BS EN 894-4:2010

BSI Standards Publication

Safety of machinery — Ergonomics requirements for design of displays and control actuators

Part 4: Location and arrangement of displays and control actuators

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National foreword

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Foreword

This document (EN 894-4:2010) has been prepared by Technical Committee CEN/TC 122 “Ergonomics”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2010, and conflicting national standards shall be withdrawn at the latest by December 2010.

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

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This European Standard has been prepared to be a harmonized standard in the sense of the Machinery Directive and the associated EFTA regulations.

This document is a type B standard as stated in EN ISO 12100.

The provisions of this document can be supplemented or modified by a type C standard.

NOTE For machines which are covered by the scope of a type C standard and which have been designed and built according to the provisions of that standard, the provisions of that type C standard take precedence over the provisions of this type B standard.

1 Scope

This European Standard contains ergonomic requirements for the location and arrangement of displays and control actuators in order to avoid hazards associated with their use.

This European Standard applies to displays and control actuators for machinery and other interactive equipment (e.g. devices and installations, instrument panels, control and monitoring consoles).

This European Standard is not applicable to the location and arrangement of displays and control actuators which are manufactured before the date of its publication as EN.

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.

EN 614-1, *Safety of machinery — Ergonomic design principles — Part 1: Terminology and general principles*

EN 894-1:1997+A1:2008, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 1: General principles for human interactions with displays and control actuators*

EN 894-2:1997+A1:2008, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 2: Displays*

EN 894-3, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Part 3: Control actuators*

EN ISO 9241-11, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 11: Guidance on usability (ISO 9241-11:1998)*

EN ISO 9241-110, *Ergonomics of the human-system interaction — Part 110: Dialogue principles (ISO 9241-110:2006)*

EN ISO 12100-1:2003 *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology (ISO 12100-1:2003)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100-1:2003 and the following apply.

3.1
control/display ratio
C/D ratio
ratio of the movement of a control actuator to that of an associated element, display or controlled object

3.2
elements
generic term for displays and control actuators on consoles and panels

3.3
primary element
element frequently used for direct operation and monitoring of the system which includes safety and emergency related elements

3.4
secondary element
element not frequently used for the direct operation of a system

EXAMPLE The time and duration of use can be freely selected.

3.5
grouping
arrangement of several elements of a system in such a way that they appear to be associated functionally

3.6
coding
procedure within the design process by which categories of information (e.g. form, colour, etc.) are allocated to elements for the purpose of reliable identification

3.7
arrangement
way of combining or separating displays and control actuators relative to their function, task and/or location

3.8
surface
surface on which elements are positioned and arranged, considering task priorities, information flows, and space constraints

4 Principles for location and arrangement of displays and control actuators

The location and arrangement of displays and control actuators are intended to ensure the general reliability, safety and efficiency of the human-machine system. The most important tasks of the operator are to monitor, control and ensure continuous availability of the technical system and the interaction of its elements. This shall place the operator in a position to fulfil the following functions correctly and on time without becoming overtaxed:

— to perceive the current tasks;

— to control the operation;

— to select and/or develop suitable action strategies.

Basic principles for human machine interaction are given in EN 894-1.

The following describes a design procedure that will assist designers and manufacturers in complying with the requirements in this standard. It consists of six main phases, each of which contains several more detailed steps. These steps should be carried out iteratively until the requirements are met. The procedure is illustrated in Figure 1. In Phase 0 the initial information about the overall purpose, design goals and roles of the operators (see EN 894-1) is assembled.

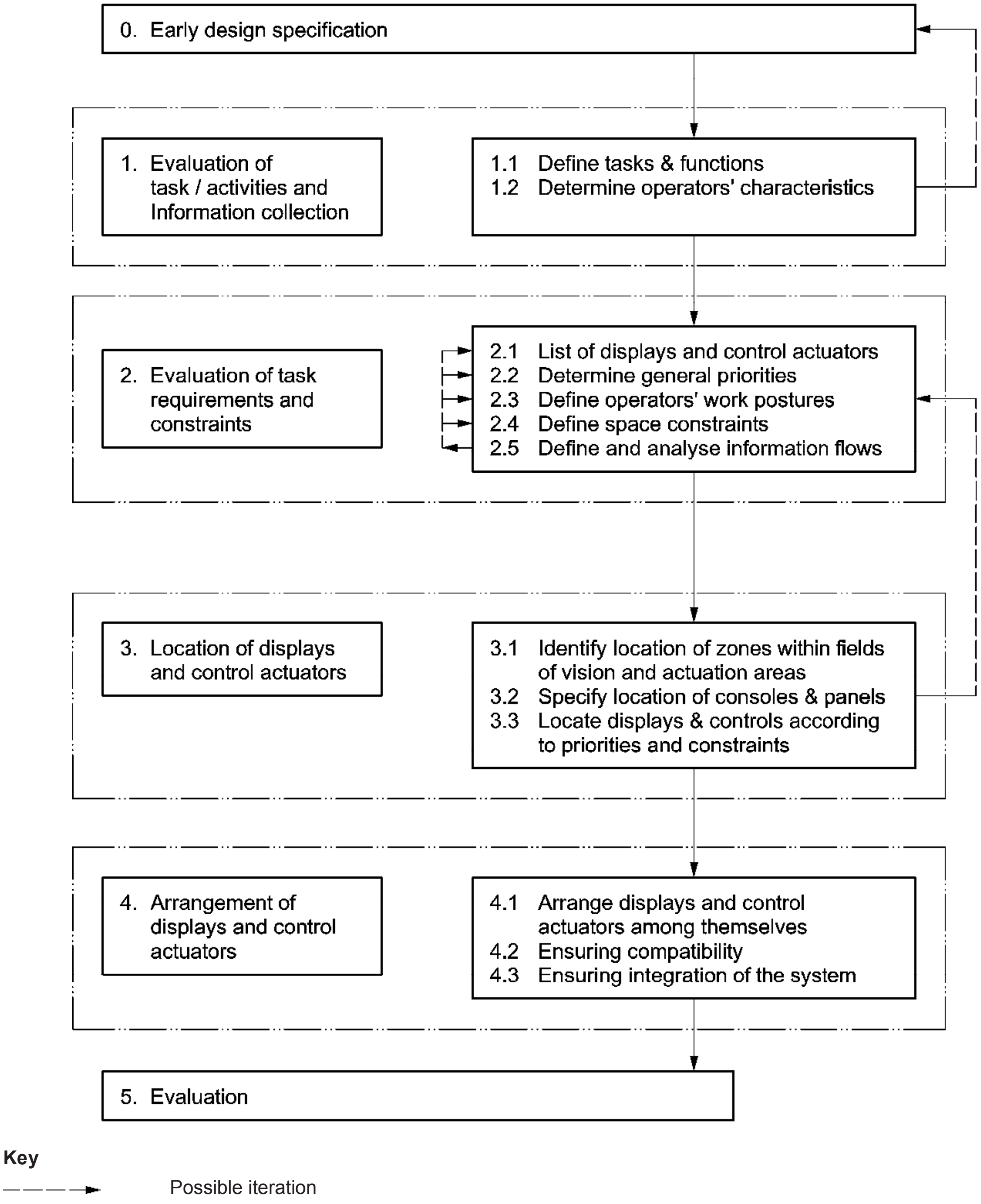


Figure 1 — Design procedure for location and arrangement

NOTE For details of each step see Clause 5 (e.g. step 1.1 is in 5.1.1; step 3.1 in 5.3.1).

5 Phases and steps for location and arrangement of displays and control actuators

5.1 Phase 1 – Evaluation of task/activities and information collection

5.1.1 Step 1.1 – Define tasks and functions

Typical operator tasks are e.g. monitoring, error detection, diagnosis of faults and performing control actions; the following operating situations should be considered: start up, normal operation, troubleshooting, shutdown, emergency stop, etc., see EN 894-1, -2 and -3.

Task sequence and relevant information flows shall be recorded for each relevant operating situation.

If two or more operators may work at the same workplace the interactions between their tasks, control actions and information flows shall be specified to help avoid possible conflicts and improve overall safety.

5.1.2 Step 1.2 – Determine the operators' relevant physical and cognitive characteristics

The general principle as defined in EN 614-1, e.g. strength, body size, visual acuity, skills, experience and disabilities, shall be considered. Specific information on relevant physical characteristics for displays and control actuators is given in EN 894-2 and -3.

5.2 Phase 2 – Evaluation of task requirements and constraints

5.2.1 Step 2.1 – List of displays and control actuators

Types of displays and control actuators which comply with the relevant requirements of EN 894-2 and EN 894-3 should be compiled in a list.

Technological features and/or constraints such as for multifunctional elements, e.g. touch screens, scroll balls, remote or handheld controllers need to be assessed.

5.2.2 Step 2.2 – Determine general priorities

The task requirements for each operational situation shall be specified and prioritized taking into account safety, performance and usability goals. Task requirements include accuracy, speed, force, frequency, importance, duration of use, sensitivity to error and sequence of use, etc.

Tasks should be assigned a level of priority, i.e. primary or secondary elements as defined in 3.3 and 3.4.

These priorities are used in Phase 3 to help locate displays and control actuators, and to exclude unnecessary elements.

The activities that make up the tasks should be identified, this helps to choose the most appropriate physical arrangements, e.g. which parts of the task can be done seated, which parts of the task require communication with other operators, which parts of the task require problem solving activities. There also needs to be consideration of the operator's action strategy in each operating situation.

The following constraints on activities shall be considered where appropriate:

a) need for direct vision over the top of a console e.g. when monitoring supplementary information;

b) need for continuous direct vision while controlling e.g. during a driving task, using a mobile machine;

c) need for indirect vision (by e.g. camera systems) while controlling;

d) need for direct vision and interaction with other people, e.g. crane operation;

e) need to use horizontal surfaces e.g. for writing, placing written material, work material, etc.

5.2.3 Step 2.3 – Define operators' work postures

5.2.3.1 General

The postures that have to be adopted when using displays and control actuators need to be specified as they strongly influence where the elements can be placed. Natural (not awkward) body postures should be selected which allow a balance between avoiding excessive movement and encouraging sufficient movement to allow a range of muscles to be used. Arrangements which allow changing of posture and do not continuously stress one part of the body should be selected. EN ISO 14738 provides additional information on how to select the main working postures.

5.2.3.2 Activities in seated position

The sitting position shall be selected particularly if the following demands are made:

— a high degree of body stability;

— high accuracy requirements.

For prolonged work periods it is important to allow for changes of posture and rest periods.

