workstations. These specifications apply to cathode ray tube (CRT) and flat-panel displays, that use monochromatic or color technologies to render at least 100 alphanumeric characters simultaneously. This standard does not address design specifications for projection, head- and helmet-mounted display, or so-called near-eye display technologies. The specific visual display devices considered in this chapter include

- Color and monochrome CRTs
- Color and monochrome flat-panel displays

Chapter 8, Furniture, presents specifications for work surfaces, seating, and selected auxiliary components. These requirements apply to designed workplaces in which users perform computer-based tasks within the range of four reference postures. This standard does not specify or advocate one particular posture for the seated or standing users of computer workstations. Rather, a range of common postures is recognized to encourage changes of posture. The specific furniture components considered in this chapter include

- Monitor support surfaces
- Input device support surfaces
- Operator work surfaces
- Chairs
- Operator supports

2.1 Guiding Principles

The specifications presented in this standard are intended to aid operator performance in tasks performed on computer workstations. The specifications support the following human factors and ergonomics objectives:

- Enhance workstation usability by improving ease of use and ease of learning
- Facilitate user performance by encouraging task proficiency and error recovery
- Accommodate users of various physical sizes and expertise levels

- Maintain user performance by allowing postural changes that minimize static loads
- Promote user satisfaction by fostering product acceptance and product usage

2.2 Limitations

Although the information contained in this standard may be generalized to the design, configuration, and use of non-office workstations, the reader is cautioned against generalizing the technical specifications. This standard is not intended to apply to transient computer work situations (e.g., using a laptop computer during airplane travel) or to workstations specially configured for individuals with physical or cognitive disabilities.

However, the use of a portable device in an office setting, such as a laptop computer in a docking station, is specifically understood to be within the scope of this standard and not to be an example of transient computer work.

Furthermore, this standard does not apply to operator health considerations or work practices. Although increased biomechanical efficiency during work periods is desirable from a human factors and ergonomics viewpoint, the focus of this standard is to support operator performance through attention to the design aspects of computer hardware and environment interfaces. No implications are made herein that conformance to this standard produces health-related outcomes.

3 CONFORMANCE POLICY

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. For example, manufacturers of keyboards need to meet only the applicable requirements in Chapter 6, Input Devices; display device manufacturers need to meet only the requirements in Chapter 7, Visual Displays; and furniture manufacturers need to comply only with the applicable requirements in Chapter 8, Furniture.

“System conformance” applies to the configuration of installed computer workstations. This level of compliance is intended for system integrators and site evaluators to ensure that installed computer workstations meet the objectives of the standard. The system conformance requirements apply to an entire computer workstation. For example, system integrators and evaluators need to meet only the applicable requirements in Chapter 5, Installed Systems, to ensure that the installation of system components supports the range of acceptable configurations.

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.

3.1 Conformance Exclusions

The standard provides specifications for selected components and configurations of computer workstations. The standard does not apply to components and configurations beyond those explicitly mentioned. It is recognized that alternative computer workstation technologies may achieve their functional objectives in an acceptable manner. Thus this standard **shall not** be used to qualify the acceptance, impede the development, or preclude the use of alternative or novel computer workstation components.

Computer workstation components are excluded from the conformance requirements of this standard if their technical design or intended usage falls outside the scope of this standard. It is the responsibility of the component manufacturer or system integrator to establish evidence and documentation for exclusion from this standard.

4 CITED STANDARDS

This standard refers to other industry, national and international standards.

ANSI/BIFMA X5.5-1998, *Desk products—Tests*

ANSI/BIFMA X5.9-2004, *Lateral files—Tests*

ANSI/BIFMA X5.3-1997, *Vertical files—Tests*

ANSI/BIFMA X5.1-2002, *General purpose office chairs—Tests*

ANSI/IES RP-1-1993—*American National Standard practice for office lighting*

ANSI S12.2 (R1999)—*American National Standard: Criteria for evaluating room noise* (ASA 115-1995)

BIFMA/CMD-1-2002, *Universal Measurement Procedure for the Use of BIFMA Chair Measuring Device (CMD)*

BIFMA G1 –2002 Ergonomics guideline for VDT (visual display terminal) furniture used in office work spaces

EN563 *Safety of machinery—Temperatures of touchable surfaces: Ergonomics data to establish temperature limit values for hot surfaces*

ISO DIS 9241-20 *Ergonomics of human-system interaction—Part 20: Guidance for the accessibility of information communication equipment and services*

ISO DIS 9241-410 *Ergonomics of human-system interaction—Part 410: Design criteria for physical input devices*

5 INSTALLED SYSTEMS

The use of individually compliant workstation components is only part of the process of achieving the productivity and comfort benefits associated with ergonomic VDT workstations. Full realization of these benefits will be achieved only when individual components are effectively integrated into a system that, as a whole, matches the capabilities of the user(s). Simply put, the workstation components as a whole must fit the worker and the work to obtain the desired comfort and productivity benefits.

This chapter presents specifications and guidance to employers and the individuals that they designate to configure computer workstations, also referred to as Video Display Terminals(VDTs), and the immediately surrounding workplace environment for the individual user. These workstations consist of input devices, visual displays, and furniture that individually comply with component specifications stated elsewhere in the standard (i.e., Chapter 6, Input Devices; Chapter 7, Visual Displays; and Chapter 8, Furniture).

