ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

ERGONOMICS RECOMMENDATIONS FOR VDU WORK PLACES

TR/22

March 1984

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European Computer Manufacturers Association
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BRIEF HISTORY

This document concerns an area new to ECMA, ergonomics. The traditional ECMA document covers either a compatibility issue (e.g. how tracks on a disk should be organized to facilitate interchange of information) or a safety aspect (e.g. how a user should be protected from high voltages). In both these cases the background knowledge is rather solid and there is not much room for variations or interpretations.

That is not the case with ergonomics. Bad ergonomic design does not usually have immediate effects nor can good design be expressed in a very precise way. Normally many factors contribute to the end result and one less optimal may be balanced by another that is better than otherwise required.

One of the major lessons of ergonomics is that all people are different, their tasks differ, and their work environment differs. They are also different in size, age, sex, sensory perception, etc. There is no such creature as "the average person". The conclusion of all this is that these recommendations are recommendations and nothing else. They have to be rather broadly stated and should be interpreted in that spirit also.

Ergonomic science cannot by its very nature give any absolute limits or figures as to where comfort ends and discomfort starts. On the other hand the reader should be aware that several countries have legislation which covers the design as well as the use of VDUs and keyboards. These rules should, of course, be obeyed. Since they may be changed based on new findings or technology advances, or new rules introduced at any time, ECMA has not included the ones, current just now, into this document.

A human operator does not change when going from a VDU to a typewriter or vice versa, and there is nothing physiologically unique or distinguishable about VDUs. Consequently many of the recommendations given here, especially in 6.1 (Office environment) are not unique to the VDU-workplace.

This report has been accepted by the General Assembly of ECMA in December 1983 for publication as an ECMA Technical Report.

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1. SCOPE

1.1 The subject of these recommendations is those physical characteristics of office work places which ECMA feels are relevant to the health and well being of human operators as well as to an efficient interface between the operator and the work place.

1.2 The component of the work place that is of primary importance to ECMA is the Visual Display Unit and its associated keyboard.

These recommendations cover this equipment as well as its close environment. They are only applicable to work places where the equipment is used intensively, although they are valid rules for good ergonomics even for other types of terminals.

Safety aspects are covered in other Standards and are not included here.

1.3 Although ECMA acknowledges that items like job content, the general organization of the job and the way the terminal is used are in many instances more important to the operator's satisfaction than the physical factors, this recommendation has been restricted to physical characteristics.

The reason is two-fold:

- Computer manufacturers have a more direct influence on technical design than on the use.
- Psychological factors have not yet reached a scientific level which renders them ready for standardization.

The physical characteristics are thus a necessary, but not sufficient condition for the efficient use of VDU work places.

1.4 The quality, reliability and durability of the product should be such that the physical characteristics specified in these recommendations are maintained throughout the useful life of the product.

2. REFERENCES

ECMA-57 : Safety Requirements for Data Processing Equipment

ECMA-74 : Measurement of Airborne Noise Emitted by Computers and Business Equipment

3. DEFINITIONS

For the purpose of the present recommendations, the following definitions apply.

3.1 Luminous Intensity

The candela (cd) is the luminous intensity in a given direction of a source which emits monochromatic radiation of frequency 540.10^{12} Hz and of which the radiant intensity in that direction is 1/683 watt per steradian.

3.2 Luminance

The luminance, at a point of a surface and in a given direction, is the luminous intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction. The unit of luminance is the candela per square meter (cd/m^2).

3.3 Luminous Flux

The luminous flux $d\Phi$ of a source of luminous intensity I in an element of solid angle $d\Omega$ is $d\Phi = Id\Omega$. The unit of luminous flux is the lumen (ℓm = 1 cd.sr).

3.4 Illuminance

The illuminance at a point of a surface is the luminous flux indicent on an element of the surface, divided by the area of that element. The unit of illuminance is the lux (ℓx = 1 $\ell m/m^2$).

3.5 Reflectance

The ratio of the luminous flux reflected from a surface to the luminous flux incident on it. The reflectance depends on the direction of the incident light, except for matt surfaces, and its spectral distribution.

3.6 Specular Reflectance

The aptitude to reflect in a specular way with respect to the incident light (gloss units).

3.7 Diffuse Reflectance

The aptitude to scatter the light in all directions other than the specular one (%).

3.8 Luminosity

Attribute of the visual sensation associated with the amount of light emitted from a given area. It is the subjective correlate of luminance.

3.9 Glare

The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the brightness of the general surroundings.

3.10 Contrast

A term that is used both in a subjective and an objective sense.

3.10.1 Subjective sense

Subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively. (Hence: luminosity contrast, lightness contrast, colour contrast, simultaneous contrast, successive contrast).