5.2.3.3 Activities in standing position

The standing position shall be selected for carrying out activities if:

— high mobility is required;

— extensive control movements are to be carried out;

— body weight is used in application of the force; and

— a large workplace is to be serviced.

5.2.3.4 Combination of activities in the sitting and standing positions

Control consoles where both standing and sitting is possible shall be set up when:

a) a firm sitting support has to be assured for precise work;

b) wide panels with displays and control actuators have to be monitored and actuation activities have to be carried out on them;

c) there is an anticipated temporary increase in task demands where another operator has to help out.

Wherever possible, the operator should be able to sit and stand in order to have the benefits of both work postures. This helps to avoid the build up of musculoskeletal problems which can occur, particularly under conditions of psychological stress, when using one posture for a prolonged period of time.

5.2.4 Step 2.4 – Define space constraints

Any restrictions on the dimensions of the space available for positioning and moving displays and control actuators shall be fully recorded. This should include restrictions for direct vision of the process or objects where this is relevant to the performance of the tasks. Restrictions can arise from technological, environmental or task limitations.

5.2.5 Step 2.5 – Define and analyse information flows

Collate information on the sequence of use of elements, their frequency of use and their relative importance. Identify any pre-existing stereotypes for the use of these elements.

Identify those elements which are used in combination, e.g. controls with their associated displays.

5.3 Phase 3 – Location of displays and control actuators

5.3.1 Step 3.1 – Identify location of zones within fields of vision and actuation areas for primary and secondary elements

5.3.1.1 General

Displays and control actuators should be located in the appropriate zones taking account of requirements for frequency, importance, accuracy and order of operation, as well as operator's work postures and physical dimensions. Surfaces on which elements are positioned and arranged should then be determined within these zones considering task priorities, information flows and space constraints.

The field of vision (monitoring area) A, B, C is defined in EN 894-2:1997+A1:2008, Figure 2.

NOTE The information in EN 894-2:1997+A1:2008, Figure 2 applies to activities when sitting or standing.

In the same way, as shown in the following Figure 2, the actuation area A', B', C' are classified in three different zones, each with a different level of suitability.

The field of vision and the actuation area are classified as follows:

— A, A' : recommended;

— B, B' : acceptable;

— C, C' : not recommended.

Thus for the various task priorities the following applies:

Elements used in primary tasks are located in recommended zones A and A’. They are used for the following:

a) maximum priority for safe operation;

b) quick and accurate reading (or actuation);

c) important indicators (or control actuators) for operating the system;

d) lengthy observation (and/or frequent actuation);

e) elements for secondary and less important tasks, if space is left.

Elements used in secondary tasks are located in acceptable zones B and B’. They are used for the following:

f) displays (or control actuators) of secondary importance that only have to be observed (or actuated) intermittently.

Elements used in less important tasks are located in the not recommended zones C and C’. They are used for the following:

g) only suitable for displays (or control actuators) that are seldom used and are of low priority or importance such as for temperature regulation in a room.

5.3.1.2 Zones within fields of vision − seated

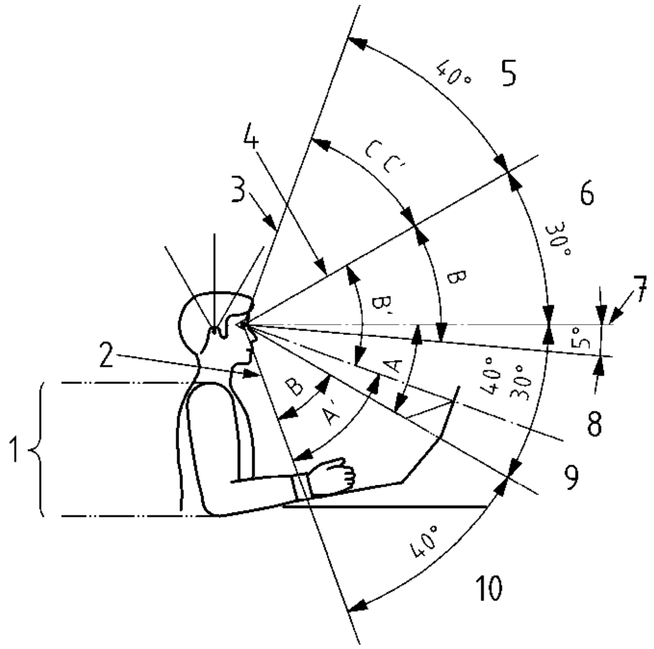
Figure 2 illustrates the display zones A, B, C. The eye height of the operators should be taken into account when calculating the position of displays using these angles. Annex A gives an example of console dimensions based on an average European sitting eye height of 1 250 mm. Further information on sight lines in different seated postures for control centre workstations can be found in EN ISO 11064-4, and for mobile machinery in EN ISO 6682. Typical distances for comfortably viewing displays such as video screens are 400 mm to 700 mm.

NOTE 1 A distinction should be made between leaning forwards, keeping vertical and leaning backwards in the sitting postures. When the posture is changed, the field of vision (or actuation) moves. For design purposes it is helpful to use the vertical (upright) position as a reference when calculating constraints on postures, for details see EN ISO 3411. Good design permits the adoption of other postures and easy accessibility.

The line of sight is located at 15° to the horizontal from the eye point. Zones (A, B, C) within the field of vision are derived from those given in EN 894-2.

It is important to ensure that discrimination of colours is not required towards the extremes of the field of vision. Figures 2 and 3 give some information about colour discrimination.

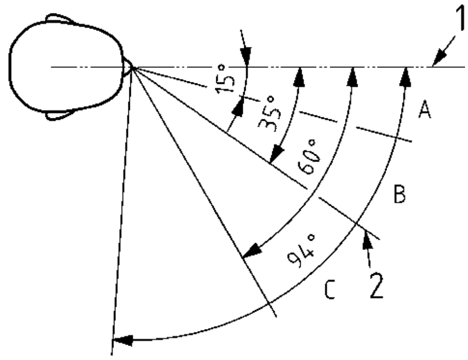
NOTE 2 The information about colour discrimination does not take account of head movement.



Key

1	Optimum control zone between elbow and shoulder height	7	Horizontal
2	Lower visual limit 70°	8	Primary display & secondary control
3	Upper visual limit	9	Primary display & control
4	Limit for colour vision	10	Primary control, secondary display
5	Low priority display, control	A, B, C	Display zones (see 5.3.1.1)
6	Secondary display, control	A', B', C'	Control zones (see 5.3.1.1)

Figure 2 — Location of Display Zones A, B, C and Control Zones A', B', C' (Vertical)



Key

1 Line of Sight-0°

2 Limit for colour vision

A, B, C Display zones (see 5.3.1.1)

NOTE 1 Vision to both sides needs to be considered.

NOTE 2 For the field of vision it is good practise to move the head 45° to left and right.

Figure 3 — Location of display zones A, B and C (horizontal)

5.3.1.3 Zones within actuation areas − seated

The zones within actuation areas are shown in Figure 2 as A', B', C' and partially overlap with the zones for field of vision A, B, C. The actuation areas should be readily reached by an operator, this means that they should be no more than 450 mm in front of the body for frequently used or important controls. The actuation area for primary elements in the horizontal plane is within a sector of about 60° in front of the operator. This sector of 60° is defined by the lateral rotation of both left and right arms in a horizontal plane. For further dimensions of actuation areas see Annex A and EN ISO 14738 and for mobile machinery see EN ISO 6682.

If all the control actuators cannot be housed in actuation zone A', they shall be as close as possible to it. EN ISO 14738 gives further information on reach zones.

It is important to consider the angles of the shoulder, elbow and wrist that will be required in order to operate a control actuator, EN 1005-4 gives some advice on suitable angles for maintaining comfort. The degree of accuracy, the frequency and duration of use will all affect the overall comfort of using a control actuator in a particular posture (EN 894-3).

5.3.1.4 Zones within field of vision and actuation areas − Standing

The zones within field of vision and actuation areas for a standing operator need not be as precisely defined as those for a seated operator because a standing operator can easily face in any direction or can walk from one position to another. Information on working heights with different visual demands are given in EN ISO 14738:2008, Clause 9:

— the 50th percentile shall be used as the basis for specifying the fields of vision and actuation areas in the standing position;

— the recommended zone within the field of vision should be between 1 370 mm and 1 680 mm above the horizontal reference surface (floor);

— in most cases lateral dimensions need not be taken into account because the operator can freely change position when standing. However, if groups of control actuators are to be operated quickly and simultaneously, their sideways separation should be within 760 mm;

- the recommended zone within the actuation area should be between 1 040 mm and 1 370 mm above the horizontal reference surface;
- actuation area positions more than 1 830 mm above the horizontal reference surface are not suitable;
- actuation area positions less than 920 mm above the horizontal reference surface are not suitable.

Annex A provides further information on dimensions of a standing console that is based on average European body measurements.

5.3.1.5 Zones for combined sitting and standing positions

Special attention should be paid to specifying a similar eye height for both the sitting and standing positions by using an adjustable raised seat and adjustable foot support. EN ISO 14738 contains information on suitable dimensions for raised sitting. An installation angle for surfaces with displays of 50° to 70° from the horizontal is suggested. (See Annex A, Figure A.2.)

5.3.2 Step 3.2 – Specify location of consoles and panels

5.3.2.1 External shape and inclination of surfaces of consoles and panels

The following points shall be taken into account when specifying the shape and inclination of the surfaces:

- the displays for the particular visual tasks such as observation, screen or scale reading and activities that are to be carried out;
- the avoidance of parallaxes of displays by correct design of the shapes and inclination of the surfaces;
- prevention of unintentional actuation;
- location and direction of movement of the controls so that they are easy to handle;
- adequate space for the body of the operator in the selected work postures and for the activities of operators in a team;
- task constraints (e.g. need for direct vision in control room or vehicle, need for direct vision and personal interaction, need for using horizontal work surface);
- technological constraints (e.g. touch screens, scroll bars, remote controls, handheld controls).

Work surfaces of consoles and panels can be used for various purposes, e.g. as writing surfaces or for accommodating certain control actuators, e.g. joysticks.

The working surfaces should preferably be horizontal or nearly horizontal (no more than 15°).

Information on the space required beneath a console (leg room) can be found in EN ISO 14738 and for mobile machinery in EN ISO 6682.

5.3.2.2 Surfaces for locating primary and secondary elements

A distinction shall be made between surfaces for locating primary and secondary elements. As far as possible primary elements should be located in the A zone for field of vision and the A' zone for actuation. The overlap of the A zone for displays and the A' zone for control actuators is comparatively small, it should be used for those elements which require quick and accurate identification and rapid actuation. Secondary elements can be located in the appropriate zone B or where necessary, for occasional use, in zone C.