Definition of Employer: the individual or organization responsible for the proper workstation setup. Typically, the employer will utilize Facility Designers, Interior Designers, Facility Managers, Installers, System Integrators, In-house Health and Safety Professionals, Ergonomists, and so forth, to provide the necessary workstation initial design, setup, adjustments, and maintenance to assure compliance with this standard.

The installation and configuration of ergonomically sound workstations involves several key considerations:

- Employers need to ensure that the individual hardware components, such as support surfaces and chairs, meet their associated design specifications stated elsewhere in this standard.
- Employers need to ensure that the hardware components are compatible with one another when arranged in the actual workstation. This consideration might be characterized by assessments such as “Can this chair be used with this desk?” and “Can this input device be used with this support surface?”
- Employers need to ensure that the configured workstation properly fits the user(s). Some users have body dimensions that lie outside the design ranges used in the equipment specifications of Chapters 6, 7, and 8 of this standard. In such cases the specifications and guidance of this chapter may be of benefit in configuring workstations to suit these individual needs.
- Employers need to ensure that users are informed about the proper use and adjustment of the workstation components. Users’ knowledge of the workstation capabilities needs to include an understanding of the underlying human factors and ergonomics objectives achieved and to be maintained in the configuration of the component devices.
- 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.
- Improperly configured workstations will likely fail as a system to achieve a good fit with the individual user’s requirements, regardless of the compliance of individual hardware components. Thus the specifications in this chapter stem from a systems engineering perspective and are intended to foster compatibility among components when installed and configured into a computer workstation.

5.1 Purpose and Scope

The purpose of this chapter is to provide specifications and guidance to individuals who have responsibilities for acquiring, installing, and integrating computer workstations. These individuals need to recognize and understand the interdependencies among the individual workstation components.

The scope of this chapter covers the configuration of workstation hardware components, lighting, acoustics, temperature, ventilation, and product emissions.

Specifications as to the design of individual hardware components are not presented in this chapter. The reader is directed to use Chapter 6, Input Devices; Chapter 7, Visual Displays; and Chapter 8, Furniture, as companion specifications when considering the design of the individual hardware components.

5.2 Design Specifications

5.2.1 GENERAL SPECIFICATIONS

This standard recognizes that VDT users frequently change their working postures to maintain comfort and productivity. Four reference postures are used in this standard to represent a range of postures observed at computer workstations (see Figure 5-1).

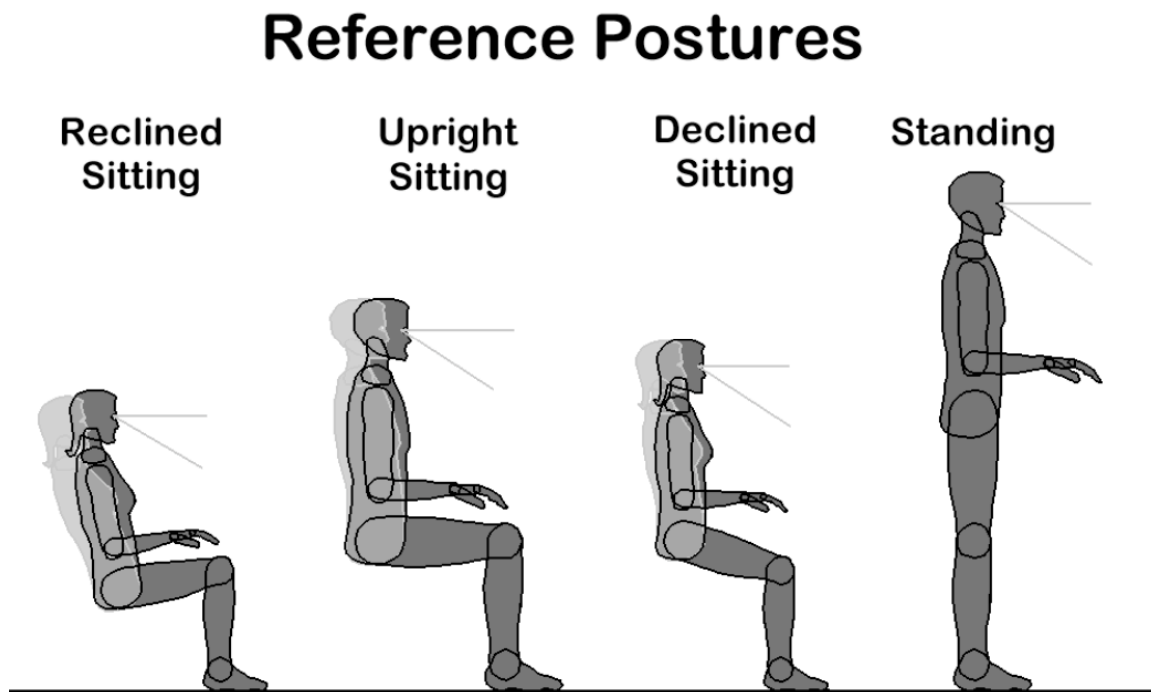


Figure 5-1. Reference postures for computer workstation users.

The four reference postures are characterized as the following:

Reclined sitting. In the reclined sitting posture, the user's torso and neck recline between 105 and 120 degrees to the 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 (Kroemer, Kroemer, & Kroemer-Elbert, 1994; Sanders & McCormick, 1993). 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 are equally comfortable or productive.

