INTERNATIONAL STANDARD

ISO 11064-4

First edition
2004-07-01

Ergonomic design of control centres —

Part 4: Layout and dimensions of workstations

Conception ergonomique des centres de commande —

Partie 4: Agencement et dimensionnement du poste de travail

Reference number
ISO 11064-4:2004(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11064-4 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

ISO 11064 consists of the following parts, under the general title *Ergonomic design of control centres*:

— *Part 1: Principles for the design of control centres*

— *Part 2: Principles for the arrangement of control suites*

— *Part 3: Control room layout*

— *Part 4: Layout and dimensions of workstations*

— *Part 5: Human-system interfaces*

— *Part 6: Environmental requirements for control centres*

— *Part 7: Principles for the evaluation of control centres*

Introduction

This part of ISO 11064 establishes ergonomic requirements, recommendations and guidelines for the design of workplaces in control centres.

All types of control centres are covered, including those for the process industry, transport and dispatching systems or emergency services. Although this part of ISO 11064 is primarily intended for non-mobile control centres, many of the principles are relevant to mobile centres such as those found on ships, locomotives and aircraft.

User requirements are a central theme of this part of ISO 11064 and the processes described are designed to take into account the needs of users at all stages. The overall strategy for dealing with the user requirements is presented in ISO 11064-1. ISO 11064-2 provides guidance on the design and planning of the control room in relation to its supporting areas. Requirements for the layout of the control room are covered by ISO 11064-3. Displays and controls, human computer interaction and the physical working environment are presented in ISO 11064-5 and ISO 11064-6. Evaluation principles are dealt with in ISO 11064-7.

The ultimate beneficiaries of this part of ISO 11064 will be the operator within the control room and other users. It is the needs of these users that provide the ergonomic requirements that are addressed by the International Standards developers. Although it is unlikely that the end user will read this International Standard, or even know of its existence, its application should provide the user with interfaces that are more usable, and a working environment which is more consistent with operational demands and result in a solution which will improve system performance and will minimize error and enhance productivity.

Ergonomic design of control centres —

Part 4:
Layout and dimensions of workstations

1 Scope

This part of ISO 11064 specifies ergonomic principles, recommendations and requirements for the design of workstations found in control centres. It covers workstation design with particular emphasis on layout and dimensions. This standard covers primarily seated, visual-display-based workstations although sit/stand workstations are also addressed. These workstations are to be found in applications such as transportation control, process control and security installations.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9241-3:1992, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 3: Visual display requirements*

ISO 9241-5:1998, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 5: Workstation layout and postural requirements*

ISO 9355-2:1999, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

ISO 11064-3:1999, *Ergonomic design of control centres — Part 3: Control room layout*

ISO 11428:1996, *Ergonomics — Visual danger signals — General requirements, design and testing*

3 Terms and definitions

For the purposes of this part of ISO 11064, the following terms and definitions apply.

3.1
control workstation
single or multiple working position, including all equipment such as computers and communication terminals and furniture at which control and monitoring functions are conducted

[ISO 11064-3:1999, definition 3.7]

3.2
cone of fixations
angular extend to which the line of sight can be swept by rotating the eyeball in the skull while the head rests

3.3
legibility
visual properties of a character or symbol that determine the ease with which it can be recognized

[ISO 9241-3:1992, definition 2.17]

3.4
line-of-sight
line connecting the point of fixation and the centre of the pupil

[ISO 9241-3:1992, definition 2.18]

3.5
nearpoint
nearest viewing distance to which the eye accommodates

3.6
normal line-of-sight
inclination of the line-of-sight with respect to the horizontal plane, when the muscles assigned for the orientation of the eyes are relaxed

3.7
percentile
percentage of population of which specific characteristics fall below or are equal to a given value in a cumulative distribution

3.8
reach envelope
three-dimensional space in which an operator can comfortably reach and manipulate controls by either hand while assuming a posture normally anticipated for the task

3.9
task zone
space determined by the equipment and activities required for the conduct of a particular task

3.10
visual angle
angle subtended at the eye by the viewed object, e.g. a character or symbol

3.11
visual field, field of vision
physical space visible to an eye in a given position

[ISO 8995:1989, definition 3.1.10]

NOTE 1 In this standard the use of both eyes is assumed for visual field considerations.

NOTE 2 The position of the visual field depends on the direction of the line-of-sight.

NOTE 3 Separate, distinct stimuli in the visual field will be detected even if they appear simultaneously.

NOTE 4 While the extent of the visual field is approximately ± 35° around the line-of-sight, only 1° ... 2° of these are for sharp vision.

3.12
work environment
physical, chemical, biological, organizational, social and cultural factors surrounding a person in his or her work space

[EN 614-1:1995, definition 3.5]

3.13
work space
volume allocated to one or more persons in the work system to complete the work task

[EN 614-1:1995, definition 3.4]

3.14
workstation
combination of work equipment for a particular person in a work space

[ISO 11064-2:2000, definition 3.5]

NOTE It is possible that several persons share a particular control workstation, or that several persons alternate several workstations within any period of time (i.e., on an hourly, daily, weekly basis).

3.15
work task
task
activity or activities required to achieve an intended outcome of the work system

[EN 614-1:1995, definition 3.2]

