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Ergonomic requirements for the design of displays and control actuators —

Part 2:
Displays

Spécifications ergonomiques pour la conception des dispositifs de signalisation et des organes de service —

Partie 2: Dispositifs de signalisation

Reference number
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Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

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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.

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.

International Standard ISO 9355-2 was prepared by the European Committee for Standardization (as European Standard EN 894-2:1997) and was adopted, under a special "fast-track procedure", by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*, in parallel with its approval by the ISO member bodies.

ISO 9355 consists of the following parts, under the general title *Ergonomic requirements for the design of displays and control actuators*:

— *Part 1: Human interactions with displays and control actuators*

— *Part 2: Displays*

— *Part 3: Control actuators*

— *Part 4: Location and arrangement of displays and control actuators*

Annex A of this part of ISO 9355 is for information only.

Ergonomic requirements for the design of displays and control actuators —

Part 2:
Displays

1 Scope

This part of ISO 9355 gives guidance on the selection, design and location of displays to avoid potential ergonomic hazards associated with their use. It specifies ergonomics requirements and covers visual, audible and tactile displays.

It applies to displays used in machinery (e.g. devices and installations, control panels, operating and monitoring consoles) for occupational and private use. Specific ergonomics requirements for visual display terminals (VDTs) used for office tasks are given in the standard ISO 9241.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9355. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9355 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 7731, *Danger signals for work places — Auditory danger signals.*

IEC 61310-1, *Safety of machinery — Indication, marking and actuation — Part 1: Requirements for visual, auditory and tactile signals.*

IEC 61310-2, *Safety of machinery — Indication, marking and actuation — Part 2: Requirements for marking.*

3 Definitions

For the purposes of this part of ISO 9355, the following definitions apply:

3.1
operator
the person or persons given the task of installing, operating, adjusting, maintaining, cleaning, repairing or transporting machinery [EN 292-1]

3.2
work task
an activity or activities required to achieve an intended outcome of the work system [EN 614-1]

3.3
work equipment
machinery, tools, vehicles, devices, furniture, installations and other components used in the work system [EN 614-1]

3.4
signal
stimulus related to the status, or change in status, of work equipment which has a potential effect on the senses of an operator. This European standard describes signals which may be detected by the eyes (from visual displays), the ears (from auditory displays), or the skin (from tactile displays)

3.5
display
device for presenting information that can change with the aim of making things visible, audible or discriminable by touch (tactile)

3.6
digital display
display in which the information is shown in numerical code

3.7
alphanumeric display
display in which the information is shown as a combination of digits and letters

3.8
analogue display
display in which the status information is shown as a function of length, angle or other dimension. In the case of visual displays, the information may be shown as a function of pointer deflection, length of a bar graph, or similar visual quantity. In the case of auditory displays, information may be transmitted as a function of pitch or loudness. In the case of tactile displays, the information may be transmitted as a function of the display's vibration (frequency or amplitude), or of the display's displacement

3.9
symbols
letters, digits, pictorial representations, or combinations of these, used for labelling a display's graduations, or as a means of identifying the display itself

3.10
perception
psychophysiological process occurring in the central nervous system, the product of which is knowledge about the environment. Perception is a dynamic process and is not determined merely by the parameters of the signals which initiated it. As a consequence, it is possible that the information obtained may be incomplete, uncertain, or incorrect. Knowledge may be based on one or more of the following levels of perception: detection, identification, and interpretation. Detection is the perceptual process by which the operator becomes aware of the mere presence of a signal. Identification is the perceptual process by which the detected signal is distinguished from other signals. Interpretation is the combination of perceptual and cognitive processes by which the contents and significance of the identified signal are recognised.

4 Visual displays

Visual displays can be used to transmit large quantities of information to the operator, in a variety of ways.

4.1 Requirements for detection of visual displays

4.1.1 Positioning the display

The physiological and functional requirements of the operator and the unobstructed lines of sight available during task performance determine the positioning of the visual display relative to the operator. The size of the operator's visual field is limited, which in turn limits the number of displays which can be attended to at any one time.