5.2.1.1 User Postures

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

- Elbow angles between 70 and 135 degrees (Cushman, 1984; Grandjean, Hunting, & Pidermann, 1983; Miller & Suther, 1981; Weber, Sancin, & Grandjean, 1984) (Figure 5-2)
- Shoulder abduction angles less than 20 degrees (Chaffin & Andersson, 1984; Karlqvist, Hagberg, Köster, Wenemark, & Ånell, 1996) (Figure 5-3)
- Shoulder flexion angles less than 25 degrees (Chaffin & Andersson, 1984) (Figure 5-4)
- Wrist flexion angles less than 30 degrees (Hedge, McCrobie, & Morimoto, 1995; Rempel & Horie, 1994) (Figure 5-5)
- Wrist extension angles less than 30 degrees (Hedge et al., 1995; Weiss, Gordon, Bloom, So, & Rempel, 1995; Rempel & Horie, 1994)
- Torso-to-thigh angles equal to or greater than 90 degrees (Chaffin & Andersson, 1984) (Figure 5-6)

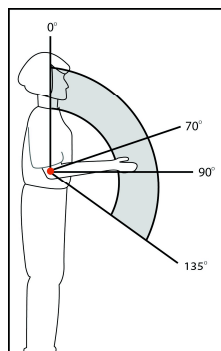


Figure 5-2. Elbow reference postures.

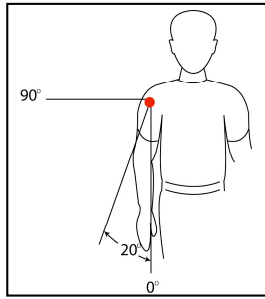


Figure 5-3. Shoulder abduction reference postures.

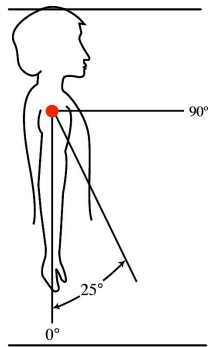


Figure 5-4. Shoulder flexion reference postures.

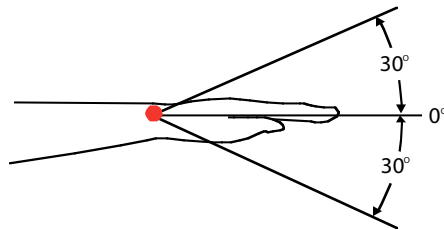


Figure 5-5. Wrist flexion and extension reference postures.

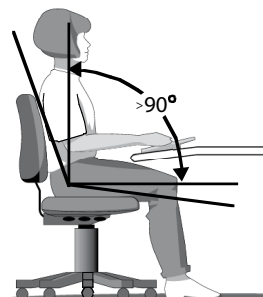


Figure 5-6. Torso-to-thigh reference postures

There is wide variation in physical size among the working population. For example, there is a difference of 34 cm (13.4 inches) in height between a small woman and a tall man in the anthropometric database (Gordon et al, 1989) used in this standard. Moreover, personal work styles, fluctuation in task content throughout the workday, and worker physiology all dictate variation in working posture. This combined variation of size and posture, if not accounted for in the design of equipment, results in a mismatch between the user and equipment and, in turn, inefficiencies in the work process (Chaffin, 1984). Such work inefficiencies can add as much as 2% to 22 % to task performance times (Dainoff, 1990; Niebel, 1984).

These postural guidelines are appropriate for all users. Consequently, they may be used for guidance when the individual user is outside the range of sizes that the equipment specifications in this standard have been designed to accommodate.

5.2.1.2 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

Controls that conform to the users' expectation for function, method of operation, and location and that are easy to identify, manipulate, and access from the reference postures facilitate movement (Burandt & Grandjean, 1963; Kleeman & Prunier, 1980; Lueder, 1994; Shute & Starr, 1984; Winkel & Oxenburgh, 1990).

Elderly or disabled users may have special requirements with regard to adjustment controls. Some considerations for these user groups are:

- Inadvertent activation of controls while tactilely locating and identifying the control or controls
- Ability or inability 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

5.2.1.3 Adjustable Surfaces

Adjustable workstation surfaces **shall**

- Use a fail-safe mechanism to prevent inadvertent movement
- Use a control locking mechanism to prevent inadvertent operation

Adjustable surfaces that hold heavy objects, such as a visual display, can present a hazard to users. For example, adjustable surfaces moving relative to each other may create pinch-point hazards, either while in operation or in the event of failure.

Elderly or disabled users may have special requirements with regard to adjustment surfaces. Some considerations for these user groups are:

- Accessibility for individuals in wheelchairs

5.2.1.4 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

In adjustable workstation furniture, surfaces move relative to one another. This may lead to pinch-point hazards in which fingers, arms, or legs can be caught between moving surfaces or parts. This can occur, for example, when a motorized work surface moves past a fixed surface or when clearance between a seat adjustment lever and the bottom of the seat is inadequate. The size of the clearance gap necessary to avoid pinch points will depend on which limb might be involved, but it can be determined with reference to the appropriate 95th percentile male dimension.

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

5.2.1.5 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

Poorly installed cables can present hazards, cause unintended motion of input devices, and/or limit device usage. The characteristics of cables to consider in the workstation configurations include length, weight, tension, flexibility, and location.

5.2.2 BENEATH THE WORK SURFACE

5.2.2.1 Leg and Foot Clearance

The installed system **shall**

- Provide adequate leg and foot clearance in the chosen reference posture or postures

The installed system **should not**

- Hinder the foot, leg, or knee in alternative or auxiliary (non-VDT) work positions

Providing adequate clearance under the work surface to allow users to change posture during work periods is a cardinal principle in human factors and ergonomics (Pheasant, 1986). *Adequate clearance* is defined as sufficient clearance to allow the user to assume the desired working position without unintentionally touching workstation components.