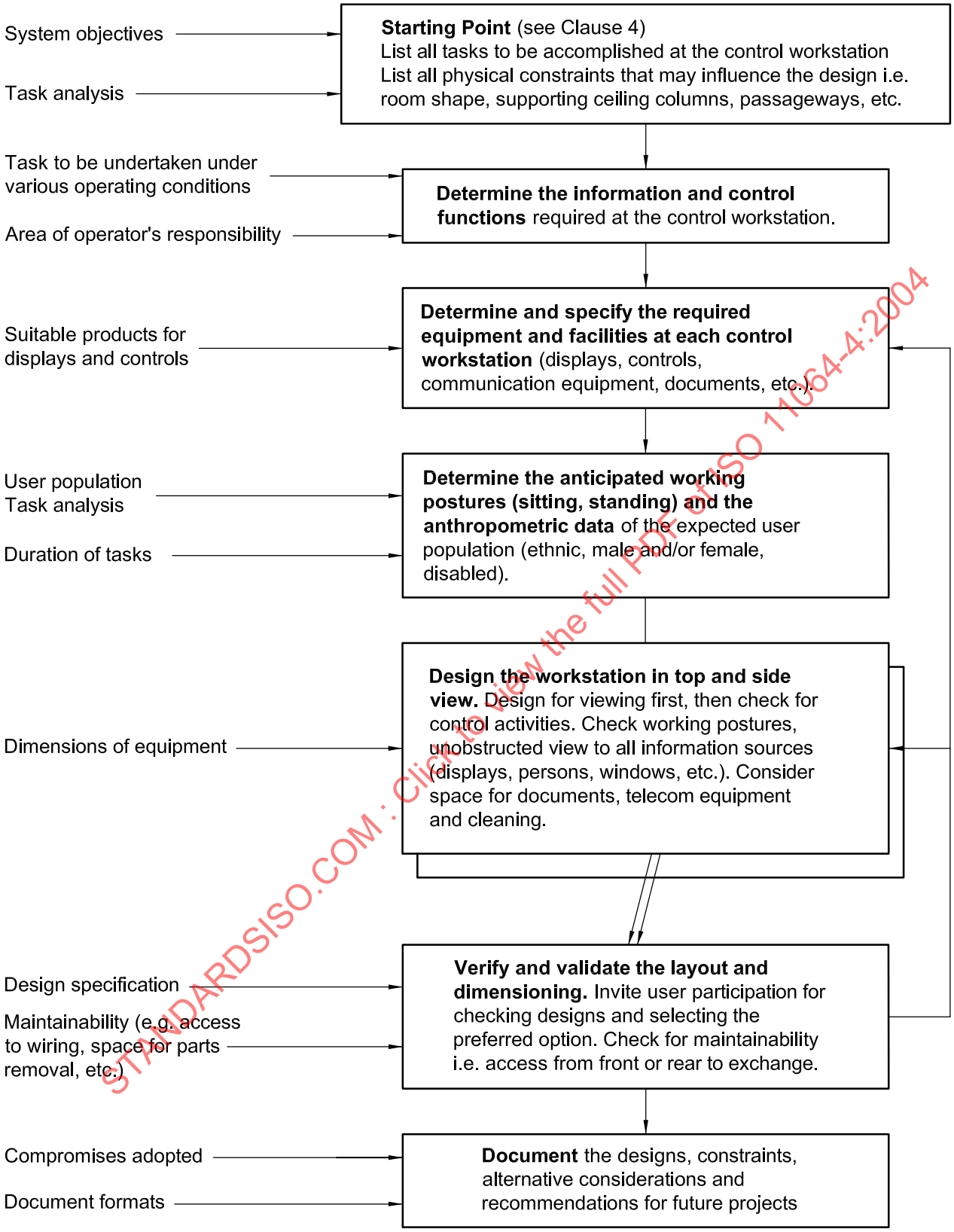
4 Initial workstation layout considerations

The starting point for control workstation design (shape and dimensions) is a list of work tasks and related work characteristics. The human operator may need certain facilities, such as displays, input devices, and communication equipment. Work space may also be required for special control-room-related tasks such as paper work. For each task, a compilation of the requirements of the associated devices is needed. By taking account of job designs, task zones are combined together into control workstation arrangements. The grouping of control workstations into control room layouts is discussed in ISO 11064-2 and ISO 11064-3.

Requirements identified for each task zone are inputs for detailed engineering of workstations.

The following iterative procedure, outlined in Figure 1, can be used as a systematic approach to designing workstations. The order of stages may vary according to the design situation.

A systematic approach to designing workstations is presented in Figure 1. The sequence of stages involved in this process may vary as a result of iterations and this may have an impact on the appropriate tasks, which need to be undertaken at each stage.



NOTE Each design stage in the process may result in a feedback loop to one of the earlier steps.

Figure 1 — Control workstation design steps

5 Factors determining control workstation design

This clause is mainly concerned with control workstations with one or more visual displays, communication tools and space for administrative functions and documentation.

5.1 User population

Workstations shall be designed to accommodate from the 5th to the 95th percentiles of the intended user population. When considering the user population, account shall be taken of all features likely to be exhibited by the intended users including gender, age, ethnic backgrounds and disabilities, e.g. if users are expected from both genders, consider the anthropometric data of the 5th percentile women up to 95th percentile men.

5.1.1 General user considerations

Workstations shall be designed according to human capabilities, limitations and needs. Consequently, the design shall take into consideration the characteristics of the user population including working postures, visual and aural needs, reach envelopes and their collective influences on workstation layout and dimensions.

5.1.2 User requirements

The layout and dimensioning of control workstations shall be governed by the anthropometric dimensions of the user and any requirements for movement to accomplish their tasks. Anthropometric data are usually given in terms of percentiles.

General anthropometric requirements are the following.

a) The percentile values referred to in this part of ISO 11064 shall be computed from the set of anthropometric data of the expected user population.

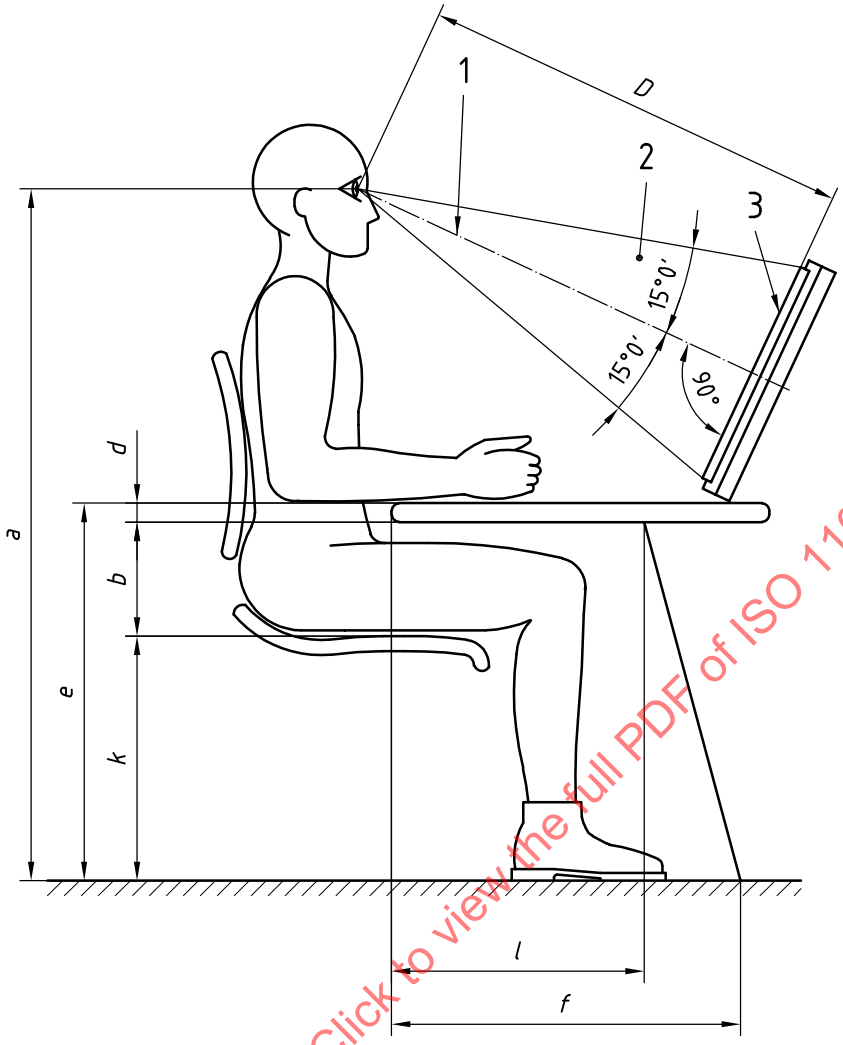
b) Control workstation dimensions shall accommodate at least a range from the 5th to the 95th percentile of the user population.

c) The following anthropometric data shall be used to primarily determine the control workstation dimensions:

   — Reach envelope: 5th percentile of the user population, e.g. reach to critical dimensions.