Surfaces are located taking account of the imposed space constraints. It is important that sequential use of primary or secondary elements should not cause a conflict, e.g. hiding high priority elements. Information from the primary visual elements shall be visible at all times and in a fixed position.

The following requirements apply:

— control actuators forming a functional unit with displays shall be located directly beneath the displays;

— control actuators with a higher priority should be located in the actuation zone A'.

Where there are limitations on the surfaces available, multifunctional elements shall be preferred.

5.3.3 Step 3.3 – Locate displays and control actuators on consoles and panels according to priorities and constraints

5.3.3.1 Requirements relating to accommodating elements

When accommodating displays and control actuators on consoles and panels, the priorities relate to fields of vision and actuation zones. The following requirements apply:

a) primary elements shall be located in display zone A or control zone A';

b) secondary elements should be located within display zone B or control zone B' so that they are easily accessible if required;

c) elements of little importance to the system should be located at points that warrant the lowest priority (display zone C or control zone C'), e.g. elements not used during continuous operation;

d) where two operators use certain elements simultaneously:

   1) elements that are primary for both operators shall be duplicated or, for displays, positioned so that they are clearly visible to both operators;

   2) secondary elements should be positioned closer to the operator who uses them most;

   3) special arrangements may need to be put in place to ensure that conflicts cannot occur.

5.3.3.2 Location of displays – Requirements

The information from step 2.2 on the activities shall be used to help locate the displays. Then, after locating displays in the appropriate zone corresponding to their importance (see 5.3.1), the following needs to be considered:

— take account of the sequence of readings;

— to ensure situational awareness for more than one operator, relevant elements shall be located so that they can be seen and interpreted similarly by these operators;

— provide the same displays for the same functions and/or units;

— displays should clearly indicate the operating function;

— ensure that displays for different functions have clearly different appearances;

— locate similar displays in the same way;

— locate the surfaces orthogonally to the line of sight, as far as possible;

— avoid/minimize parallaxes, reflection, glare, specular reflection, heavy shadows.

5.3.3.3 Location of control actuators – Requirements

The information from step 2.2 on the activities shall be used to help locate the control actuators. Then the following needs to be considered:

— locate important and frequently operated control actuators in zone A' (the recommended actuation area);

— take account of the sequence of operation of the control actuators (from top to bottom and from left to right – following the stereotype employed in Western countries);

— provide the same control actuators for the same functions;

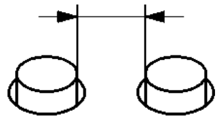
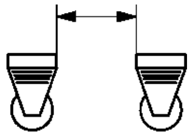
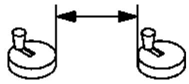
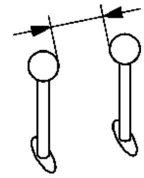
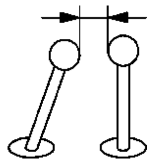
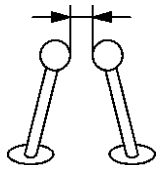
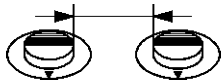
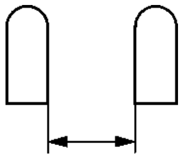
— ensure that control actuators for different functions have clearly different appearances (coding);

— locate similar control actuators with the same function in the same way;

— ensure that separation distances are no less than the minima in Tables 2 and 3. For handheld microelectronic devices smaller dimensions may be appropriate however safety critical functions will need to be carefully designed to avoid unintentional activation;

— use the recommended separation distances in Table 2 for high priority tasks.

Table 1 — Separation distances for control actuators on consoles or similar surfaces

Control Type	Type of use	Separation distances (mm)		Illustration
		Minimum	Recommended	
Push Button and sliders	One finger – randomly	13	50	
	One finger – sequentially	6	25	
	Different fingers	6	13	
Toggle switch	One finger – randomly	19	50	
	One finger – sequentially	13	25	
	Different fingers	16	19	
Cranks	One hand – randomly	50	100	
	Two hands – simultaneously	75	125	
Levers (forward/ backward) [a]	One hand – randomly	50	100	
	Two hands – simultaneously	75	125	
Levers (left/right) [a]	One hand – randomly	50	75	
	Two hands – simultaneously	75	100	
Knobs (turnable)	One hand – randomly	25	50	
	Two hands – simultaneously	75	125	
Pedals	One foot – randomly	100	150	
	One foot – sequentially	50	100	

a See [1] in bibliography.

Table 2 — Minimum separation distances between different types of control actuator

Dimensions in millimetres

	Push buttons	Toggle switches	Continuous rotary controls	Rotary selector switches	Discrete thumbwheels
Push buttons	–	13	13	13	13
Toggle switches	13	–	19	19	13
Continuous rotary controls	13	19	–	25	19
Rotary selector switches	13	19	25	–	19
Discrete thumbwheels	13	13	19	19	–

The shape of the control actuator shall be adapted to the part(s) of the body that is intended to operate it. The ratio of the size of the control actuator to the size of the surface it is mounted on should be considered. The purpose, action and frequency of use will determine the suitability of the position and mounting surface of the control actuator (see EN 894-3 for information on selecting suitable control actuators).

5.4 Phase 4 – Arrangement of displays and control actuators − principles and applications

5.4.1 General

Ergonomic design measures shall ensure that the operator is able to carry out the following functions without being overloaded:

a) to perceive and perform emergency related tasks quickly and positively;

b) to perceive the current tasks such as function-related monitoring of the system, diagnosing or correcting faults, maintenance or ensuring availability of the system, etc.;

c) to understand the operating situation, i.e.:

1) always to have an "internal overall picture" of the operating conditions and phases, circuits, duties, etc.;

2) to observe, accurately detect, identify and follow the information flows;

3) to interpret them with the relevant aids;

d) to select, develop and perform adequate, i.e. timely, action strategies suited to the situation.

To do this, the relevant displays and control actuators shall be arranged, i.e. grouped or divided up, in a suitable way. The following aspects shall be noted in particular:

e) the arrangement should help to identify operational situations and to interpret them quickly;

f) the groupings and sub-assemblies shall be aligned with specific tasks. The arrangement shall reflect in an easily comprehensible way the design and functional structures of each human-machine system;

g) the arrangements should reflect the process, causes and/or consequences of the operating situations;

h) the order and clarity of the groupings shall be optimized to avoid clutter;

i) the movement of the actuators and the indicated functions should correspond to the intended effect;

j) the location of groups of elements should take account of the shape and construction of the machine and operators' expectations of their placement.

Large numbers of elements shall be arranged to reduce the information an operator has to monitor and control. Applying the principles of grouping and dividing helps to achieve this. Such arrangements form the basis for perceptual organisation and of the resulting cognitive processes (see also EN 894-1:1997+A1:2008, A.3.3) such as formation of an internal picture by identification and interpretation. This includes:

k) the contrast between the background (e.g. colour of the consoles and panels) and the elements located in each particular operational situation;

l) forming a pattern;

m) enclosing an assembly of elements in a frame;

n) marking the relationship of elements by proximity or space;

o) generating an impression of relationship through homogeneity of colour, shape, size, grouping structure, layout in the room, flashing frequency, etc.;

p) common behaviour through the same direction of movement, frequency of occurrence , speed, etc.

NOTE Uniform grouping and patterns are quicker to spot than others, are seen more accurately, assessed more reliably, retained in the memory better and deviations from the norm are noticed more quickly and larger numbers of elements are seen more clearly.

5.4.2 Step 4.1 – Arrange displays and control actuators among themselves – Grouping

5.4.2.1 General

When arranging elements, the requirements for the basic structures of the groupings are designed to optimize order, simplicity, clarity, uniformity (homogeneity), etc.

Overall, this is used to reduce information and increase redundancy.

Arrangements should try to minimize the cognitive requirements on the operator during human-machine dialogue relative to perception, processing, or questions of capacity.

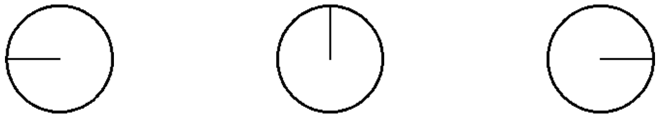
Some examples of ways of achieving this are:

a) grouping in rows and columns. Regular arrangements provide order and can help operators to locate elements. Irregular arrangements are more difficult to use but are able to highlight particular elements. Subgrouping shall be used with large regular arrangements (Figure 4);

a) Regular arrangement   b) Irregular arrangement

Figure 4 — Grouping

b) using quadrant divisions for marking conditions and types of duty such as Off = 9 o'clock, Normal = 12 o'clock and Maximum = 3 o'clock on displays and control actuators (Figure 5).



a) Off b) Normal c) Maximum

Figure 5 — Use of quadrant divisions to improve clarity

Where a control actuator is linked to a particular display, it shall be located so that the operator's hand does not cover the display.

The following sections describe ergonomics principles which provide a basis for grouping displays and control actuators including coding methods and means for ensuring compatibility.

5.4.2.2 Principle of proximity (distance)

Minimum distances (proximity) amongst otherwise large ones between elements in an assembly give the impression of operational association in a group. Larger distances between smaller ones separate assemblies and split groups up as shown in Figure 6.

Figure 6 — Related elements grouped by proximity

Proximity as a grouping and dividing principle is easy to use for large assemblies that are to be combined.

a) Proximity can be easily combined with others.

b) Many different shapes of elements can be grouped with proximity.

The distances between elements in groupings or divisions depend to a large extent on the shapes.

c) Minimum distance between rectangular shaped displays within a group is approximately 1/20th of the height of displays. For numerical displays minimum dimension is about three times the width of the stroke. All framing is part of the display, not separation.

d) For groupings of elements of a mixture of shapes such as circles, rectangles, etc. larger distances should generally be used. Usability testing may be required to check the arrangement is satisfactory (see for example EN ISO 9241-11).

e) The distances between groups should be increased in a relevant ratio to the above (for instance geometric or logarithmic, not arithmetic).

f) Sub-groups formed by distance only have 70 % to 100 % of the distance to elements in other sub-groups.

g) All elements in the group should lie within the appropriate field of vision.