The important dimensions under a work surface are sufficient height for leg clearance; sufficient width for hip, leg, and foot clearance; and sufficient depth for knee and foot clearance. Chapter 8 (Section 8.3.2.0, Operator Clearances) gives dimensional specifications for leg and foot clearance necessary to accommodate a population ranging in size from a 5th percentile female to a 95th percentile male in all four of the reference positions.

5.2.2.2 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

A chair with a seat pan that is too high commonly results in a concentration of pressure on the popliteal area at the back of the knee (Chaffin & Andersson, 1984). Appropriate height adjustment and rounded edges on the front of the seat pan facilitate reduction of pressure in the popliteal area. When this is not feasible, as when there is an insufficient range of height adjustment to accommodate an individual, footrests can act to relieve the popliteal pressure by providing the needed support to the feet.

Footrests are necessary postural supports for users when the adjustment ranges of the chair, work surface, input device support surface, and display support surface do not allow the user's feet to be supported by the floor in the relevant reference postures. Moreover, adjustable footrest heights will accommodate a broader range of users and reference postures—the tallest footrest is determined by a female user with the smallest popliteal height sitting in a chair that is adjusted to its maximum seat height.

5.2.3 IN FRONT OF THE WORK SURFACE

5.2.3.1 Chairs

The chair used to support the user at the workstation **shall**

- Have a lumbar support
- Have a backrest that reclines
- Have a seat pan that adjusts for height and tilt
- Support at least one other of the seated reference postures in addition to the upright sitting posture
- Provide support to the user's back and thighs in the chosen reference postures

The system integrator **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

Utilizing a chair that complies with the specifications of Chapter 8, Furniture, allows the use of at least two of the three seated reference postures. This facilitates use of multiple working postures.

5.2.3.2 Chair Casters

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

- Be appropriate for the type of flooring at the workstation

Chair casters and flooring interact with one another to affect the mobility and safety of seated operators. Chair casters that are matched properly to flooring allow operators to change position without having to assist with their arms or to push so hard that the chair reclines. Mismatched chair casters and flooring increase users' efforts to push, pull, or maneuver the chair and may cause inadvertent chair movements while users are sitting down or rising. Generally, hard-wheel chair

casters are used on soft flooring, such as carpeting, whereas soft-wheel chair casters are used on hard flooring, such as wood, concrete, or tile. Regular maintenance of casters is critical for continued acceptable performance.

5.2.3.3 Chair Seat Pan and Backrest Adjustments

The seat pan of the chair used to support the workstation user **shall**

- Be height adjustable
- Have a user adjustment for tilt

NOTE: “User adjustment for tilt” is defined as any method of activating the movement of the seat pan/backrest. This can be either through the use of manual devices (levers, knobs, adjustments, etc.) or by movement of the body/body weight.

The seat pan of the chair used to support the workstation user **should**

- Be wide enough to accommodate the clothed hip width of a 95th percentile female
- Be of sufficient depth to allow the user’s back to be supported by the backrest without contact between the back of the user’s knee and the front edge of the seat pan
- Have a tilt lock or stop position that the user can select while seated, if a tilt lock is provided (a stop limits motion in one direction, whereas a lock limits movement in two directions)
- Have a rounded front edge

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

- Not constrain the user’s torso to a position forward of vertical
- Not force a torso-thigh angle less than 90 degrees
- Allow adjusting the angle between the backrest and seat pan to an angle of 90 degrees or greater
- Allow the user to recline at least 15 degrees from the vertical

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

- Allow the user to control the resistance necessary to recline the backrest
- Provide support to the lumbar and thoracic regions of the back

The chair **should**

- Have a means of adjusting the backrest tension

A seat pan that is too high precludes using the floor for support of the feet and legs. This commonly results in a concentration of pressure on the popliteal area at the back of the knee (Chaffin & Andersson, 1984). Appropriate height adjustment and rounded edges on the front of the seat pan facilitate reduction of pressure in the popliteal area.

Conversely, a seat pan that is too low raises the legs and thighs off the seat pan and concentrates pressure on a small portion of the buttocks overlying the ischial tuberosities (Chaffin & Andersson, 1984). A seat pan that is too low may also increase the likelihood of awkward postures such as arm

flexion, shoulder abduction, and reduced thigh-torso angles (hip flexion) and thereby degrade user comfort and/or performance.

Torso-thigh angles less than 90 degrees increase compressive loading on the disc of the spine, increase the loading on back muscles, and produce uncomfortable pressure concentrations on the thighs (Chaffin & Andersson, 1984). Similarly, provision of lumbar support decreases compressive loading of the spine (Chaffin & Andersson).

Seat pan and backrest adjustment characteristics vary among chairs. Some chairs have an automatic mechanism linking seat pan tilt with the backrest. In others, the user must independently adjust the angle for both.

The backrest's function is to support, or counteract, the force attributable to the action of gravity on the mass of the torso. Adjustments that increase or decrease the tension on the backrest allow it to act as a spring with variable stiffness, supporting greater or lesser amounts of torso weight. Tension adjustment is necessary to accommodate users with different masses and to accommodate user preferences as to how much of their torso weight the chair will support in the selected working posture. This is commonly achieved by means of a user-adjustable control, although some chairs may sense body mass and adjust backrest tension accordingly.