   — Clearances: 95th percentile of the user population, e.g. clearances under worksurfaces.

The key anthropometric dimensions for consideration of a seated operator are shown in Figure 2. Any design solution selected should not unnecessarily disadvantage members presenting extreme anthropometric dimensions of the user population. Design parameters proposed should be checked against the relevant characteristics of the user population.



Key

1 normal line of sight
2 optimal cone of fixations (i.e. allows fixation of any position just by eye movement, no head movement required)
3 display
D viewing Distance
a eye height
b thigh clearance
d desk thickness
e elbow/surface height
f feet clearance
k popliteal height
l upper leg clearance

NOTE For details see 6.2.2, 7.1 and 7.2.

Figure 2 — Illustration of the key anthropometric dimensions of a seated control console

EXAMPLE

For standing vertical panels, controls should not be so low that the standing-tall user must stoop to reach down to them.

— In those cases where no clothing allowances are specified in the anthropometric database, the dimensional effects of footwear and clothing shall be considered.

— The effects of different postures shall be considered. (See Figure 3 for the effects on reach envelopes and clearances based on different postures.)

If it is impossible to cope with this range from the 5th percentile to the 95th with a fixed control workstation, an adjustable workstation shall be considered.

It may be necessary to combine anthropometric data though caution should be exercised when doing this.

Usually the native anthropometric data set is based on “nude” subjects. Some data sources, however, include clothing allowance on certain dimensions.

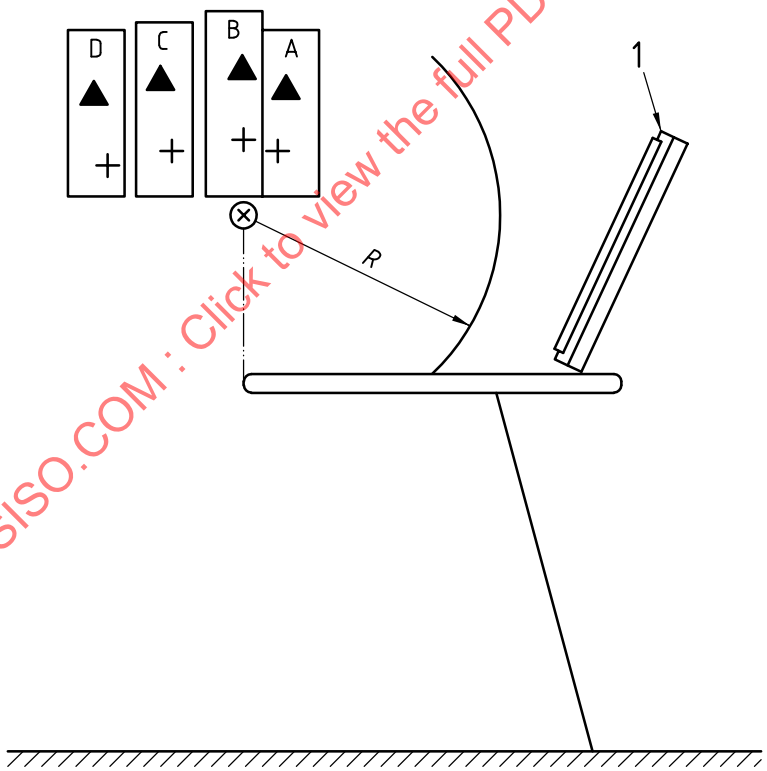
Another allowance concerns the so-called slump factor (a correction made to data collected in an erect posture). The slump factor is an attempt to simulate more natural and relaxed postures. In some sources, this factor is included, in others this is not the case. Therefore, data sources should be checked carefully before being applied.

Typically, control workstations will be operated by multiple users who might exhibit a range of anthropometric features. Control workstation design and layout should take account of this variable user population.

Adjustability should be considered for those workstation-related dimensions which do not accommodate the 5th to 95th percentile users. This might be achieved by adjustable desk heights, the foot clearances, viewing distances, or the orientation of displays.

— Adjustable control workstations should be considered to accommodate at least a range from the 5th percentile to the 95th percentile of the determining body dimensions of the user population (see 7.2).

— Adjustment devices should be easy and safe to use from a seated position.



Key

1 display

▲ eye-point of the 95th percentile dimensions, see Table 1

\+ eye-point of the 5th percentile

⊗ shoulder joint of the 5th percentile bent forward

A eye-points in “bent forward” posture

B eye-points in “erected” posture

C eye-points in “reclined” posture

D eye-points in “relaxed” posture

R handreach of the 5th percentile

Figure 3 — Seated work postures corresponding to Table 1

5.2 Visual tasks

The basic visual tasks are “Detection” and “Identification” (see A.3).

5.2.1 General visual considerations

When arranging displays, the following factors and their interrelationship should be taken into account:

a) The eye heights which depend on

- anthropometric data of the user population, and
- the postures (cf. Figure 3 and Table 2) of the users while accomplishing their tasks (e.g. monitoring, interacting).

The influence of work surface adjustability, i.e. chair height on the eye height, shall be considered. Refer to the appropriate anthropometric data set for input to the calculations.

b) Viewing distances should be chosen taking full account of

- eye strain,
- the nearpoint of the eye,
- the visual angle required to identify the characters on the screen, and
- the task.

c) The normal line-of-sight (see Table 2).

NOTE See Annex A for guidance on determining the arrangement of control workstation displays.

5.2.2 General visual recommendations

Accurate identification of a character depends on its legibility (its contrast, font style, colour, size, etc.), as well as the viewing distance (see Annex A for further details):

- The viewing distance shall be based on the following considerations concerning character height.
- For VDUs, the minimum height of monochrome Latin characters shall subtend 15 minutes of angle (in accordance with ISO 9355-2). Recommended Latin character heights are, however, 18 to 20 minutes of angle (in accordance with ISO 9241-3). For a quick approximation, the following calculation shall be used:
  - Maximum viewing distance (for rectangular view on the middle of a display area) = 215 × Latin character's height

  NOTE For a detailed calculation of the arrangement of displays, see Annex A.

  - Character height is given by the height of capitals and numerals of the smallest font size in use on the screen.
- Viewing distance, for identification of characters and symbols, shall be > 500 mm, since large groups of users (for instance older users without spectacles) will have difficulties to accommodate their eyes to shorter distances.
- For minimizing eye strain, the viewing distance should be 700 mm or greater (see Bibliography [9]). Larger viewing distances improve depth of focus.

NOTE Typically, control workstations need to accommodate writing areas, keyboards, phones and communication equipment, etc. in front of the display. For this reason, larger viewing distances may be required which would have an impact on, for example, font sizes, display formats.

Assuming a reclined seated position, the normal line-of-sight is straight forward in the horizontal plane and approximately 15° below the horizontal in the vertical plane (see Table 1). This is the starting point for the following requirements:

— Displays (see ISO 11064-3) requiring frequent or critical monitoring (e.g. operator working screens) shall be arranged in front of the operator in the primary display zone. The primary display zone, when the line-of-sight direction is not imposed by external task requirements, is in the vertical plane within an angle of 40° above and below the normal line-of-sight. In the horizontal plane, this range will be approximately 35° left and right of the line-of-sight for monitoring tasks (see ISO 11428) and more if head and body movement are taken into account.