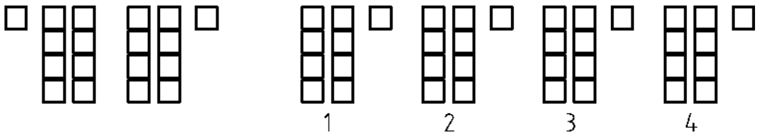
If points f) and g) cannot be fulfilled simultaneously, other grouping principles should be used.

5.4.2.3 Principle of symmetry

The principle of symmetry is used when combining several components with the same function in a system. Vertical or horizontal directions of observation are possible depending on the sequence of use and the functional structure. For two groups mirror imaging of the blocks is preferred. For more than two groups of blocks similar parallel combinations improve perception and interpretation.

Criteria for arranging blocks of elements result from the hierarchy of the tasks, the way that operators use the elements and their stereotypes.

Blocks of elements can be combined in parallel as shown in Figure 7.



a) Two groups **b) More than two groups**

Figure 7 — Combination of blocks with the same elements

5.4.2.4 Principle of similarity

Elements more or less similar as regards colour, shape, size, spatial layout or behaviour are perceptually organized into groups by the principle of similarity. This effect persists even over large intermediate spaces containing other elements or groups.

This makes it possible to group or split up adjacent elements and also easier to find more distant but operationally associated elements.

The principle of similarity is most frequently used for grouping or splitting up and it is the most important and versatile of the principles that can be used.

The resistance of a grouping to deliberate reorganization depends on the following conditions:

- the greater the number of similar elements, the stronger their association appears;
- the more that similar features are united on elements in the same way, then the stronger the grouping;
- similar elements can only be strongly associated if there are no other elements nearby with which they might be confused;
- the less similarity that exists relative to common features, the looser the connection;
- complete similarity brings with it the strongest connection.

a) Colour

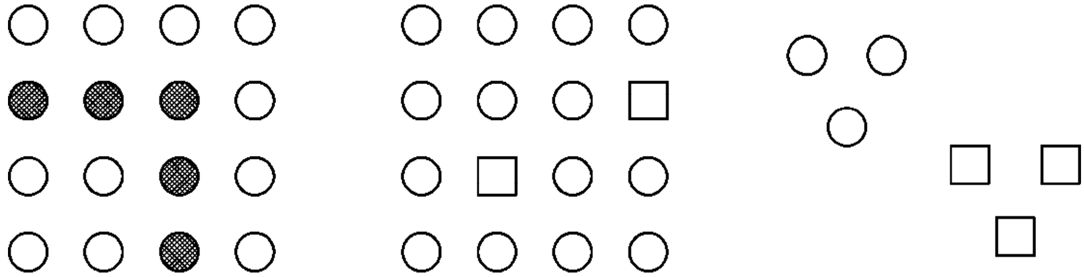
Similarity of colour is the most important case in the principle of similarity for what, in spite of random change of location, is directly visible as associated and different from the others, e.g. by shapes (Figure 8a)).

b) Shape

Similarity of shape is an effective way of grouping control actuators and displays. It is important, however, to ensure that elements are sufficiently differentiated so that they cannot be confused with each other. Figure 8b) shows the use of shape.

c) Structure of arrangement

Similarity of the positional arrangement of elements (e.g. displays and control actuators) makes them appear as associated even over large distances. Figure 8c) shows the use of structured arrangement of elements.



a) Using colour | b) Using shape | c) Using structure of arrangement

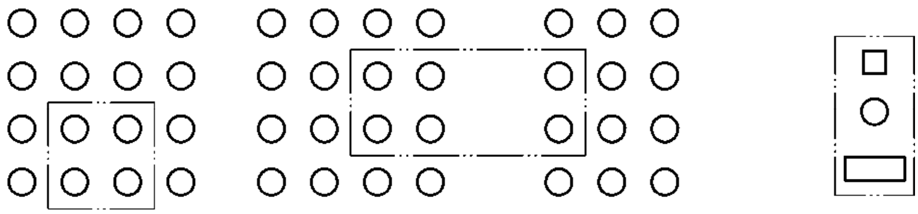
Figure 8 — Effects of similarity

d) Behaviour

Similarity of behaviour (e.g. the same movement of several elements in one direction or flashing at the same time) forms elements into groups and makes them stand out from others.

5.4.2.5 Principle of framing

Framing is a way of organizing groups of elements for specific purposes. Boundaries around groups, normally in the shape of rectangles or circles are used for this. Colour, relief or tactile differences can provide a frame. Those elements inside the frame are visually separated from other elements in the assembly, this helps to designate particular groups as shown in Figure 9.



a) Within a group | b) Between adjacent groups | c) To make different elements clearly visible as a group

Figure 9 — Effect of framing

The principle of framing shall be applied:

a) to highlight the profile of groups or sub-groups already subordinate to other principles (see figure above, through proximity or distance);

b) to combine adjacent elements within and between groups because they are associated operationally or in a related situation;

c) to make elements of different function, shape, colour or size clearly visible as a group by enclosure.

NOTE For groups of elements framing takes precedence over all the other perceptual organization principles.

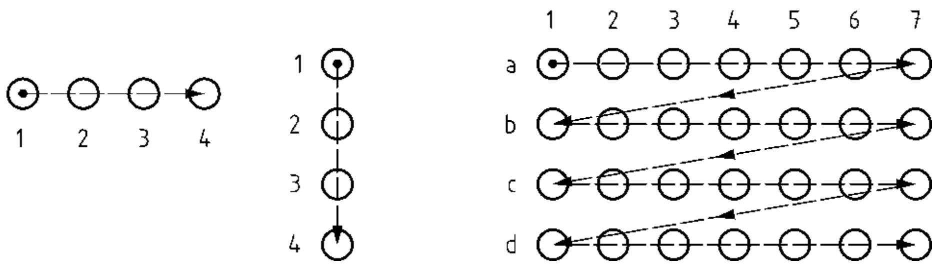
Groups of elements can be arranged according to their use for a specific task of the operator (e.g. start-up of an installation, monitoring of a process, maintenance, testing). Thus, for example, the control actuators needed to start up a machine should all be grouped together following the principle of framing. This form of grouping by framing is particularly necessary when large numbers of elements in a complex arrangement have to be used quickly and reliably.

5.4.2.6 Principle of sequential ordering

The principle of sequential ordering provides ways for arranging elements in the order of use within groups. This is used for:

- control actuators that are operated in a specific order (essential in the case of safety-relevant sequences);
- displays that have to be read in a certain order.

For horizontal and vertical groups of elements their sequence should be left to right and top to bottom (following the stereotype employed in Western countries). Any numbering system should follow this sequence as well. Within a matrix the sequence should be left to right across the rows and then down the columns (Figure 10).



a) Horizontal arrangement **b) Vertical arrangement** **c) Matrix arrangement**

Figure 10 — Sequence of use for horizontal, vertical and matrix arrangements

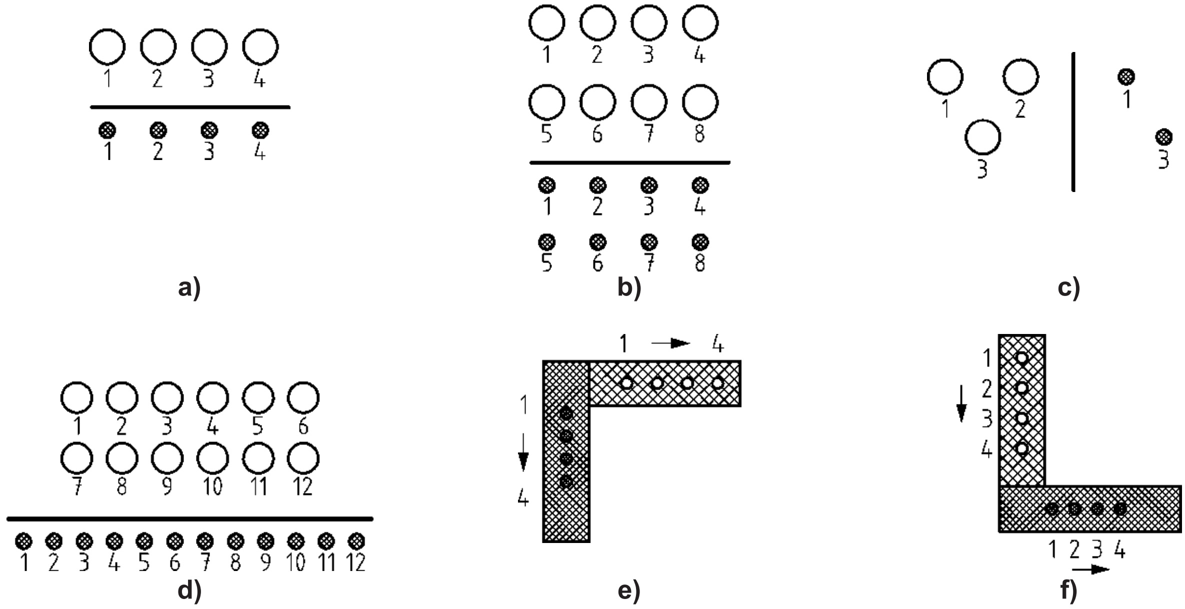
If several linked pairs of displays and control actuators are used sequentially they should be grouped and located in sequence as shown by the numbers in Figure 11. Four possible arrangements a) to d) are shown. Labels and (optionally) numbers, indicating each corresponding display and control actuator, shall be positioned on or underneath each element.

If a line of displays is vertical and the associated line of control actuators horizontal, the relative sequence of displays and control actuators shall be similar. This also applies to displays in a matrix arrangement (Figures 11e) and 11f)).

If operationally related displays and control actuators are located on different panels, the impression of association shall be given as follows in order to avoid confusion:

- the relative locations of displays and control actuators shall have the same structure on both panels;
- separate panels for displays and control actuators shall never be located opposite each other.

For large numbers of elements related displays and control actuators shall be placed as close together as possible. Their separate identity, arrangement and functional identification shall remain evident.



NOTE Empty circles represent displays, shaded circles represent control actuators

Figure 11 — Sequential grouping of displays and control actuators

5.4.2.7 Use of coding

Coding as a means of grouping, splitting up, highlighting or identifying is used:

— to facilitate human-machine-dialogue;

— to illustrate the functional structure of a system and the relationships between the elements and groups;

— to establish, identify and interpret simply and directly information shown on system states and processes;

— to harmonize the ways of representing information.

When designing an arrangement the aim should be to increase the compatibility between elements and the cognitive area, i.e. to reduce the cognitive effort in the human machine dialogue. This will:

— reduce errors and time needed for the cognitive processing of information;

— help to suppress information that is not required for the specific tasks;

— simplify the pictorial representation of the position, status of the system;

— promote consistent arrangements aiding operators to transfer to other installations.