5.2.3.3.1 *Armrests*

If provided, the armrests of the chair used to support the workstation user **shall**

- 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 Section 5.2.1.1, User Postures

If provided, the armrests of the chair used to support the workstation user **should**

- Be adjustable in height
- Allow adjustment of the clearance width between the armrests
- Be detachable

This standard does not require the use of armrests on chairs but suggests leaving the decision of whether or not to utilize them with the user or system integrator.

Practically, sufficient clearance between the armrests allows the user's hips to pass between them while moving from sitting or standing without touching the armrests.

Support for the arms reduces the loading of the spinal and shoulder muscles (Chaffin & Andersson, 1984) and assists in entering or leaving the chair.

If the armrests are too high, they will force the user to raise and abduct the shoulders. Shoulder abduction increases the likelihood that the user will experience discomfort (Karlqvist et al., 1996).

Armrests that are too widely separated force the user to abduct the shoulder, increasing the likelihood of user discomfort. Similarly, armrests that are too high or too low commonly lead to awkward postures. Finally, armrests may be so large as to force the user to sit far away from the input devices, resulting in undesirable extended reaches and/or other awkward postures.

5.2.3.4 **Input Device Location**

For both seated and standing work, the input-device support surface **shall**

- Adjust in height, or a combination of height and tilt, to allow placement of the input device within the recommended space
- Provide adequate leg and foot clearance
- Provide adequate space for multiple input devices (e.g., keyboard and mouse)

For seated work, the input-device support surface **shall**

- Allow the user to work in at least **two** of the reference postures without compromising the postural design criteria described in Section 5.2.1.1, User Postures

If detachable, 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 three seated reference postures in addition to the standing reference posture described in Section 5.2.1 without requiring the user to violate the user postural criteria described in Section 5.2.1.1, User Postures

The recommended space for the location of input devices is a three-dimensional volume defined by reference to the user. The boundaries of the space are swept out by the user's forearm-hand length when the forearms are first held parallel to the horizontal plane and the included elbow angle is then allowed to vary between 70 and 135 degrees. 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 limits of the recommended space are determined by thigh clearance. The recommended space is illustrated in Figures 5-7a and 5-7b.

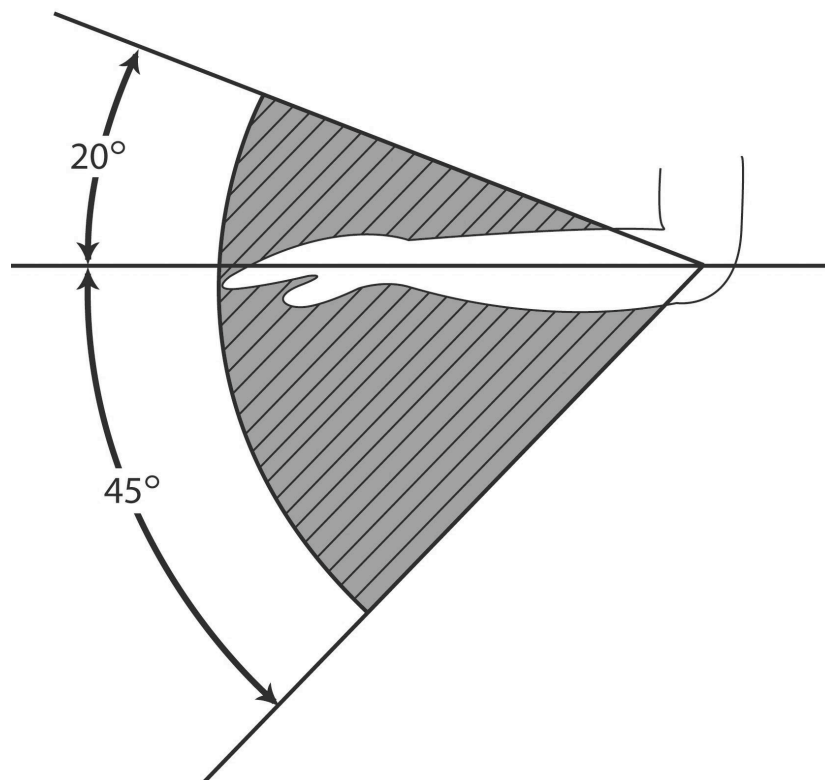


Figure 5-7a. Side view of recommended space (shaded area) for placement of input devices

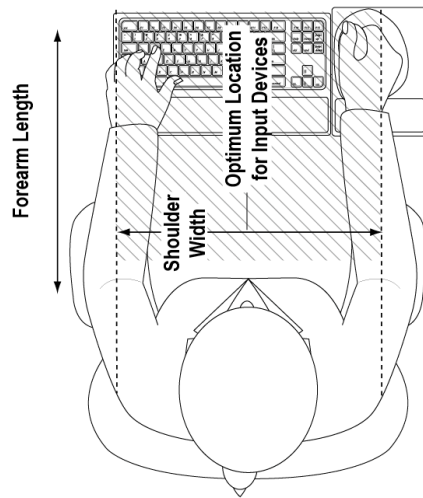


Figure 5-7b. Top view of recommended space (shaded area) for placement of input devices.