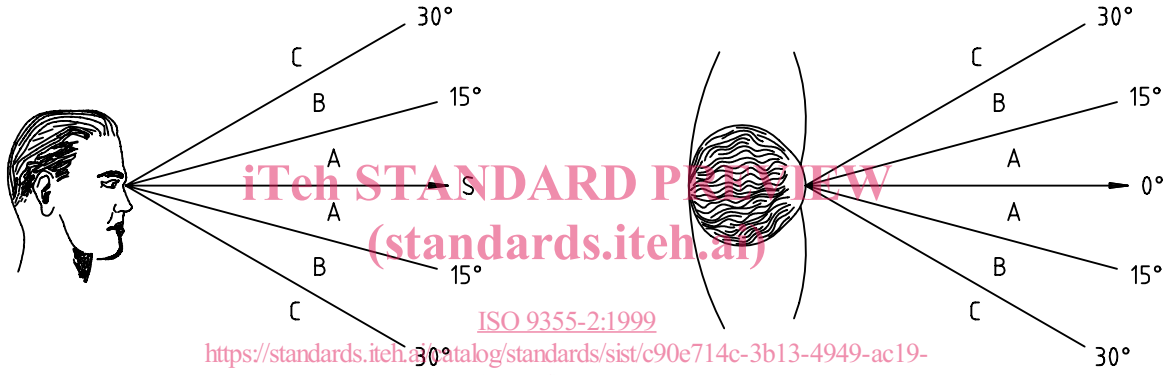
Two different types of visual task are distinguished: detection tasks and monitoring tasks. Detection tasks are those where the operator has to be alerted by the system, monitoring tasks are those in which the operator actively seeks information.

Three zones of decreasing efficiency for visual signal detection are identified for both detection and monitoring tasks as "Recommended", "Acceptable" and "Not suitable" (see Table 1). The centre-lines of the "Recommended" and "Acceptable" zones lie in the median plane and correspond with the line of sight, as shown in Figures 1 and 2. In the detection task the line of sight depends on the main centre of attention. For monitoring tasks displays may be positioned around a line of sight that is at an angle below the horizontal which is known to be more comfortable for the operator.

The angles presented in these figures are general ergonomic recommendations; it is assumed that the operator has normal vision, and is able to maintain a relaxed and stable (preferably seated) position, close to the displays.

Table 1 — Levels of suitability

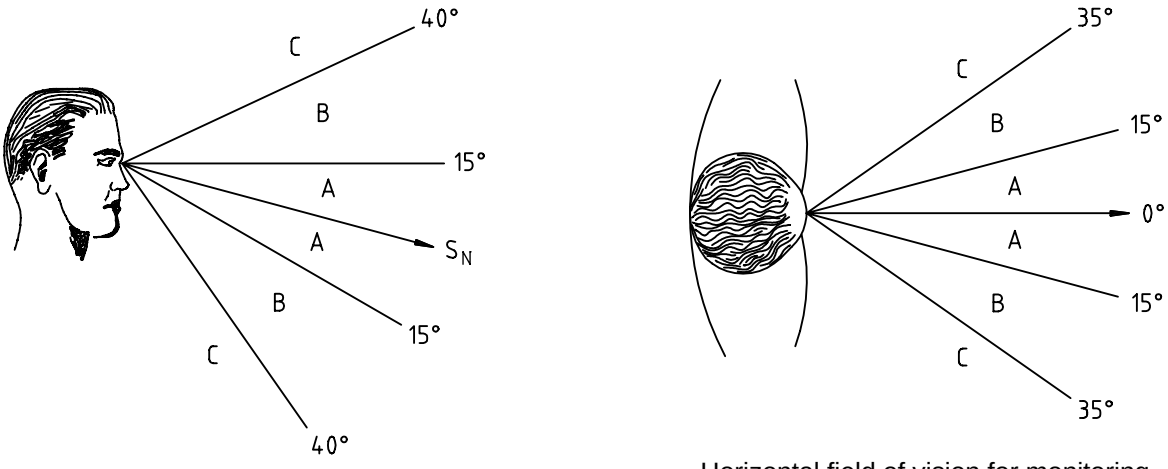
Level of suitability	Significance
A: Recommended	This zone shall be used wherever possible
B: Acceptable	This zone may be used if the recommended zone cannot be used
C: Not suitable	This zone should not be chosen



Vertical field of vision for detection — Horizontal field of vision for detection

Legend: S: Line of sight, direction is imposed by external task requirements

Figure 1 — Detection tasks



Vertical field of vision for monitoring — Horizontal field of vision for monitoring

Legend: S_N: Normal line of sight, 15° to 30° below the horizontal

Figure 2 — Monitoring tasks

Visual displays shall not be positioned outside the "Recommended" and "Acceptable" zones unless appropriate aids have been provided by the designer. For example additional auditory displays, or other devices which do not require large changes in the operator's posture. The "Not suitable" zone should only be used for displays which are not critical for safe operation.