The following aspects should be taken into account in the representation of the individual types of coding:

— type of tasks;

— user categories (operators, supervisors, maintenance personnel, engineers, assistants, etc.);

— performance requirements such as accuracy, speed, quality, quantity, duration, frequency of use;

— room to accommodate the displays and control actuators (visibility and actuation space);

- cultural customs and habits;
- types of coding that are currently used;
- number and alternative types of elements to be coded;
- limitation to the fewest possible types of coding;
- provide no more than two types of coding for one element.

Coding should comply with the following:

a) coding systems should take account of operators' knowledge and expectations;

b) codes should be compatible for all operators (e.g. engineers should not use different codes to normal operators for the same items);

c) the number of types of coding should correspond to the dimensions of the information presented.

EN 894-1, EN ISO 9241-110 and EN ISO 9241-11 provide further advice on how to match systems to operator characteristics.

Annex B describes different coding principles and gives some advice and requirements for their use.

There is no general rule for preferring one coding method ahead of another. The most efficient solution is to be determined by testing.

Connecting up several coding methods in one element is possible. This reinforces its separation from a group.

Combinations of codings should help:

d) to optimize the selection, combination and interpretation or use of elements in more complex interrelationships;

e) to make it possible to present more than one dimension of information in a display;

f) to ensure it is possible to identify and interpret elements that appear to be similar but can have different functions (e.g. signalling lights and pushbuttons with auxiliary illumination).

Table 3 shows suitable combinations of different coding techniques. Annex B describes these techniques in more detail.

Table 3 — Combinations of coding techniques

Coding method \ Coding method	Colour	Shape	Size	Brightness	Length of lines	Angular position	Flashing	Alphanumeric signals	Auditory signals	Position	Icons/Symbols
Colour		X	X	X	X	X	X	X	X	X	X
Shape	X		X				X				X
Size	X	X					X	X			X
Brightness	X										
Length of lines	X					X					
Angular position	X				X					X	
Flashing	X	X	X					X	X		X
Alphanumeric signs	X		X				X			X	
Auditory signals	X						X				
Position	X					X		X			
Icons/Symbols	X	X	X				X				

X Suitable combinations of coding methods.

Visual signals can be used with auditory signals to reinforce their meaning.

Because some people have poor colour recognition abilities colour should only be used as a secondary means of coding or combined with an additional type of coding.

For further information on coding see Annex B.

5.4.2.8 Other aspects

It is often necessary to differentiate elements, groups or systems from others.

Location of elements can be used to differentiate those with special importance, for example:

— locating important elements at the edge of the group;

— the starting point within a task sequence may be represented by the upper corner element on the left side of the group (following the stereotype used in Western countries);

— the finishing point may be represented by the lower corner element on the right side of the group;

— the emergency stop element can be located outside of the group (see EN 418 for specific requirements for emergency stop equipment);

— start/stop or on/off elements usually have a special importance and may be located at a distance from other groups of elements.

In addition to location, the importance of some elements within the group may be shown by a different shape, colour, contrast, flashing, format, etc.

Where groups or systems can appear to be very similar (see 5.4.2.3) it is necessary to ensure that demarcation between them allows the operators to easily identify the correct group or system. For example colour coding of similar control rooms to differentiate them from each other.

5.4.3 Step 4.2 − Ensuring Compatibility

5.4.3.1 General

The designer needs to provide for compatibility between the expectations of the operator when operating the control actuators and the behaviour of the system and displays. This means that the maximum possible correlation has to be created between the behaviour of the system and the displays and control actuators.

The aim of a designer should be to minimise the cognitive demands on the operators while maximising efficiency, safety and reliability in terms of:

— time and accuracy of actions;

— time and accuracy of detection and discrimination of critical situations;

— reactions or decision making time;

— easy learning;

— minimising errors, even in critical situations;

— unambiguous reaction in case of an error (e.g. emergency stop);

— quick restoration of operating states to what they had been previously;

— the effects of environmental conditions.

Design requirements relate to:

a) taking into account the usual control activities practised without training;

b) taking into account general stereotypes and any specific cultural stereotypes;

c) taking into account the relationships between displays, control actuators and system behaviour (including the information system);

d) requirements for similarity of the movements for the displays and control actuators for certain tasks in specific operating situations with installations and devices;

e) positioning elements with the same function in the same position in the various groups;

f) location of displays and control actuators in front of the operator in order to obtain clear relationships in terms of movement and direction.

g) integration of elements to be used in a specific or similar association in different competing activities or tasks;

EXAMPLE Generating a cooling effect by one actuation movement both opening a valve for cool air and closing a valve to restrict hot air.

h) the relationships between direct movements shall be noted (e.g. between control actuators, displays and technical systems).

5.4.3.2 Requirements for different types of control actuators and their position

a) Movements and position of control actuators shall be similar to the reaction shown on the corresponding displays;

b) straight movements of levers or toggle switches to the right, upwards and forwards "ON" or "INCREASE"; a movement to the left, downwards or backwards "OFF" or "DECREASE" (see Figure 12);

c) rotary switches and their associated displays shall behave similarly with clockwise movements for "INCREASE" and anticlockwise for "DECREASE" (see Figure 12);

NOTE For rotary valves, such as taps, increase-decrease directions are the opposite way round.

d) groups of control actuators separated by position (e.g. by intermediate spaces) shall be consistent in their directions of movement.

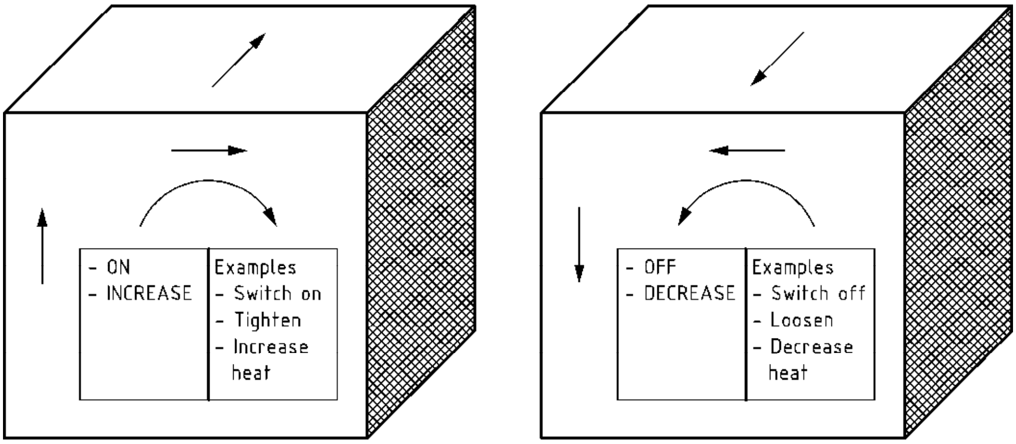


Figure 12 — Some common control actuator – Display stereotypes

5.4.3.3 Requirements relating to orientation of the direction of rotary control actuators

Pointers or indicators shall be used on rotary control actuators to give a visible and discriminable by touch reference for their orientation relative to their starting position. Where there is no very obvious feedback of the action or effect of the control actuator (a steering wheel usually gives obvious feedback of its effect) there shall be a corresponding visible index point on the background, perhaps associated with a scale, to mark the starting or zero position.

5.4.3.4 Requirements relating to orientation of the direction of linear moving control actuators

The direction of control actuators to be operated linearly for "ON/OFF" switches, lever or toggle switches shall be determined in correspondence with the relative position of the switchboard to the operator:

a) on a vertical switchboard, "ON" or "INCREASE" shall correspond to a movement upwards, "OFF" or "DECREASE" to a movement downwards (see Figure 12);

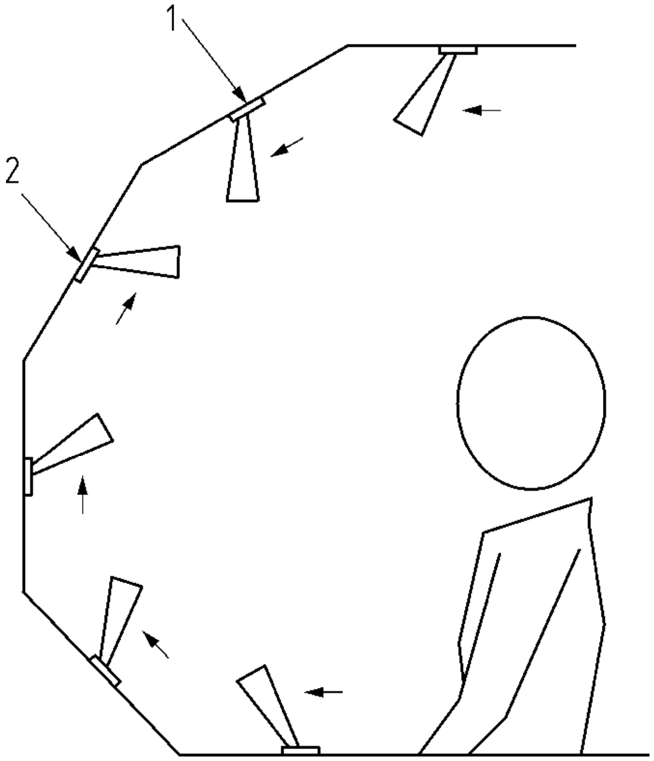
b) on a horizontal switchboard, "ON" or "INCREASE" shall correspond to a movement away from the operators (forwards), "OFF" or "DECREASE" to a movement towards the operator (backwards) (see Figure 12);

c) switch panels above head height with more than one section shall be inclined first at an angle of less than 30° and then more than 60° to the vertical in order to be able to differentiate reliably between the angles (see Figure 13). If there should only be one inclined surface above head height, angles of up to 45° are permitted.

   Nevertheless:

   1) where switch panels are angled at more than 60° down from the vertical, toggle switches should be used right or leftward instead of a up or downward movement because in this case the direction of the action of a toggle switch changes and could generate confusion (see Figure 13);

   2) where a continuous switch panel is made up of individual surfaces that form obtuse angles where they join (e.g. when the individual surfaces are arranged radially around the operator), the movements of the individual control actuators shall be the same over the whole panel. The reference surface is the middle one.