Research suggests that input devices are most comfortable to use and place less demand on the user when they are located so as to minimize shoulder abduction (Cook & Kothiyal, 1998; Harvey & Peper, 1997; Karlqvist et al., 1996; Paul & Nair, 1996). This is achieved when the devices are approximately located within the shoulder span of the user and within forearm reach. Similarly, users report equal comfort and productivity for a wide range of elbow angles (Cushman, 1984; Grandjean et al., 1983; Miller & Suther, 1981; Weber et al., 1984). Adjusting the height and tilt of support surfaces for input devices may be necessary to facilitate neutral wrist posture (Berqvist, Wolgast, Nilsson, & Voss, 1995; Hedge & Powers, 1995; Karlqvist, 1998).

This standard specifies a location for input devices. Work surface space, if used as input device support, would need to be at least wide enough to support the input devices in the recommended space but may be wider to accommodate other work tasks.

5.2.3.5 Arm and Wrist/Palm Supports

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

- Be provided for the user's forearms and/or wrists/palms
- Adjust in height and tilt
- Attain the wrist and arm postural design criteria specified in Section 5.2.1.1, User Postures

Research has indicated that these devices are beneficial to performance when configured and used properly (Andersson & Ortengren, 1974; Erdilyi, Sihvonen, Hilin, & Hanninen, 1988; Schuldt, 1988).

Opinions vary regarding the use of wrist/palm supports. However, rests for the wrist/palm and forearm have been shown to reduce muscle activity and to facilitate more neutral wrist angles when used

appropriately (Albin, 1997; Damann & Kroemer, 1995; Feng, Grooten, Wretenberg, & Arborelius, 1997; Grandjean, 1987).

Wrist/palm supports that are less than 3.8 cm (1.5 in.) deep (see Figure 5-8) may not be appropriate as they may cause increased contact pressure (Paul & Menon, 1994). Wide, flat surfaces (>3.8 cm; 1.5 in.) for wrist/palm supports are recommended.

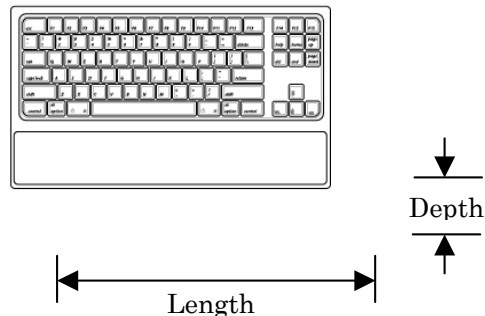


Figure 5-8. Nomenclature for wrist/palm support dimensions.

5.2.4 ON TOP OF THE WORK SURFACE

5.2.4.1 Horizontal Work Envelope

When located on the horizontal surface, the input devices **shall** be

- Located as specified in 5.2.3.4

The horizontal work envelope **should**

- Accommodate the user postural design criteria described in Section 5.2.1.1, User Postures
- Be at least 70 cm (27.6 in.) wide

The most commonly used objects **should**

- Be located in the primary work zone

The primary work zone (illustrated in Figure 5-9) is the shape swept out on the work surface by rotating the forearm horizontally at elbow height. Arm motions within this area reduce the physiological cost of movement and improve movement speed and accuracy (Konz & Johnson, 2000).

Space requirements must be determined by analyzing the task requirements. The suggested range of minimum widths for normal work activity is comparable to the 95th percentile male forearm-to-forearm breadth plus a 7.5-cm (3-in.) movement allowance. A work surface of minimum width would not be appropriate for tasks that require space for equipment other than the VDT.

This standard specifies a location for input devices. Work surface space, if used as input device support, would need to be at least wide enough to support the input devices in the recommended space but may be wider to accommodate other work tasks.

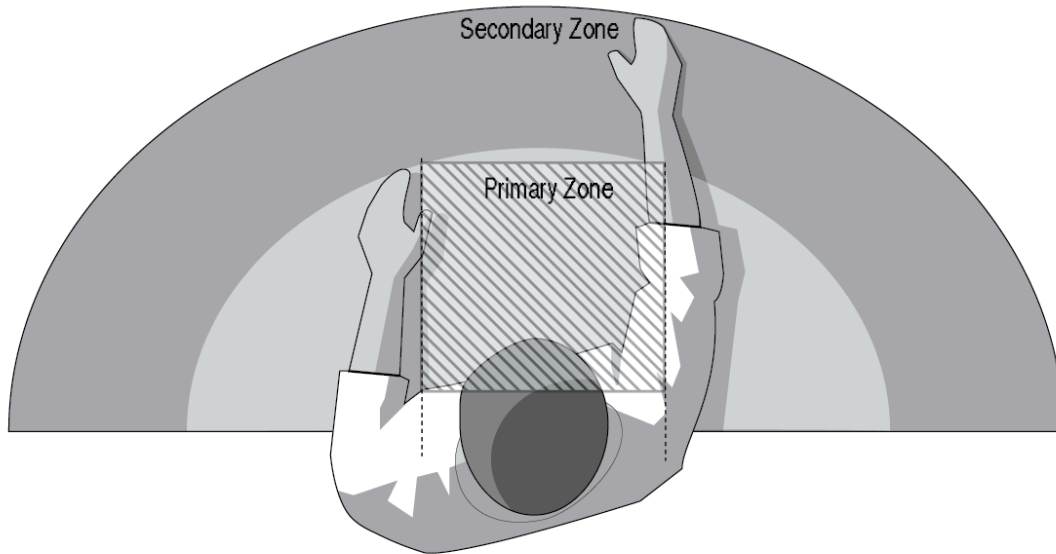


Figure 5-9. Recommended space for input devices and primary, secondary, and tertiary horizontal work zones.