— Where information from off-workstation displays (such as large screens, wall and mimic panels, etc.) is required for the operator's task, this shall be fully visible from all expected working positions in the control room (see ISO 11064-3).

5.3 Auditory tasks

5.3.1 General auditory considerations

Control workstations may be equipped with a variety of sound-generating devices. They may be used in alerting operators to normal (e.g. feedback, phone) and abnormal events, providing feedback to keyboard operations, and conveying person-to-person messages. Unlike the visual systems that require direct lines of sight to be effective, audible devices, e.g. speakers, bells, buzzers, etc. can be mounted in a variety of locations and still be effective in conveying information to the operator. The location of the devices is often governed by operating practices, areas of responsibility, shared or dedicated control workstation allocations, etc.

5.3.2 General auditory requirements and recommendations

General aural requirements and recommendations include the following.

— Sound-producing devices shall be located and mounted such that their function is not compromised.

— Where alarm indications can be provided by other than auditory means, silencing may be permissible. Silencing should be possible from the normal working position of the operator.

— Global silencing, i.e. silencing from any one workstation where multiple workstations exist, may be employed depending on specific operational and safety practices.

— It shall be possible to readily associate a particular audible signal with a unique workstation in multiple control workstation configurations.

— Use of spatial separation to aid identification when multiple auditory sources are present.

— The impact of background noise should be considered when designing auditory alarms (see ISO 11064-6)

5.4 Working postures

5.4.1 Posture considerations

An operator assumes several postures while accomplishing a task, seated, standing and alternating between seated and standing positions. The design implications of these alternatives on general workstation arrangements are presented in Clause 7.

As a general principle, seated workstations are appropriate for lengthy periods of operation and standing control workstations for occasional use. Sit-stand control workstations may provide an alternative solution when the duration of the anticipated tasks is taken into account and a standing-only control workstation is not appropriate. The ergonomic requirements are determined by the nature of the task and operators needs for postural change. As an overall principle, any solution should allow for postural variation. See Table 1.

Table 1 — Ergonomic requirements for workstations

Ergonomic requirements		Type of workstation to be considered
Posture	Duration	
Sit	Continuous	Seated workstation
Sit and stand	Mainly seated with occasional standing	Sit/stand workstation
Sit or stand	Mixture of tasks of variable duration	Adjustable workstation
Stand	Continuous	Stand workstation

This clause considers also the postures associated with the seated operating condition.

When a seated posture is adopted, this may include *bent forward* (monitoring at a high level of attention), *erect* (typing, operating controls), *reclined* (monitoring) and *relaxed* (monitoring) postures. See Table 2 and Figure 3. Table 2 shows the effect on the operator's eye position as a consequence of varying postures; the actual dimensions to be used shall be derived from the anthropometric data of the intended user population. There are corresponding effects regarding reach envelopes, body clearances, etc.

5.4.2 Posture requirements and recommendations

General posture requirements and recommendations include the following.

— The design shall accommodate the different viewing distances and the inclination of the normal line-of-sight for the varying postures.

— The reach envelope should accommodate the bent forward and erect postures only.

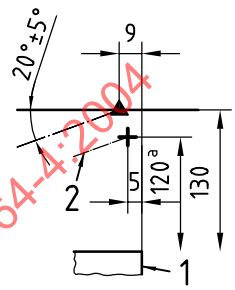
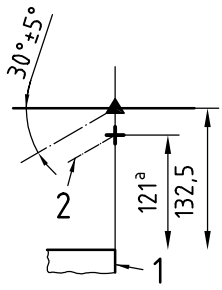
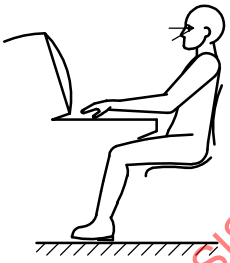
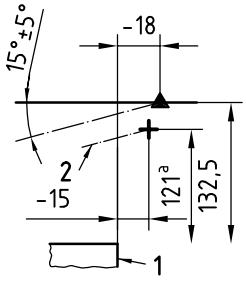
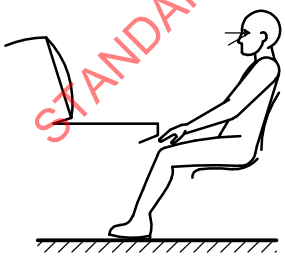
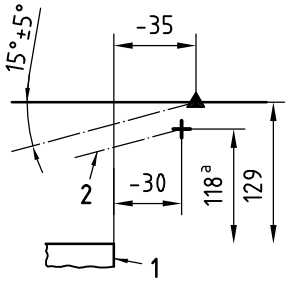
— The leg clearance should accommodate a 120° knee bend and a 10° ankle bend.

— Chairs shall be height-adjustable. For details concerning control room operator chair requirements, see ISO 9241-5.

— Adequate forearm support should be provided.

The quality of chairs used, and their durability, should take into account that operator chairs are normally used 24 h a day, 7 days a week.

Table 2 — Operations and postures

Posture	Normal line-of-sight inclination	Corresponding operations	Remarks	Eye position ▲ 95th percentile + 5th percentile examplar data*
A: Bent forward 	20° ± 5°	Monitoring at high level of attention. Operation of controls.	— Shoulder joint above edge of console — applicable for short periods of time — max. handreach determined by the 5th percentile	
B: Erect 	30° ± 5°	Typing. Handwriting. Operation of controls.	— handreach of the 5th percentile up to 50 cm from the edge of the console — eyes just above the edge of the console	
C: Reclined 	15° ± 5°	Monitoring	— eyes up to 18 cm (95th percentile) away from the edge of the console	
D: Relaxed 	15° ± 5°	Long-term monitoring. Talking to others	— eyes up to 35 cm (95th percentile) away from the edge of the console	

Key

1 Edge of the console

2 Normal line-of-sight

a Above floor.

6 Control workstation layout

Control workstation layout shall take account of the tasks to be carried out at the workstation. In addition to the task analysis, such design considerations as user population, working postures, equipment to be housed, etc. will dictate the physical shape and dimensions of the workstation.

6.1 General layout considerations

6.1.1 Displays

The arrangement of particular task areas and equipment should consider both the horizontal (plan view) and vertical (elevation view) planes. The resulting work space bounded by these horizontal and vertical planes should be located central to the position of the operator. In practice, the operator shall not be required to fixate in one location. The overall design should accommodate the operator's visual, tactile, and aural needs in relation to the display, control and communication tasks, as well as consideration for operator's physical postures, e.g. sitting, standing, etc.

Emphasis should be placed on centrally locating those visual displays and indicators that present primary information. The same is true for most frequently used displays or those associated with high-priority information such as alarms, overviews, interactive control displays, etc. The method given in Annex A covers all these aspects in combination. Care should be given to avoid distractions, while at the same time making secondary information accessible in a convenient way.