Key

1 60° or more from vertical

2 30° or less from vertical

← "on" or "increase"

Figure 13 — Direction of movement of linear control actuators

5.4.3.5 Requirements relating to rotary control actuators with circular displays

a) In a display with a movable pointer and a fixed scale, movement of the control actuator in a clockwise direction shall lead to a similar movement of the pointer and vice versa (see Figure 14a)).

b) In a display with a fixed pointer and movable scale, no standard direction of movement is generally provided for (if possible, these displays should not be used). If a scale moves in the anti-clockwise direction, the values shall increase and the values on the control actuators also go in the "INCREASE" direction.

c) If a circular scale is only visible in one part of the arc, the rotating knob shall be positioned near the inner part of the arc or under the display (see Figures 14b) and 14c)).

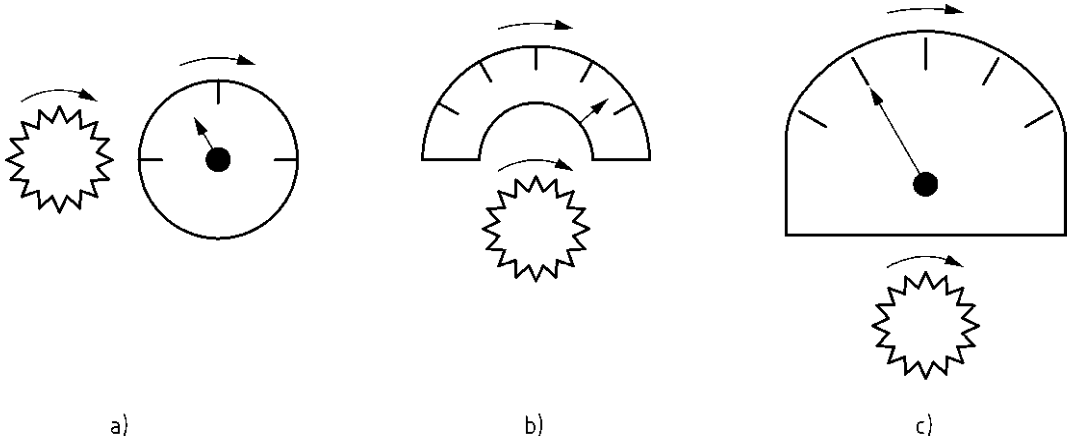


Figure 14 — Rotary control actuators and rotary displays

5.4.3.6 Rotary control actuators with linear displays

a) If a rotary control actuator and a linear display are both located in the same plane, that part of the control actuator near to the display shall move in the same direction as the moving part in the display (see Figure 15).

b) A rotary control actuator shall never be located above a display or to the left of a vertical display so as to prevent incompatible movement of the control and the display's response.

c) The movement of a control actuator in the clockwise direction shall lead to a movement of the pointer upwards or to the right (see Figure 15).

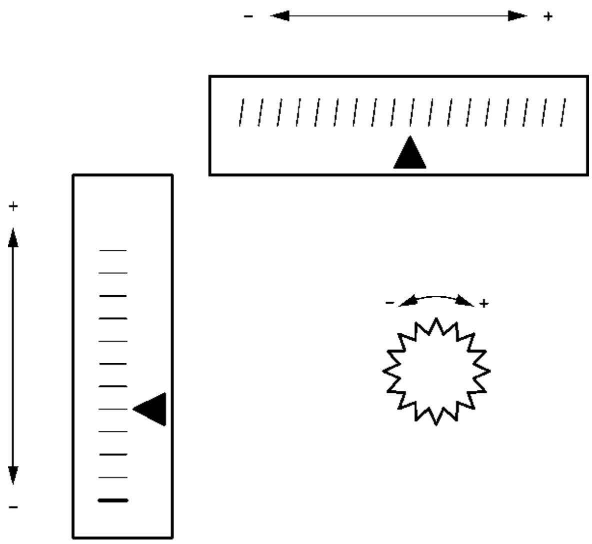


Figure 15 — Rotary control actuator with linear displays

5.4.3.7 Linear control actuators with circular displays

Where a display directly reflects the movement of a control actuator, the following should be used:

A linear control actuator if:

a) the pointer moves through an arc of less than 180° (see Figure 16a));

b) the movement of the control actuator is parallel to the path of the pointer travel or the pointer and control actuator move in the same relative direction (see Figure 16b)).

NOTE A rotary control actuator should be used if the pointer of the display moves through an arc of more than 180°,

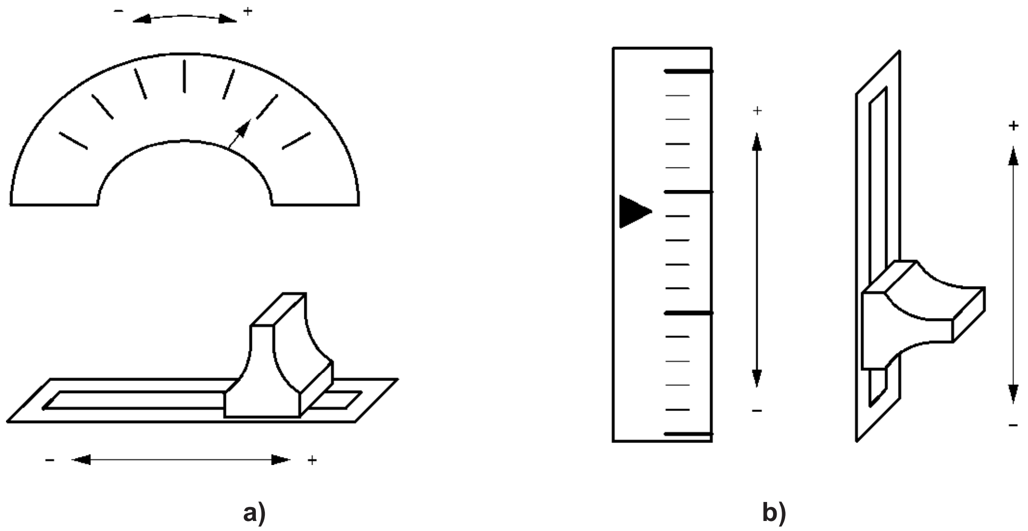


Figure 16 — Linear control actuators and displays

5.4.3.8 Compatibility of coding principles

Codings are keys for the identification of elements and their meanings for system functions. Methods include labelling, colours, shapes, localization, grouping structures, spatial distances and time intervals (e.g. flashing speed), sequences, etc. The role of coding is to make it easier for the operator to understand the systems status and decide how to interact with it. Coding compatibility results when uniformity and similarity of the use of individual coding methods is ensured in the system.

EXAMPLE The colour RED always means danger (see IEC 73).

The following aspects will help ensure compatible coding systems:

a) drawing up of a coding plan;

b) clearly define the allocation of labels to the elements;

c) remove any danger of confusion by avoiding similarity of the coding;

d) ensure uniformity of the coding of certain element and system functions;

e) do not give one coding multiple meanings;

f) keep the number of codings as low as possible;

g) follow the language and terms commonly used by the operators.

5.4.3.9 Compatibility with regard to the time response of displays and systems to control activities

After effecting control activities, the operator expects corresponding system reactions. Delaying acknowledgements from the system until later creates considerable stress for the operator. Time compatibility exists if the system and/or displays react in good time. A risk assessment will help to establish suitable system response time. If the system has lengthy reaction times, aid shall be given in the form of more rapid intermediate information.

5.4.3.10 Control/display ratio (C/D ratio)

The C/D ratio is the ratio of the movement of a control actuator to that of an associated element, display or controlled object.

Optimising the C/D ratio shortens the time needed for fine adjustments and reduces the number of errors in sequential tasks. The following will help to achieve a suitable C/D ratio:

a) when setting up control devices, consider the accuracy requirements, time requirements and error rates in the control activities;

b) design the scale of the display and the range of movement of the control actuator so that the need for frequent adjustment is minimized.

5.4.4 Step 4.3 − Ensuring integration of the system

5.4.4.1 General

The designer should consider not only the physical arrangement of the machine but also its impact, physical and mental, on the people in the system and its environment.

In order to help achieve a well integrated process design in a system the following aspects should be considered (see also EN ISO 9241-110):

a) there should be an adequate understanding of the relationships between the tasks, the tools and the problems solving processes which have to be undertaken;

b) the knowledge, experience, understanding and training of the operators;

c) operating stereotypes, the operators' in-built reactions;

d) there should be a plan for how symbols are used throughout the system;

e) language: elements should be consistent and use terms with which the operators are familiar;

f) there should be a simplified representation of the cause/effect network (input and output variables);

g) ensure that operators can readily co-ordinate their actions, by ensuring that the procedures are clear for everyone;

h) ensure that operators can readily co-operate, this requires that they can understand what the system is doing, and that everyone has the same understanding of the situation.

Furthermore ensuring suitable integration of the system needs to consider the way in which the operators actually carry out their tasks. This may require trials in the design process with intended operators (test personnel) and should involve them in simulations, mock-ups or walk throughs.

It should be noted that the system does not only include normal operation but also cleaning, repair, maintaining and dismantling.

5.4.4.2 Taking account of the complexity of a system

To take account of the complexity of a system it is important that all its components and their interactions are addressed. Some rules and assessment principles that should be followed are:

a) reduce the amount of information to the minimum necessary. Provide redundant information only where this will help avoid errors;

b) formation of groups and sub-groups of similar system functions to be monitored and controlled by the operator;

c) ensure that there is adequate identification and differentiation of elements and groups to achieve clarity, speed and safety of operation;

d) improve the quality of the information by increasing its affordance (the properties of the object that influences its usefulness). This refers to how the shape of an object gives information about how to use it (for example, an icon showing a lock and key);

e) provide for specialisation in certain tasks (e.g. monitoring, setting up). This may involve arranging all the display and control elements needed for a particular task in one place;

f) make provision for both top-down and bottom-up analysis for testing and fault diagnosis;

g) ensure it is possible to easily compare actual values with their required set points.

Sometimes the complexity of a task reveals the gap between the requirements of the task and the capabilities of the operator. Thus the interaction between the task and the operator should particularly be studied (see EN 614-2).

Compatible devices allow operators to use them in a suitable manner, without particular instructions. The coupling is compatible for an operator when it corresponds with their perceptions, understanding (cognitive processes) and their stereotypes (for example, to turn a tap clockwise to shut it off).

It is important to find solutions for managing complexity but not only by automation. This could lead to a degradation of the activity which can cause boredom or monotony.

5.5 Phase 5 – Implementation and evaluation

5.5.1 General

Implementation and evaluation should ensure that occupational comfort, safety, and efficiency are achieved and that, in fact, the work is adapted to the operator.

NOTE This means that operator collaboration is essential to validate (or invalidate) job performance. It also validates (or invalidates) the solution principles and helps to optimize choices.