5.2.4.2 Monitor Support Surface

The visual display support surface **shall**

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

The visual display support surface **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.)

Viewing conditions are based in part on the visual effort needed to accommodate and converge on the viewable display surface at close distances. Near work causes the eyes to converge and the lenses to accommodate. This causes the extraocular and ciliary muscles of the eye to contract and maintain contraction (Turville, Psihogios, Ulmer, & Mirka, 1998). This is thought to contribute to visual discomfort in VDT workers. Studies indicate that users with normal visual capabilities often report greater visual fatigue for viewing distances of 50 cm than for 100-cm viewing distances (Jaschinski-Kruza, 1990), and these observers often consider 50-cm distances too close (Jaschinski-Kruza, 1988, 1990, 1991).

These design limits, however, may need to be shortened for users of some flat-panel display workstations or for users with low visual capabilities, given that they may need closer viewing distances (even less than 40 cm [15.7 in.]) to achieve acceptable postures and viewing. Nevertheless, it is often advantageous to locate frequently viewed surfaces at or near the same optical distance to minimize visual fatigue.

Optimal viewing of a visual display is influenced by numerous factors in the workstation, such as the physical image quality of a monitor (resolution, addressability, pixel shape, subpixel arrangement, luminance and color contrast, viewable screen size), the screen information layout and font characteristics (typeface, font size), the user's posture (angular alignment to screen), visual capabilities (optometric corrections), and the ambient light conditions (screen illumination, glare, reflections). Display-support surfaces that allow adjustment of the alignment between the user and the viewable screen area during a work session are essential to achieving optimal viewing conditions.

A common approach to achieving optimal viewing conditions often begins by ensuring that the physical image quality of the screen is appropriate for the workstation environment. One important factor has been to ensure that the viewing distance allows alphanumeric characters rendered on the screen (in their primary or default font) to subtend at least 16 arc minutes of visual angle (2.3 mm at 50 cm viewing distance; 0.1 in. at 19.7 in.). This minimum character size is necessary to ensure legibility (Snyder & Maddox, 1978) and it should be increased to at least 20 to 22 arc minutes for readability.

5.2.4.3 Monitor Viewing Angle

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

- Be located 15 to 25 degrees below horizontal eye level

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

- Be located more than 35 degrees off axis (i.e., from the user's predominant line of sight) while the user is gazing straight ahead

The entire visual area of a visual display terminal 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 posture

The vertical height of a VDT screen represents a compromise between minimizing visual discomfort and musculoskeletal discomfort of the neck and shoulders. In general, lowering a screen or increasing the viewing distance will reduce visual discomfort. However, lowering the screen increases the loading on neck and shoulder muscles. Display screen height above eye level has also been associated with musculoskeletal discomfort.

Research findings indicate that viewers prefer downward gaze angles for near work (Heuer, Breuwer, Roemer, Kroger, & Knapp, 1991; Hill & Kroemer, 1986), whereas upward gaze angles—especially those involving backward tilting of the head—cause discomfort. Several researchers found that downward gaze angles lead to reduced eyestrain and visual fatigue (Owens & Wolf-Kelly, 1987; Tyrell & Leibowitz, 1990), improved accommodation and vergence for close work (Heuer & Owens, 1989), and reduced evaporation of the tear layer (Tsubota & Nokamori, 1993).

However, other researchers have found that gaze angles greater than 35 degrees result in increased muscle loading (Turville et al., 1998; Sommerich, Joines, & Psihogios, 2001). Long periods of work requiring sustained forward tilt of the head by 30 degrees or more can cause discomfort (Chaffin, 1973). Because users may not rotate their eyes comfortably more than 30 degrees downward (in relation to their head position) during sustained viewing, gaze angles lower than 60 degrees for long periods may cause discomfort.

Horizontal eye level to screen center angles of 15 to 20 degrees at distances of 75 to 83 cm (29.5 to 32.7 in.) appear to be a reasonable compromise (Sommerich et al., 2001). Allie, Purvis and Kokot

(2005) suggest placing the top of the viewing area 5 degrees below horizontal eye level, with the center of the screen 25 degrees below horizontal eye level is an appropriate “middle ground” between visual and musculoskeletal demands.

5.2.4.4 Document Holders

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 monitor screen
- Be stable when loaded with the intended materials

Adjustable document holders allow users to read and/or transcribe hard-copy materials without assuming awkward postures (Bauer & Wittig, 1998). Placing the hard-copy materials at a distance from and angle to the user similar to those of the monitor minimizes changes in visual accommodation and vergence, thereby reducing visual effort.

5.2.5 SURROUNDING THE WORK SURFACE

5.2.5.1 Illuminance

Workplace illumination **shall**

- Not degrade the image quality on the display

NOTE: Chapter 7 provides further information regarding image quality

Workplace illumination **should**

- Be sufficient for the effective performance of the required task
- Range between 200 and 500 lux (18.6 to 46.5 foot-candle) on the work surface for light-emitting displays

In general, ambient illuminance should be sufficient to support the visual tasks that will be done at the computer workstation or on associated paper documents. Reading blueprints, for example, requires relatively high illuminance on the document (as high as 1000 lux (93 foot-candle) to ensure comfortable viewing. A task light is a solution in such an instance. Task lights need to be positioned carefully to avoid causing glare on the computer display. An adjustable fixture that allows the user to change the direction of the light is recommended so that glare on the display is minimized.