— Viewing angles should be assessed at various vertical and horizontal planes to verify compliance with those recommended in relation to the operator's working position and postures (see Annex A). The operator should preferably look directly at the centre of the primary information and towards the frequently used ancillary equipment, i.e. pushbutton/switch arrays, security systems, etc.

If the operator is temporarily at a secondary location [i.e. discussion, desk (administrative tasks), printer, etc.], he should be able to look back at primary displays.

Control workstations equipped with multiple displays, i.e. typical table top or console mounted VDU´s (CRTs, Flat Panel LCDs) etc., require special attention regarding placement and layout.

The maximum number of displays which can be used at a single control workstation is a major consideration which shall be based on a task analysis. It is generally considered that, from a dedicated operator's working position, and with current technology, not more than 4 displays (of up to 25 inch diagonal) can be satisfactorily monitored and operated. Where monitoring of the general situation is concerned, it may be possible for an additional number of monitors to be viewed, though this would be likely to involve the operator moving away from the front edge of the control console. Where there is a need to monitor and operate more than 4 displays, a secondary work position may need to be provided alongside the main position. This ensures acceptable viewing angles relative to shared controlling devices such as keyboards, mouse, trackballs, etc. Where the operator has no fixed location, more displays may be placed in a row and still ensure acceptable legibility. The cross-section analysis described above may suggest employing a curved or segmented design.

A full range of operational scenarios, e.g. start-up, shut-down, disturbances, outage operation, etc., should be considered when determining the quantity and arrangement of the displays and associated controls.

The selection of display types and quantities has an impact on the control workstation layout. Attributes such as size, weight, heat dissipation, electromagnetic interference/radio frequency interference susceptibility, etc., are factors to consider when selecting display technology for a control workstation.

The use of wall-mounted displays and their associated visual requirements are covered in ISO 11064-3. In general, any large wall-mounted or projected display may be used for primary or secondary information and its design and specification should take account of the information presented on associated control workstations as well as any constraints created by the vertical dimensions of these workstations.

6.1.2 Controls

A variety of technologies may be incorporated into the control workstation's design to enable an operator to exercise control over the displayed data, input of data and text, or the manipulation of control states, modes, etc. Commonly implemented technologies include fixed and variable function keyboards, touch-screens, mouse, trackballs, voice-actuated controls, light pens, conventional controls, etc. Depending on the specific task requirements and frequency of use, one or more input techniques may be more suitable than others. Requirements and guidance on the selection and application of various input technologies can be found in ISO 11064-5.

6.2 Layout requirements

6.2.1 Displays

Display characteristics, including contrast, flicker, jitter, character-font and -size, all contribute to legibility. Apart from legibility, the viewing conditions like viewing distance, ambient lighting, etc. (see Figure A.1) determine the operator's perception of information. For a first assessment, see 5.2.2. There are several principles for locating displays on control workstations:

— Table-top displays; it should be possible to tilt and swivel the display screen.

— Built-in displays; built-in displays have fixed orientations. When carefully designed in terms of anthropometric data and viewing conditions (see Annex A), this solution may be acceptable.

— The arrangement of the displays should consider operator tasks which may require access while sitting, standing or both.

— Preferably, the user should be able to adjust the control workstation easily to ensure a good working posture.

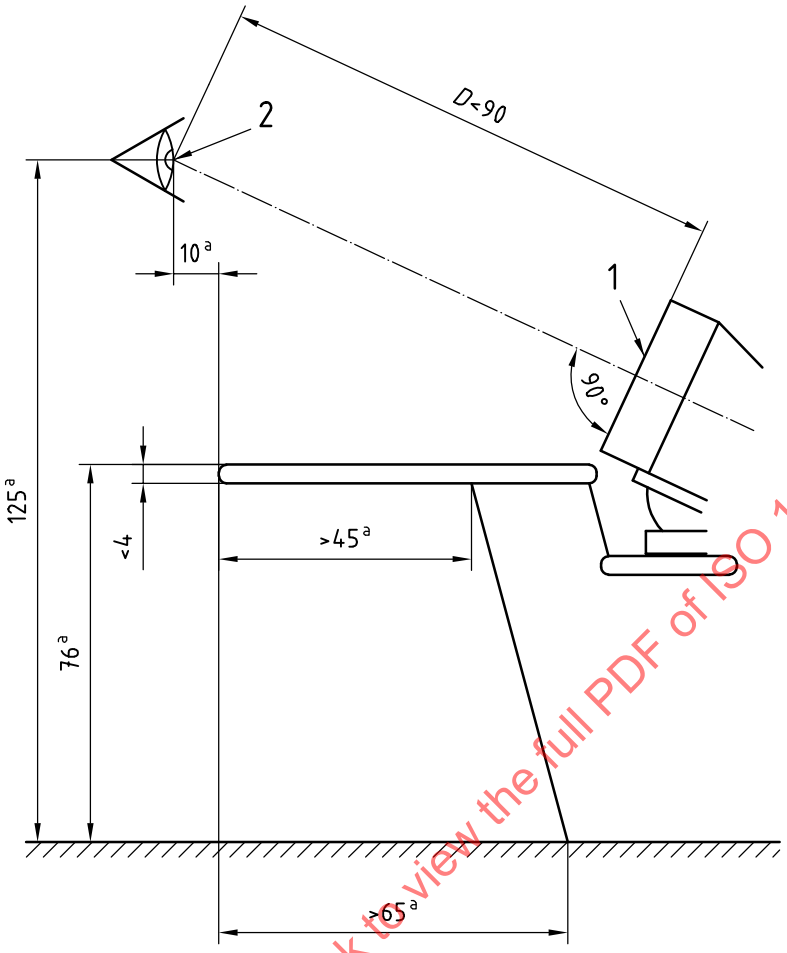
— In the case of a non-adjustable working height, special attention should be given to the vertical position of the displays. Important factors are eye height, viewing distance, field of vision, cone of fixations and normal line-of-sight. For the combined impact of all these factors, see Annex A.

— Annex A should be used as an approach to determine the position of single and multiple display screens.

In order to match the *normal line-of-sight* (see Table 2) when large display screens are employed, it may be necessary to place the screen at a lower level than the work surface (see Figure 4).

It is recommended that the design be planned such that it can accommodate future changes and additional equipment.