The design and its implementation shall be based on an assessment of the tasks, the working situation and the job's activities (reference to similar already existing activities may be necessary). This ergonomic approach will highlight the true job constraints in the initial job situation, reference situation, or during simulation, in order to propose the best solutions.

Thus evaluation consists of ensuring that the initial objectives, the implemented solutions, and their results, all correspond. Differences often appear during the proving phase but the knowledge acquired throughout the design process, added to that resulting from observation of ergonomic aspects during this phase will allow the design to be further improved and a suitable result achieved.

Once a system is implemented it is important that provision is made for monitoring and reviewing its effectiveness and feeding back this information to further refine the design.

5.5.2 Steps for carrying out an evaluation

a) Verify and validate the layout and dimensioning. Taking account of variability of people and products and the needs for circulation of operator and equipment. Check that operators can reach and see all the necessary elements. Look at the effect of the shape and configuration of the panels and consoles on how operators can carry out their tasks;

b) verify that the arrangements of the control actuators and displays is consistent with the way the machine functions (e.g. the movement of a part of the machine corresponds to how the actuating element moves);

c) it is necessary that systems are error tolerant – assess the effects of incorrect actuation and ensure the error can be easily recovered;

d) verify the operability of the various steps needed to carry out each task. This should be done under the environmental conditions that will occur in the final operation (lighting, noise, temperature, etc). Often a simulation of actual use will be used, then it is necessary to consider the effects of additional operators and equipment that will be present in the final implementation. There is a need for ensuring that informal communication between operators is taken into account. Check that operators can operate the controls in sequence and obtain the necessary information at the correct time;

e) consider cleaning, maintaining and repairing activities. Conduct trials using people who carry out this type of work;

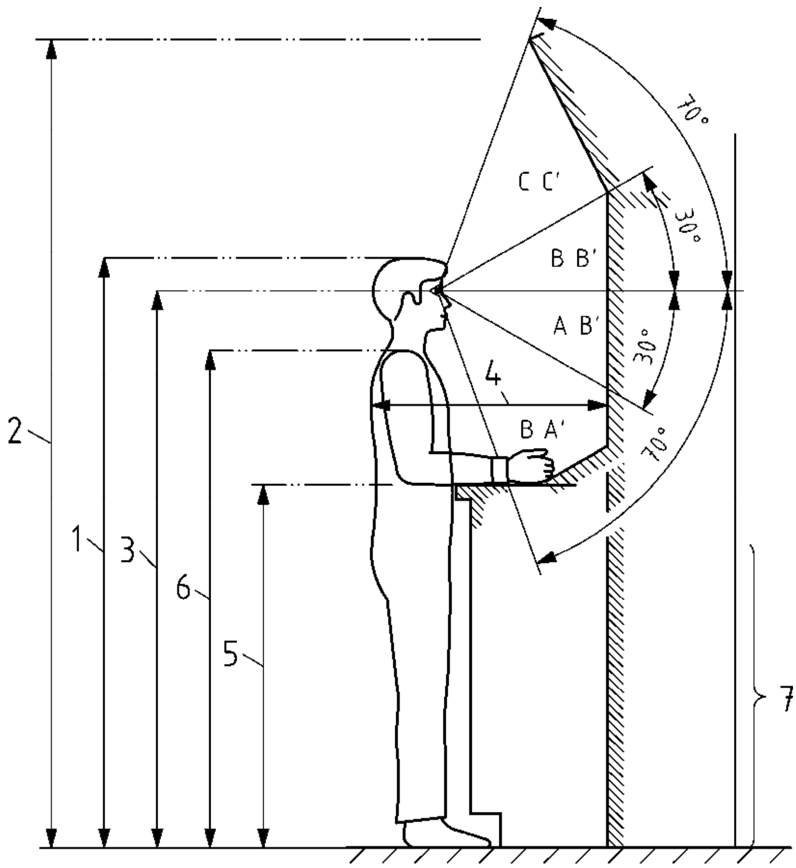
f) verify that the result of the evaluation is satisfactory and that important aspects have not been omitted. In particular it may be necessary to check the adequacy of the documentation (e.g. handbooks, manuals) and its usability (see EN ISO 9241-11);

g) after the proving phase continue to observe how the machine is operated and gradually make corrections when necessary.

Annex A
(informative)

Dimensions for sitting and standing consoles

Figures A.1 and A.2 show the location of zones for displays A, B, C and control actuators A', B', C' in relation to standing and seated workstations (consoles). The figures indicate by reference number the body measurements which are relevant for the design of suitable workstations. Values for these dimensions are given in Table A.1. Tables A.2 and A.3 give values for the angles of the zones.



Key

1 to 6	See Ref. No. in Table A.1.
7	Low priority control zone ≤ 920 mm
A to C	See Table A.2.
A' to C'	See Table A.2.

Figure A.1 — Body measurements and the location of zones for the standing operator

Table A.1 — Body measurements (unclothed) used for console design

Ref. No.	Human body measurement	Value [d] mm			Definition see EN ISO 7250-1:2010, subclause no.
		Percentile P			
		5	50	95	
	Standing operators				
1	Stature (body height)	1 530	1 719	**1 881**	4.1.2
2	Vertical reach	**1 910** [b]	2 051	2 210	-
3	Eye height, standing	1 420	**1 603** [a] (1 580)	1 750	4.1.3
4	Forward reach, from wall	**615** (605)			4.4.2
5	Elbow height	960	**1 078** [a] (1 050)	1 190	4.1.5
6	Shoulder height	1 260	**1 424** [a] (1 390)	1 570	4.1.4
	Sitting operators				
7	Seated eye height (from floor) [c]	(1 050)	**1 234** [a] (1 183) (790 + 444)	(1 395)	4.2.2 + 4.2.12
8	Lower leg length (popliteal height)	340	**444** [a] (430)	505	4.2.12
9	Eye height from seat	680	**790** [a] (780)	860	4.2.2
10	Elbow height from seat	190	**243** [a] (230)	280	4.2.5
11	Shoulder height from seat	510	**623** [a]	695	4.2.4
12	Elbow grip length (Elbow to centre of fist)	327	362	**389** [b]	4.4.3
13	Thigh clearance	112	146	**170** [a]	4.2.13
14	Knee to floor	460	530	**602** [a]	4.2.14
15	Buttock to inside knee	430	499	**560** [a]	4.4.6
16	Buttock to outside knee	543	604	**664** [a]	4.4.7

[a] Values taken from International data on anthropometry (OSH Series, No. 65.) ILO Geneva, 1990.

[b] Values are taken from "Kleine Ergonomische Datensammlung 2002".

[c] The "Seated eye height (from floor)" is identical with the "Design-Eye-Position".

[d] A standard with updated data is under development (future EN ISO 7250-3).

NOTE 1 All other values are taken from EN 547-3:1996+A1:2008.

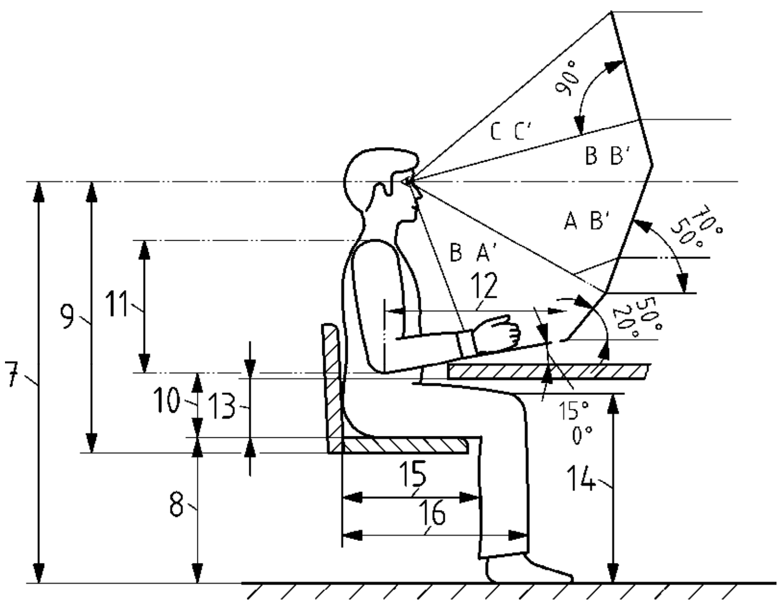
NOTE 2 Bold values should be used for construction.

NOTE 3 For shoes 30 mm (approx.) should be added to body heights.

The above data for European people is for both men (95th percentile) and women (5th percentile), the 50th percentile is an estimated average for both men and women. See EN ISO 15537 for further data for the world wide population.

Table A.2 — Location of Zones in standing position

Zone		Angle
A	Primary display zone	0° to – 30°
B	Secondary display zone	– 30° to – 70° 0° to + 30°
C	Low priority display zone.	30° to + 70°
A'	Primary control zone	– 30° to – 70°
B'	Secondary control zone	0° to – 30°
C'	Low priority control zone	0° to + 50°



Key

7 to 16 See Ref. No. in Table A.1.

A to D See Table A.3.

A' to C' See Table A.3.

NOTE For seated operators of mobile machinery the seat index point (SIP) according to EN ISO 3411:2007 is used.

Figure A.2 — Body measurements and the location of zones for seated console design

The design of consoles should be based on the measurements of the intended population. Values for large (95th percentile), average (50th percentile) and small (5th percentile) measurements of particular body dimensions are necessary in order to construct consoles and panels which match the range of operator dimensions.

Table A.3 — Display and Control Zones in sitting position

Zone		Angle
A	Primary display zone	0° to – 30°
B	Secondary display zone	0° to + 30° – 30° to – 70°
C	Low priority display zone.	+ 30° to + 70°
D	Colour limits	0° to + 30° 0° to – 40°
A'	Primary control zone	– 30° to – 70°
B'	Secondary control zone	+ 30° to – 30°
C'	Low priority control zone	+ 30° to + 70°

Table A.4 — Indication of head and eye movement angles

Head and eye movement angles	Angle
Optimum eye rotation (vertical and horizontal)	– 15° to + 15°
Optimum Head movement angles vertical	– 15° to + 30°
Optimum Head rotation angles	15° to 20° to each side

NOTE These values are indicative as there is much variability within the population.

For further information on anthropometric requirements see EN ISO 14738. For further information on zones of comfort and reach see EN ISO 6682.

Because of the variability in height within operator populations it is much preferred to provide adjustable height consoles for both sitting and standing workstations wherever this is possible.