Below 100 lux (9.3 foot-candle) , the user’s ability to read printed paper may be impaired. This finding is especially true for older workers, who need more light to read comfortably than do younger ones. Illuminance levels between 200 and 500 lux are sufficient for standard visual tasks (Illuminating Engineering Society, 1993). These tasks include reading printed text and text on a CRT display.

When specifying the illuminance levels at the workstation, it is important to consider the display technologies that will be used in those environments. High illuminance at emissive computer workstation screens, such as CRT displays, can reduce character contrast and impair visual performance. An upper limit of 500 lux for ambient lighting is recommended to maximize screen visibility for these types of displays (Illuminating Engineering Society, 1989, 1993).

Unwanted light may be controlled by positioning light sources, use of window shades, glare screens, and so forth.

5.2.5.2 Luminance Balance

Luminance from environmental sources in the user's field of view that are greater than 5 degrees of arc **should**

- Not exceed 10 times the average screen luminance for negative-polarity screens (bright characters on dark background)
- Not exceed 3 times the average screen luminance for positive-polarity screens (dark characters on bright background)

Correct luminance balance in a workstation allows comfortable viewing of the display. Properly balanced luminance sources produce a visual environment in which bright spots do not distract the user.

For negative-polarity screens, surround luminances that are brighter than the screen average luminance result in the best visual performance. Under these conditions, visual performance is not degraded until the background luminance approaches 100 times the average screen luminance. The best visual performance occurs when the background luminance is approximately 5 times the average screen luminance.

For positive-polarity screens, the best visual performance is obtained when the background luminance is approximately equal to the average screen luminance. Under these conditions, visual performance is not degraded substantially until the background is more than 20 times the average screen luminance.

5.2.5.3 Acoustical Noise

The maximum level of background noise emission from a computer workstation and its components **should**

- Have Balanced Noise Criteria (NCB) rating ranging between 38 and 43

The ideal general recommendation is to strive to achieve an NCB rating within the range as low as possible. Higher NCB ratings should be used only when economic circumstances dictate.

The NCB values given assume occupied spaces, with heating/ventilation/air conditioning (HVAC) operating and all other sources of normal and interior and exterior noise also operating (ANSI S12.2, 1999). These levels allow oral communication and provide an environment quiet enough to aid concentration on mental tasks. It has been shown that people normally raise their voices about 0.5 dB for every 1 dB increase in the background noise level (Kryter, 1985).

If the background noise levels are higher than desired, noise may be reduced by using carpeted floors, ceiling acoustical tiles, draperies, and sound-absorbing/isolating partitions or other sound-absorbing materials (Kleeman, 1991). Separating noise sources from the work environment with walls or partitions or by covering equipment with an acoustical enclosure also effectively reduces noise.

5.2.5.4 Mechanical Vibrations

The stability and function of computer workstation components **should not**

- Be impaired by vibration

Excessive mechanical vibration can adversely affect users' task performance as well as the intended operational levels of the computer workstation components. For example, mechanical vibrations of the visual display can reduce perceived image, and mechanical vibrations of furniture can loosen position adjustment settings. Mechanical vibrations can also cause unwanted noise in the work area.

Examples of vibration sources at computer workstations include components of the workstation (impact printers, cooling fans), structural features of the facility (air-conditioning systems), and nearby equipment and pedestrian traffic in the work area.

5.2.5.5 Contact Surface Temperature

Surfaces of the workstation components that the user is expected to touch with bare skin **shall**

- Not exceed the exposure times and temperatures for the surface materials listed in Table 5-1

Table 5-1. Surface Temperature and Contact Time

Material	Time/Temperature (degrees Celsius**)				
	1 s	4 s	10 s	10 min	8 h*
Unpainted metal	65	58	55	48	43
Lacquered metal	75	61	55	48	43
Enameled metal	70	60	56	48	43
Ceramic, glass, stone	80	70	66	48	43
Plastics	85	74	70	48	43
Wood	110	93	89	48	43

* Amount of contact area (more than 10% of skin surface area) or contact with vulnerable structures (such as the airways) invalidates the 8-hour values given here. From EN563 *Safety of machinery—Temperatures of touchable surfaces: Ergonomics data to establish temperature limit values for hot surfaces*.

** Degrees Celsius = 5/9 (Degrees Fahrenheit – 32)

Only a few surfaces of the computer workstation and its equipment present thermal contact hazards to users. Surfaces that are intended to be touched, such as the back panel of the computer and connector surfaces, need to be cool enough to avoid skin burns (Parsons, 1993). The values shown are from EN563 (1994).

5.2.5.6 Ambient Thermal Conditions

The ambient temperature **should**

- Range between 20° and 23.5° centigrade (68° to 74.3° Fahrenheit) during the heating season and between 23° and 26° centigrade (73.4° and 78.8° Fahrenheit) during the cooling season

The relative humidity of the air in the workstation **should**

- Range between 30% and 60%

The air velocity **should**

- Be less than 20 cm/s (7.9 in./s)

The rate of heat exchange between people and their surroundings is a major factor affecting alertness, comfort, and task effectiveness. The thermal parameters of the computer workstation are not significantly different from those for comfort at office workstations in general. However, any additional heat gain from the computer and its components needs to be considered when designing a computer workstation environment.

In workplaces with relative humidity below 30%, some computer users, particularly those wearing contact lenses, may report dryness of the eyes. This condition may be exacerbated by higher airflow