Dimensions in centimetres



Key

1 monitor 21“ diagonal

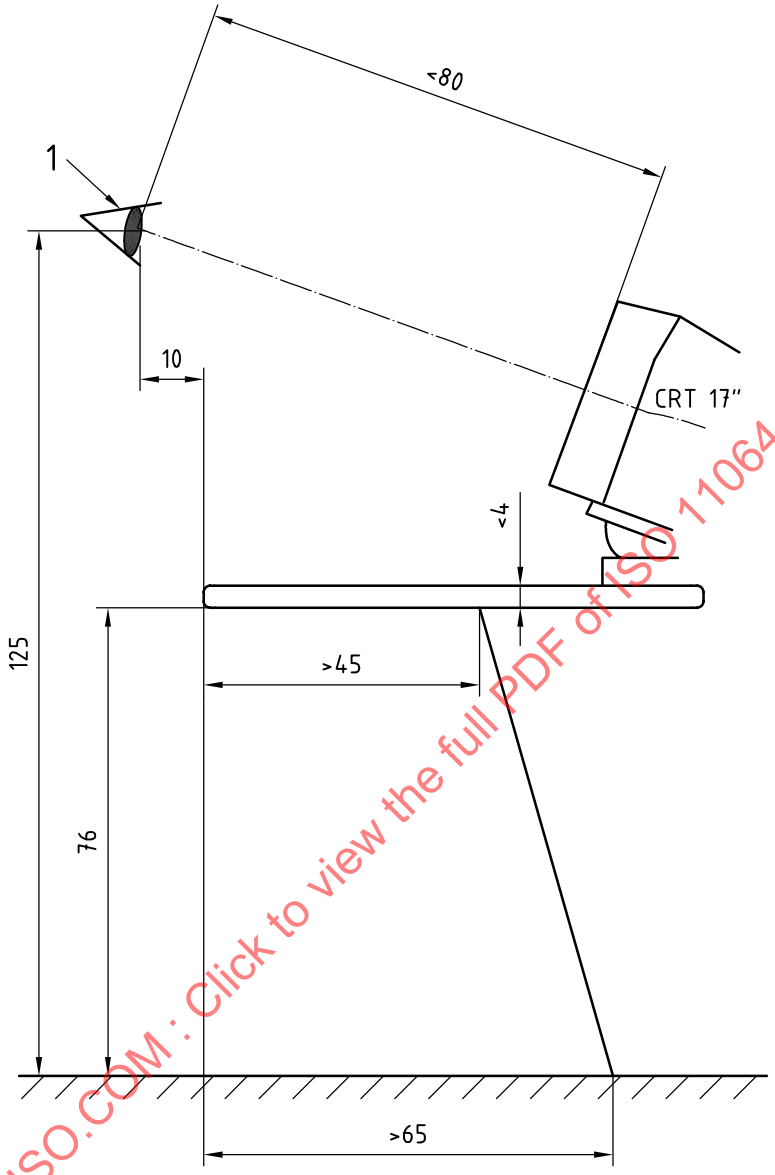
2 design eye-point

D viewing distance

a Examples; the values of the anticipated user population shall be applied.

Figure 4 — Example of dimensions for a seated control workstation

Dimensions in centimetres



Key

1 design eye-point

Figure 5 — Example of dimensions for a standing control workstation

6.2.2 Controls

There are several principles for locating controls on control workstations:

a) Keyboards should preferably be located in the centre of the operator's usual work space. This could be in front of a single display or centred between two displays as determined by the task analysis, information allocation, etc.

b) If movable keyboards are used, sufficient space should be provided to allow swivelling of the keyboard around a vertical axis 30° in a clockwise or counter-clockwise direction from normal (60° total).

c) Other keyboard requirements shall include

— inclination: 5° to 15°,

— height (front side): < 20 mm,

— height above work surface (middle row): ⩽ 30 mm,

— distance between key top: 17 mm to 19 mm

d) A minimum space of 150 mm deep and the width of the keyboard shall be available for supporting the operator's forearms and wrists in front of the keyboard.

e) The control workstation design shall be “ambidextrous” as far as the placement of one-handed devices such as a mouse, trackball, etc. There shall be adequate space and cabling facilities to place such devices to the left or right of the user.

f) Similar ambidextrous requirements shall be considered for “mouse-only” control workstation designs. Other requirements include the following.

— A space shall be available for placement of a 200 × 240 mm mouse pad. The space shall allow for swivelling of the mouse pad around a vertical axis 30° in a clockwise or counter-clockwise direction from normal (60° total).

— A minimum space of 150 mm depth and the width of the mouse pad shall be available for supporting the operator's forearms and wrists in front of the mouse pad.

Where controls can be moved to suit left or right-handed operation, these controls should be adaptable to right respectively left-hand use. For example the buttons must be reconfigured on the mouse/trackball so that the index finger is doing the traditional “right click” functions and the other buttons for the lesser functions.

As a practical matter, most left-handed users become quite adept at using right-handed mouse/trackballs. In fact, they are often at an advantage in that they are able to use the mouse and still write with their preferred hand if their task involves both computer input and checking off or writing on paper copy.

A far more serious concern is that left-handed users are apt to forget to change their mouse/trackball configuration back and the next right-handed user may have problems using the input device.

g) Space for track-ball operation shall be provided and comply with the same requirements as for a mouse regarding forearm support and arcs of rotation.

h) The use of shared devices, i.e. one keyboard, mouse, etc. for multiple display devices, is preferred over having dedicated keyboards for each display device. Ideally, the system software should self-select the controlled display as the pointing symbol (cursor) is moved from one display to the other. In some instances, it may be advisable, for safety reasons, to have a dedicated control for each display. In this case, these controls shall be unambiguously related to their associated displays.

i) Input devices shall not compete for work surface space with other items such as telephones, operating manuals, log books, etc. These items should have their own space as dictated by their physical size, frequency of use, emergency priorities, etc. Other considerations include

— possible need for task lighting for printed materials,

— suitable placement of devices within the anticipated reach envelopes,

— possible shielding of any light-generating devices to prevent glare or annoying distractions.

j) Frequently used controls should be within reach of the operator working in an erect work posture and from the expected work locations at the console (see Figure 3). For engineering purposes, it suffices to use as an approximation the 5th percentile armreach minus 50 mm (grasping compensation).

k) Frequently used controls shall not be positioned above the shoulder height of the 5th percentile user.

l) Input devices (controls, keyboard, mouse, telephone) should preferably be freely moveable over the work surface in front of the displays (see ISO 9241-3). They may be built-in, if there are special requirements (e.g. vibration, earthquake conditions).

m) The height of keyboards, mice, trackballs and other input devices should be approximately at or below the elbow height (see ISO 7250) of the seated operator.

n) In positioning emergency controls, the time allowed for between alarm and activation by the operator shall be taken into account.

o) Emergency controls shall be protected against accidental activation.

6.2.3 Other workstation tasks

A console may have to accommodate task zones for administration, documentation, communication, training on-the-job and/or supervisory tasks.

Usually, several other types of task zones on workstations are located in a control centre; these may give rise to requirements including space for the layout of drawings, short meetings or coffee breaks for example.

Should permit handling be required, the precise needs should be established by a task analysis. Where a counter is required, its height shall be based on the elbow height of a standing, small operator (5th percentile).

6.2.4 General

Other general requirements and recommendations are as follows.

— Layout of a workstation shall take into account: access requirements (for maintenance) and cable management. In the case of table-top VDUs, input devices and communication equipment access for maintenance (or instrument exchange) shall always be straightforward. In the case of built-in equipment, easily removable access panels, or free space around the devices, etc. should be considered.

— The requirements for future change, e.g. spare space for additional equipment, modified working practices and task allocations, etc., should be considered.

— Safety and stability of the workstation (such as the risk of structural failure or excessive heat conductivity of work surfaces) shall be taken into account (refer to ISO 9241-5).