Annex B
(informative)

Coding Methods

Table B.1 gives an overview of requirements for different coding methods with examples.

Table B.1 — Overview of coding methods

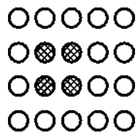
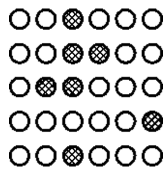
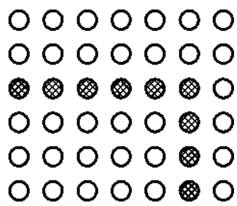
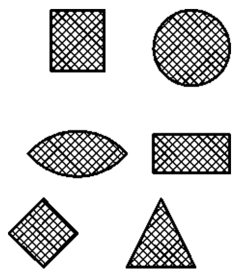
Type	Use, selection	Requirements (design)	Examples, illustrations
1. Colour	i) Aid for quick identification. discrimination and interpretation of elements, groups Highlighting of elements/operating states. ii) Grouping, associating and splitting up (dividing, subdividing) of large quantities of elements for coding according to functions and sub-functions. iii) Orientation when searching or jumping from specific and functionally associated identical elements. iv) Selection of colours (status indicators for system): - red: attention, hazard, emergency, warning; - yellow: caution; - green: normal operation, safety, good conditions; - white: neutral, background colour for alphanumeric signs, no action; - blue (cyan): background colour to accentuate zones; - black: background for active symbols (see EN 894-2) with changing ambient lighting.	Provide brightness and colour contrast. • good levels of illumination are necessary for colour discrimination (see EN 894-2); • colours should be selected that have good spectral separation, normally no more than three saturated colours are recommended (plus black and white); • select as great brightness differences as possible; • it is not recommended to combine red and green, or red and blue; • good combinations are red/white, yellow/black, black/white. See Annex C for further information on colour combinations. NOTE The field of view for each colour is slightly different.	1) Colour as means of coding for grouping  2) Colour as means of splitting up (separating).  3) Colour as means of orientation, searching and aligning. 
2. Shape	i) Aid for visual and touch discrimination and identification of control actuators outside the field of vision or in changing lighting conditions. ii) High degree of recognition required. iii) Grouping (connecting) and splitting up of elements. iv) Searching over large distances and over several elements.	- Select geometrically regular shapes: equilateral triangles, squares, circles, rectangles. - Avoid sharp edges. - For dimensions and other shapes, see EN 894-2 and –3.	1) Shape as means of identification.  2) Touch discriminable examples (see EN 894-2).

Table B.1 *(continued)*

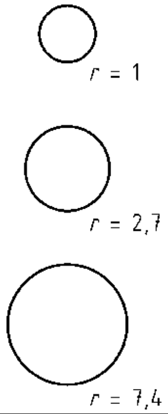
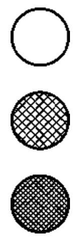
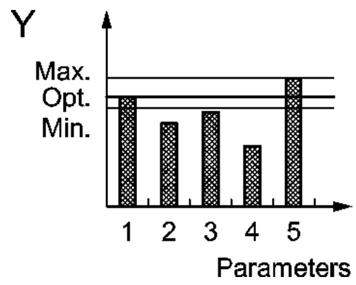
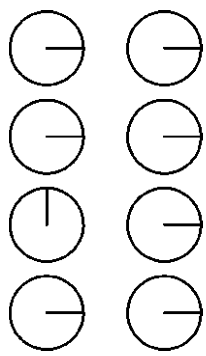
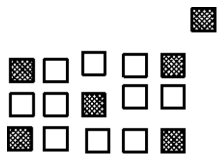
Type	Use, selection	Requirements (design)	Examples, illustrations
3. Size	i) Applicable for digits, word displays and buttons to highlight elements of one group. ii) Information on the importance of one element amongst others. iii) Connecting elements with the same function over large distances and jumping over several elements.	1) Specify no more than three sizes for discrimination purposes. 2) Indicate differences in sizes exponentially. 3) Leave adequate space between control actuators that have to be identified by touch.	Exponential (e^n) differences in sizes. 
4. Brightness	i) Highlighting information (elements) from a group. ii) Emphasising importance. iii) Directing attention. NOTE Unequal degrees of brightness lead to premature tiredness and the suppression of darker displays.	1) For discrimination select exponential differences in brightness. 2) Take account of the full range of anticipated ambient lighting levels to ensure that both brightly and weakly illuminated elements are clearly visible. 3) The brightest element should not be more than 40 times brighter than the darkest element. 4) Use greater brightness for greater importance. 5) Do not use brightness coding if using shape or size coding.	Exponential differences in brightness. 
5. Length of lines, bars	i) Pictorial representation for the continuous displays of several parameters in a delimited field. ii) Balancing in collective display. iii) Combining many parameters and reduction of information. iv) Facilitating interpretation and monitoring.	Show the lines and bars in a co-ordinate system to facilitate identification and interpretation.	
6. Angular position of pointers and knobs of identical displays and control actuators	1) Method for homogenizing the representation of information. 2) Reduction of the amount of information. 3) Facilitating monitoring and interpretation (see EN 894-2).	1) Use quadrant positions of pointers and knobs in round scale displays and switches: - 9 o'clock = zero position; - 12 o'clock = zero position for values to left and right of the zero; - 12 o'clock or 3 o'clock normal operation. 2) To homogenize scale divisions, select % graduations for the same shape of scale. 3) To show disturbance from the normal operating condition (see figure).	

Table B.1 *(concluded)*

Type	Use, selection	Requirements (design)	Examples, illustrations
7. Flashing	i) Attract attention with regard to individual parameters of fields. ii) Indication of emergencies. iii) Requirement for immediate action. iv) Discovering target in highly populated control surfaces. v) Do not use in the case of long screen afterglow.	1) Flashing rate: 1 Hz to 5 Hz - 2 Hz to 3 Hz recommended; - minimum flash duration: 50 ms. 2) Use higher rates for the more critical information. 3) The on and off rates shall be approximately 50 % each. 4) Provide for switching off when critical point has been localized.	See ISO 11428, EN 981
8. Alphanumeric signs (numbers, letters)	i) Numbers are mostly used for showing precise information. ii) Uppercase letters for equipment designations and inscriptions. iii) Uppercase and lowercase lettering for descriptive information. NOTE See also item 11.	1) for suitable shapes for digits see EN 894-2. 2) Note that the requirements for stroke width, width and height of characters are different according to the contrast (positive or negative) and to the type of display, active (light emitting) or passive (EN 894-2:1997+A1:2008, Table 2). 3) Speed of change of digit no faster than 0,5 s.	See EN 894-2
9. Auditory signals	i) Supplementing a visual display to stimulate attention. ii) Aid in the event of poor visibility. iii) Information on activities to be carried out immediately. iv) Where visual attention may be occupied.	1) The language used shall suit the intended operators. 2) Only present information that is needed by the operators. NOTE In complex situations, high demands are made on mental functions such as memory. Language communication should be arranged so that it does not add to the demands on the operator.	See ISO 11428, ISO 8201, EN 981
10. Position	i) Specifying a location for elements on the basis of: – importance; – function; – sequence of use; – positional relationship.	1) Positional coding systems shall be used consistently throughout. 2) Positional coding should not prevent necessary sight of the process.	
11. Icons, symbols	i) To specify/reduce the amount of information the operator needs. ii) Where information is required independent of a particular written or spoken language.	1) Take into account expectations of the operator. 2) Only use well known symbols. 3) Symbols and icons shall be explained in the accompanying manual.	Graphical symbol standards. See EN 60073

Annex C
(informative)

Suitability of Colour Combinations

Table C.1 — Suitability levels for the combination of coloured symbols and their backgrounds

Background colour / Colour of the symbols	White	Yellow	Orange	Red, Purple, Violet, Blue, Cyan, Green, Grey [a]	Black
White		--	#	+	++
Yellow	--		--	#	+
Orange	#			--	+
Red, Purple, Violet, Blue, Cyan, Green, Grey [a]	+	#	--	*	--
Black	++	+	+	--	

[a] These colours have similar reflectance values and for this reason are grouped in the same cells.
\# Suitable for highly saturated colours only.
* Deficiencies in colour vision shall be taken into account. The use of saturated colours can help discrimination.

Suitability levels:

++ Highly suitable
+ Suitable
-- Not suitable

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC on machinery.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 2006/42/EC

Clause(s)/subclause(s) of this EN	Essential Requirements (ERs) of Directive 2006/42/EC	Qualifying remarks/Notes
All clauses	1.1.6, 1.2.2, 1.2.3, 1.7.1.1, 1.7.1.2	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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[5] EN 418, *Safety of machinery — Emergency stop equipment, functional aspects — Principles for design*

[6] EN 614-2, *Safety of machinery — Ergonomic design principles — Part 2: Interactions between the design of machinery and work tasks*

[7] EN ISO 3411:2007, *Earth-moving machinery — Physical dimensions of operators and minimum operator space envelope (ISO 3411:2007)*

[8] EN ISO 6682, *Earth-moving machinery — Zones of comfort and reach for controls (ISO 6682:1986, including Amd 1:1989)*

[9] EN 61310-3, *Safety of machinery — Indication, marking and actuation — Part 3: Requirements for the location and operation of actuators (IEC 61310-3:2007)*

[10] IEC 73, *Short-circuit currents — Calculation of effects*

[11] EN 1005-4, *Safety of machinery — Human physical performance — Part 4: Evaluation of working postures and movements in relation to machinery*

[12] EN ISO 11064-4, *Ergonomic design of control centres — Part 4 Layout and dimensions of workstations (ISO 11064-4:2004)*

[13] EN ISO 14738, *Safety of machinery — Anthropometric requirements for the design of workstations at machinery (ISO 14738:2002, including Cor 1:2003 and Cor 2:2005)*

[14] EN ISO 15537, *Principles for selecting and using test persons for testing anthropometric aspects of industrial products and designs (ISO 15537:2004)*

[15] EN 547-3:1996+A1:2008, *Safety of machinery — Human body measurements — Part 3: Anthropometric data*

[16] EN 60073, *Basic and safety principles for man-machine interface, marking and identification — Coding principles for indicators and actuators (IEC 60073:2002)*

[17] EN 981, *Safety of machinery — System of auditory and visual danger and information signals*

[18] EN ISO 7250-1:2010, *Basic human body measurements for technological design — Part 1: Body measurement definitions and landmarks (ISO 7250-1:2008)*

[19] ISO 8201, *Acoustics — Audible emergency evacuation signal*

[20] ISO 11428, *Ergonomics — Visual danger signals — General requirements, design and testing*

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