Where the operator's ability to discriminate colour is important for the correct use of displays, the limits of the "Acceptable" zone must be reduced, because the size of the central visual field (which is sensitive to colour) is smaller than the field which is sensitive to white light.

4.1.2 Functional relationships between the display and the operator

In general, these relationships are of two types. The first is where the operator seeks out and observes the display. The second is where the operator's attention is demanded by the display itself (e.g. flashing warning or acoustic alarm); or the operator is alerted by one or more types of display (e.g. a combination of visual and auditory displays); or the operator is alerted by the status of the system to check the display.

For either of these two functional relationships, the most frequently used and/or the most important display shall have the highest priority for location in the immediate area of the operator's natural line of sight (Zone A). Lower priority displays may be located towards the periphery of vision (Zone B or even Zone C if necessary).

Conditions which maximize the effectiveness with which alerting or warning displays gain attention shall be achieved by design. Since the human visual system is sensitive to change in the visual environment, the designer could choose, for example, a flashing characteristic to alert the operator, as the changing nature of a flashing display will be readily detected. Note that the flashing characteristic should be coupled with low luminance, to avoid the creation of afterimages in the operator's eyes. Alternatively, it may be useful to couple an auditory display with a continuous, low luminous intensity visual display.

4.1.3 Environmental factors

The most important environmental factors are illumination and vibration. Special care should be taken to design displays that compensate for their possible adverse effects.

At workplaces with passive (non light emitting) displays there should be an illumination intensity of at least 200 lx. Where this is not possible, compensatory measures must be taken, e.g. enlargement of the displayed information, provision of local lighting or active illumination (light-emitting displays). Shadows with high contrast or reflections disturb perception and shall be avoided. Thus, room lights which may produce reflections on displays shall be installed at illumination angles taking account of the typical viewing directions. Compensatory measures are to incline the displays and/or install non-reflective display surfaces. Light sources that allow the differentiation of coloured display elements from their background shall be chosen.

Reading performance can be influenced by continuous or peak vibration of the displays, the operator or both. Low frequency (1 Hz to 3 Hz) vertical vibration of digital displays leads to large reading errors directly proportional to acceleration at accelerations above 5 m/s^2.

Reading errors increase with frequencies from 3 Hz to 20 Hz. When operators and displays are synchronously subjected to vertical vibrations, reading performance is affected least at frequencies below 3 Hz, but will decrease significantly with higher frequencies.

At frequencies between 3 Hz and 20 Hz vertical acceleration greater than 5 m/s^2 decreases reading performance, and there is a linear dependency between these two parameters. Multiple single axis sinusoidal vibration can cause a deteriorating reading performance because of interference effects. Dual axis vibration can result in one rotary movement. Reading errors and reading time will then increase with the vibration frequency.

Compensatory measures are:

a) a high luminance of the display to improve contrasts beyond the usual level;

b) a stroke width in the direction of the vibration between 5 % and 7 % of the height of the displayed characters;

c) a display vibration frequency matching the vibration frequency of the operator.

4.1.4 Other conditions to observe for facilitating signal detection

The operator's line of sight shall be uninterrupted for all ergonomically acceptable working positions, and for all anthropometric characteristics of the user population.

For good identification, representation in black and white is preferred. However, coding displays with colour can help detection where symbol density is high, or where the operator must search for specified information. Surrounding related displays with a single colour can also help to reinforce the link between the displays. See also IEC 61310-1 and IEC 61310-2.