7 Control workstation dimensions

7.1 Dimension considerations

The aim of this clause is to give guidance on the dimensioning of control workstations. Emphasis is on designs for seated operators. Many of the same principles, i.e. reach envelopes, viewing angles and distances, etc., apply to all the options of seated only, sit-stand and standing control workstations. This clause does not aim to describe all possible solutions in full detail.

7.2 Seated control workstations

For a workstation for seated postures, the following dimensions are significant (see Figure 2). They include

— vertical, horizontal, and lateral clearance of legs, knees and feet under the work surface; sufficient clearance shall be available for the tallest user's legs (95th percentile),

— work surface at or slightly below elbow height,

— support for the buttocks and legs (see 5.4.2) and support for the lower back,

— controls within optimum or maximum reach envelopes depending on frequency, priority of use (outcome of the task analysis),

— characters on instruments or displays shall subtend the required minimum visual angle to the seated control room operator (see 5.2.2),

— height of the seat pan (a footrest may be necessary in some circumstances),

— the seat height shall be adjustable.

If the user population is highly variable in size, an adjustable work surface may need to be considered (e.g. population of males and females together with a mix of users from different countries (see 5.1.2).

NOTE 1 Adjustable furniture can offer the operator options for posture change during the work shift.

An adjustable footrest shall be available for the smaller users (down to 5th percentile). Footrest dimensions should be as follows:

— minimum surface: (450 × 350) mm (width × depth);

— minimum height at front side 50 mm, height adjustable to at least 110 mm;

— minimum slope 5°, and adjustable to at least 15°.

As many users as possible should be able to rest their feet on the ground (i.e. not be hindered by a small foot rest); the implication of this recommendation is that the thickness of the table surface is minimized, 40 mm being a maximum.

NOTE 2 By minimizing the table surface thickness, giving sufficient leg clearance for tall users, as many as possible of the user population will be able to use the table surface comfortably (i.e. with their elbows on or just above the surface).

7.3 Standing control workstations

For the overall dimensions of a standing workstation, the ergonomic considerations applied for seated workstations largely apply. In addition, the following shall be considered.

— Work-top surfaces shall not be higher than the elbow height of a 5th percentile user.

— Where a view over the top is required, the maximum vertical dimension of the workstation should not exceed the standing eye height of a 5th percentile user.

— Where items need to be passed across the workstation, the horizontal dimensions should take account of the reach of 5th percentile users.

— Adequate clearance should be allowed for the feet when standing at the workstation.

7.4 Sit-stand control workstations

The same dimensioning requirements apply as for standing control workstations. In addition, sufficient space shall be provided to support any control devices and their operation (see 6.2.2) for documents, calculators, telephones, etc. as determined by the task analysis.

Annex A
(informative)

Arranging displays and control workstations

A.1 Purpose

This Annex gives examples for a scientifically proven (see [2] in the Bibliography) tool for determining arrangements of visual displays (monitors) at workstations.

A.2 Starting point

The proper arrangement of singular or multiple displays at control workstations depends on several factors:

a) eye height of the users as influenced by

— postures (that vary) when accomplishing their jobs at the workstation,

— body dimensions of the user population;

b) visual extent of the displayed characters in either direction (not restricted to the orthogonal direction);

c) frequency of visual scanning, the line-of-sight sweeps from one display to another;

d) dimensions of the displays.

The following factors are major determinants in the ergonomic arrangement of equipment on the workstation:

— viewing distance;

— display dimensions;

— angulation in terms of tilt and/or swivel;

— display position relative to height and depth of the console;

— hand-reach envelope.

To support the designer in fitting all these aspects together properly, the concept of “space of Identification” has been proven useful [1]. The concept is also applicable for reviewing the arrangement and dimensions of control workstations.

A.3 Definitions

A.3.1
space of identification
space containing all positions relative to a display (a screen or a panel) from which each character on this display can be reliably **identified**, i.e. is seen under the smallest visual angle for identification, regardless of the viewing direction

NOTE The factors that determine the “space of Identification” are listed in Table A.1.

Table A.1 — Factors determining the dimension of the “space of Identification”

Factor	Space of identification	
	increases	decreases
visual angle	the smaller the angle	the larger the angle
displayed characters	the larger the characters	the smaller the characters
curvature of display surface	if concave	if convex
display dimension	the smaller the display format	the larger the display format

A.3.2
detection
perceptual process by which a person becomes aware of the mere presence of a signal (stimulus)

A.3.3
identification
cognitive process by which a perceived form (symbol, letter etc.) or colour matches one already known by, or simultaneously presented to, the observer

NOTE Identification of characters or colours becomes easier, if context information exists, e.g. if the character to be identified is part of a word or if (a) reference colour(s) exists, to be compared with the one to be identified. When reading figures from digital displays or tag numbers, no context exists in relation to a single character. “Identification's” relationship with “detection” is further clarified in Table A.2.

Table A.2 — Interrelationship among basic cognitive terms (read the complete line as a sentence)

Term	Process			
	Mode	Quality	Object	Location
Detection	[a] Simultaneously becoming aware of		a stimuli	in the visual field
Identification	Subsequently sweeping the line-of-sight from		one cluster to another	within the cone of fixation
[a] Read this line as one sentence			a cluster may be 4 ... 6 letters (characters).	

A.3.4
visual angle
angle subtended at the eye by the viewed object, e.g. a character or symbol (see Figure A.1).

NOTE The visual angle is a measure to determine identification from a geometric point of view, regardless of the viewing distance (see Figure A.2).

According to ISO 9355-2, the character height shall be at least 15´ (ISO 9241-3 = 16´) (´= minutes of angle).

A.3.5
posture
overall position of the body, or bodily parts, in relation to each other with respect to the workplace and its components

[ISO 9241-5:1998]

NOTE To accomplish a specific task (e.g. handwriting), persons take an appropriate posture unconsciously (see [10] in the Bibliography).

In control centres, the following postures have to be taken into account:

a) Seated postures (see Table 2):

1) bent forward,

2) upright,

3) reclined,

4) relaxed.

b) Standing.

Identification of each character has to be ensured from the seated postures 1) to 3) while 4) or standing is dedicated to monitoring. In the latter case, visual requirements are less demanding (just for “detection”).

For this reason, the following concentrates on both postures 1) and 4) (see also Table 2) which are worst case for identification.

For a given person, each posture corresponds to a distinct

— position of the eyes (in the vertical as well as in the horizontal plane),

— inclination of the normal line-of-sight, and

— handreach envelope.

A.4 Application of the “space of identification”

The same procedure has to be applied separately for the horizontal and for the vertical plane. Only the procedure for the vertical plane is given here.

The scale of 1: 10 is recommended for drawing the templates (easy to calculate, drawing fits on paper format).

A.4.1 Procedure for a single monitor

Step 1:

Make a template (elevation drawing) of the working plane of the console (height above the floor and surface depth) applying the selected scale (see Figure A.3).

Step 2:

Add the eye-points of the 5th and of the 95th percentile for both bent forward and reclined postures, of the user population (see Figure A.3).

NOTE 1 The postures unconsciously taken by the users during accomplishing a distinct job are shown in Table 2.

NOTE 2 It is sufficient, to consider the extreme postures (i. e. “bent forward” and “reclined”). The corresponding dimensions (for a particular user population) are given in Table 2.

NOTE 3 If males and females establish the user population, apply the eye-points of the 5th percentile from the females, but of the 95th from the males.

Step 3:

Construct the side-view drawing of the “space of Identification” as follows (see Figure A.4)

a) Choose the maximum viewing distance D_{max}. If identification of characters and/or symbols (excluding video viewing) is the task required to be undertaken, the recommended viewing distance is 70 to 80 cm (see [9] in the Bibliography).

b) Calculate the required minimum character height on the display:

$$h = D_{\max} \frac{\sigma_{\min}}{3439}$$ (see Figure A.1)

c) Draw the side view of the screen (or panel) applying the chosen scale.

d) Draw a circle (diameter $D_{\max)}$ touching the topmost visible position.

e) Draw a circle (diameter $D_{\max)}$ touching the lowest visible position.

f) The overlap of both circles is the resulting side view of the “space of identification”. Its area is limited by the nearpoint. To consider this:

— draw a line parallel to the display surface equal to the distance of the nearpoint = 50 cm;

— add the middle axis of the screen (or panel) as an orthogonal line.

Step 4:

Copy the composite drawing developed in step 3 onto foils (overheads, transparencies, etc.).

NOTE 4 The process has been presented around the use of foils, though computer-based alternatives can equally well be applied.

Step 5:

Overlay the drawing of the console (Figure A.3) with the foil(s) (Figure A.4) to achieve Figure A.5 which is derived by the following.

— Shift and tilt the overlay until all eye-points appear within the “space of identification”

— Check if the inclination of the middle axis corresponds to the “normal line-of-sight” (see values in Table 2) for the display. Benefits: Promotes relaxed viewing, characters appear largest.

— Check if the complete height of the visible display is located within the cone of fixations. Benefit: The line-of-sight can sweep to all positions on the display without head movement. This is particularly advantageous if the task requires keeping the eyes on display for some time.

Step 6:

For on-screen controls (light pen, touch screens), superimpose hand-reach envelopes.

NOTE 5 The viewing distance chosen in the example is far greater than can be applied with on-screen controls.

Step 7:

Apply steps 1 through 6 to the horizontal plane.

A.4.2 Procedure for multiple monitors

Control workstations found in control centres consist of multiple monitors. The various displays simultaneously present different data and informational views to one operator. Consequently, the user frequently has to change his view from one display (screen) to another.

The arrangement of the various displays can be optimized in order to facilitate visual accommodation, symbol identification and overall effectiveness by applying the “space of identification” principle as used in the single monitor case. In the multiple screen situation, the monitors should be arranged as follows.

— Adjacent screens should be close together. This is for “motion economy” and minimizes space requirements.

— The viewing distance(s) to any of the frequently viewed displays should be as equal as possible.

— The line-of-sight should be orthogonal to each display.

The appropriate arrangement is easily found by applying the “space of identification”. Again, the considerations are made in the vertical and in the horizontal plane.

If, occasionally, more than one operator has to work at such a control workstation, it should be possible to swivel the monitors.

A.4.2.1 Stacked screens

To find out the proper height, distance and tilt-angles of stacked screens, proceed as follows (the example in Figure A.6 is based on two screens):

Step 1 to 7:

Complete steps 1 through 6 as outlined for a single monitor.

Step 7a:

a) Use the elevation (side) view of the console (Figure A.3) as a base.

b) Overlay two foils (output of step 4) in a manner such that both elevation-(side-) viewed displays become stacked.

c) Shift and tilt the foils until the eye-points appear within the overlapping “spaces of identification” (see Figure A.6).

Check if

— the displays are located as low as possible,

— the viewing distances to the displays are similar, or

— the upper display(s) provide information which does not require long-term observations (e.g. overviews).

Step 8a:

Apply steps 1 through 7 to the horizontal plane.

A.4.2.2 Side-by-side screens

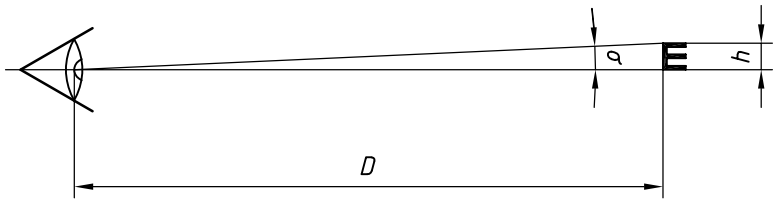
Steps 1 to 7:

Apply steps 1 through 7 as outlined for the single monitor for the top view.

Step 7b:

Proceed with the top view corresponding to the procedure applied for the side view (see step 7a).

As an example, Figure A.7 illustrates the result for the arrangement of three frequently viewed screens at a control workstation.



Key

D viewing distance at orthogonal view

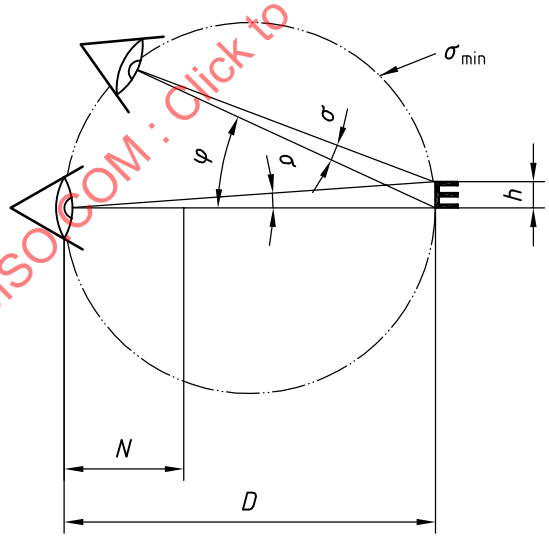
h character height

σ visual angle

NOTE For eyes of normal acuity, for optimal viewing conditions and best display quality, a visual angle of a few minutes would be sufficient, even for characters like E or B. These Latin characters demand highest visual resolution due to their utmost details in vertical section. The same is true for M and W in horizontal section. According to ISO 9355-2 for achromatic characters, the minimum value of the visual angle shall be 15 min. This value takes account of the fact that, in reality, the following features are typically less than optimum.

Subject	Viewing conditions	Object
Visual acuity up to 50 % below normal value **Adaptation** currently not optimal	**Illumination** level beyond optimum, **glare**	**Reduced** contrast, **blurred** characters, non-homogenous character and/or underground **luminance**, character **height** lower than those of capital letters.
The minimum visual angle of 15 minutes is not valid for — coloured characters, or — vibrations of object and/or subject (e.g. in transportation).		

Figure A.1 — Features determining the definition of the minimum visual angle



Key

N nearpoint

D maximum viewing distance at orthogonal view

h character height

φ angle of view

σ visual angle

σ_{min} minimum visual angle (on the circle)

Figure A.2 — Interrelationship among viewing distance D, visual angle σ and angle of view φ