4.2 Requirements for identification of visual displays

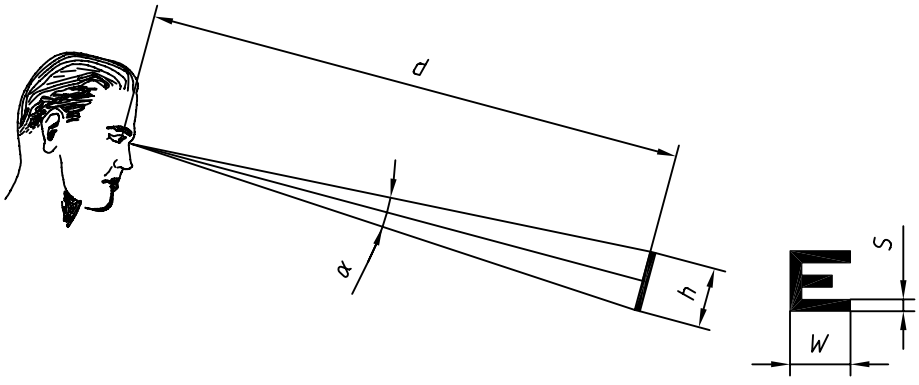
The image quality of the display shall be high under all normal and emergency observation conditions: contrast shall be as high as practicable, and confusability between displays (or components of displays) shall be minimised by using different shapes, colours, labels or any other suitable means for distinguishing one display from another.

The contrast between symbols, letters, numbers, pointers, lines and their immediate backgrounds and surroundings shall be sufficient to provide levels of legibility and discriminability which are compatible with the perceptual speed and accuracy demanded by the task. In the case of light-emitting (active) displays the contrast ratio (ratio of foreground to background luminance) shall be at least 3:1 to comply with this requirement; a ratio of 6:1 is recommended. The covers of light-emitting displays shall not reflect other light sources to any large extent (i.e. the contrast ratio between the reflected light and the surroundings shall be as low as possible), otherwise the display may appear to be on when it is not or be difficult to read.

4.2.1 Symbols used for displays

For letters and numerals simple and preferably familiar forms are recommended. It is essential to avoid confusability between characters (e.g. B with 8, 6 with 5; see Annex A). Thus, seven-segment numerals (LED or LCD) are only acceptable if their use is restricted to representing digits. Depending on the prevailing perceptual conditions, 5×7 and 7×9 dot-matrix characters may be acceptable but larger sizes of matrix shall be preferred. Where pictorial symbols are used, they shall be simple in form, and easily identified and interpreted by the population using the display.

Figure 3 defines the important dimensions which relate to character size and proportion. Note that viewing distance *(d)* is only one of a number of important factors which will determine appropriate character dimensions. The level of illuminance, the contrast between characters and background, and the overall legibility of the characters will all affect these dimensions.



Legend:

d: Distance from eye to character
α: Angle of vision of character in arc minutes
h: Height of character
w: Width of character
s: Stroke width of character

Figure 3 — Definition of the dimensions

The recommended character heights *(h)* are produced when α lies in the range of 18 to 22 arc minutes, though where α is in the range of 15 to 18 arc minutes, character heights would be acceptable, character heights produced when α is less than 15 arc minutes are not suitable. Recommended character heights can be approximately calculated by:

— The recommended range for character width *(w)* is between 60 % and 80 % of character height. Only where the display surface is curved, or the viewing angle is oblique should a range between 80 % and 100 % of character height be used. Character width of less than 50 % of character height is not suitable.

— Suitable ranges for stroke width of characters (*s* in Figure 3) are given in Table 2. It is recommended that appropriate spacing between letters (20 % to 50 % of character width) and between words (1 to 1,5 character widths) is provided.

Table 2 — Suitability of different stroke widths of characters

Type of display	Stroke width of character as a percentage of character height		Suitability level
	Positive representation[1)]	Negative representation[2)]	
Active display	from 17 to 20	from 8 to 12	recommended
	from 14 to < 17	from 6 to < 8 > 12 to 14	acceptable
	from 12 to < 14	from 5 to < 6 > 14 to 15	conditionally acceptable[3)]
Passive display	from 16 to 17	from 12 to 14	recommended
	from 12 to < 16	from 8 to < 12 > 14 to 16	acceptable
	from 10 to < 12 > 17 to 20	> 16 to 18	conditionally acceptable[3)]

1) Positive representation: dark characters on a light background.

2) Negative representation: light characters on a dark background.

3) Under particularly favourable viewing conditions.

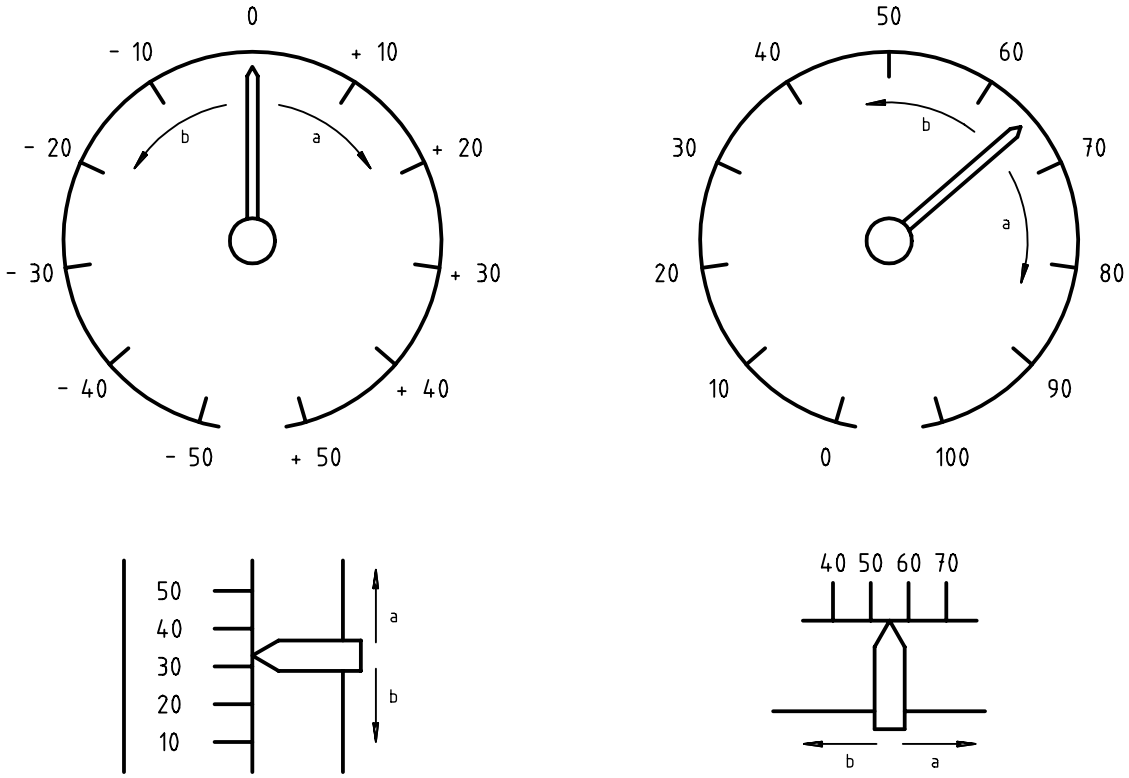
4.2.2 Digital displays

The design of the numerals, and their contrast with the background shall adhere to the recommendations above. If the digital display is mechanical (the numerals are printed on the rims of rotating wheels), it is recommended that the numerals shall be fully visible in the display window, and shall not be partially obscured as the display wheels rotate (e.g. by snap action).

Since digital displays require little space, large digits are practicable, and shall be preferred. Where many digits must be displayed, reading errors can be minimised by grouping digits into small blocks. Blocks containing three or two digits shall be preferred, unless interpretation of the display is facilitated by having more digits per block.

4.2.3 Analogue displays

The index (e.g. pointer, liquid level) shall be visible at all times, even when the index has moved off the scale itself. The use of displays with a moving index and a fixed scale is recommended. Figure 4 illustrates appropriate directions of index movement for indicating decreasing and increasing quantities.



Legend:

a) Increase

b) Decrease

Figure 4 — Appropriate directions of movement for pointers

The scale zero shall be located so that increases are denoted by either left-to-right, clockwise or upward movement of the pointer, and so that decreases are denoted by right-to-left, anticlockwise or downward movement of the pointer.

4.2.4 Choice of scales for analogue displays

To achieve good perception and to reduce reading errors, scale dimension, graduation, labelling and pointer design shall be considered.

The different dimensions of a scale shall be designed according to reading distance and environmental illumination. Table 2 gives recommendations for scale dimensions under different illumination conditions at a typical reading distance of 700 mm. For other distances a formula is given below:

$$x = d \cdot \tan\frac{\alpha}{60}$$

Legend:

x: Dimension A to G in Table 3

d: Distance from scale to eye (mm)

α: Angle of vision (arc minutes)

NOTE For ease of calculation x is approximately equal to $d \cdot \frac{L}{700}$, if *L* is replaced by the appropriate dimension A to G from Table 3 where the reading distance is 700 mm.