3.10.2 Objective sense

Contrast is a difference in luminance levels between the viewed image and its background. It is defined by CIE (Commission Internationale d'Eclairage) as follows:

$$c = \frac{Lo-Lb}{Lb}$$

where:

Lo = object luminance
Lb = background luminance.

A simpler expression also used in this document is:

$$c = \frac{Lo}{Lb}$$

3.11 Resolution

It is the number of dots per unit of length.

3.12 Sharpness

It is the gradient of the luminance from the background to the dot (cd/m^2 per mm).

3.13 Polarity of the Image Presentation

The polarity is negative when light or illuminated characters are displayed on a dark or unilluminated background. The polarity is positive in the opposite case.

3.14 Legibility

Legibility refers to the human ability to recognize quickly and correctly single symbols.

3.15 Readability

Readability refers to the human ability to transform strings of characters into meaningful units.

3.16 Reflected Luminance

Reflected luminance may be calculated using the following formula:

$$L(cd/m^2) = \frac{p \cdot E}{\pi}$$

where:

L = luminance
p = surface reflectivity
E = ambient illuminance in ℓx

4. USE OF WORKPLACES

4.1 General

The use of workplaces which incorporate VDUs, and especially the intensity of use, should be considered from the point of view of all the operational factors which contribute to the use. In broad terms these factors are:

i) The task

The task as a whole can be determined by a detailed analysis of the content and the timing of each process.

ii) The person who must carry out the task

The person's education, training in the use of the equipment and general office procedures, and other individual characteristics must be realized.

iii) The equipment provided

In addition to the VDU screen and keyboard, the work equipment may include books, files, source documents, telephone and even a conventional typewriter.

iv) The office work environment

The physical, social, organizational and motivational aspects of the office and the business in general will all contribute to the effective of the intensity of use.

The intensity of use of a workplace can be classified according to full and proper consideration of all the above aspects. The parts of a workplace which are of major interest in this document are the VDU screen, the keyboard and the source document. The relationship between these items can, for example be classified as:

- "Entry" of large amounts of data or text;
- "Reading" of large amounts of data or text;
- "Dialogue", is a sequence of short entry or reading activities.

In determining the intensity of use for a particular VDU workplace, it is important to establish first of all whether or not the display and keyboard are used by the operator as primary tools in performing the tasks. In a case where the nature of the tasks which a particular operator carries out is very diverse over a given period of time, it will be necessary to examine carefully the total range of tasks in order to decide on the intensity of use to be assumed in the workplace design.

4.2 Examples

Example 1

Primary tools:

Keyboard, Source document.

Activity:
Entry of numeric and alpha-numeric data from forms. The line of sight will alternate between the source document and the keyboard. In the case of numeric data entry, the line of sight may be directed nearly continuously at the source document.

Example 2

Primary tools:

Display, Paper, Telephone

Activity:
Information enquiry, noted on paper by hand or communicated by telephone. The main activity is selecting and reading the information on the screen. Normally, this type of use is sporadic. Such applications are usually found at travel desks, libraries, etc.

Example 3

Primary tools:

Paper

Activity:
Mainly manual paperwork, with support from a display and keyboard. Information is occasionally demanded from the computer and also sometimes information is returned by the user. The line of sight moves between the paper, the display and the keyboard. As office automation increases, there may be a shift towards more intensive use of the display/keyboard. Typical users would be professionals or executive secretaries.

Example 4

Primary tools:

Keyboard, Display, Source Document (all of equal importance)

Activity:
Continuous work with a system, mostly in the form of "dialogue". Information will be entered from a wide variety of source documents. Information is searched for and read, and modified on the screen where necessary. Data entry may also be carried out using the keyboard or pointing device. Typical applications are word processing, computer programming or graphics, by writers or other professionals.

5. RELEVANT HUMAN CHARACTERISTICS

This section is concerned only with those human characteristics which are relevant to the following sections. Those characteristics which do not require special consideration for VDU workplaces are not included.

5.1 Visual Perception

5.1.1 Vision

5.1.1.1 Adaptation and accommodation

The human eye adapts to a very wide range of luminance levels. This capability is called adaptation. Frequent adaptation processes - for example adjustments to greatly different luminance levels - influence the performance of the individual, more when the luminance level differences are large.

The capability of the eye to focus on objects of different viewing distances is called accomodation. The eye has a large depth of field (about ± 0,4 diopters), therefore all objects within that field will be reasonably in focus. The depth of field depends on the viewing distance as indicated in the following table:

OBJECT DISTANCE	DEPTH OF FIELD
40 cm	34 cm to 47 cm
60 cm	48 cm to 77 cm
80 cm	60 cm to 117 cm
100 cm	71 cm to 166 cm

5.1.1.2 Central and peripheral visual field

Sharp, clear vision of small details can only be achieved within a 1^{o} cone of vision. Perception of shape outside this field is less accurate. Colour discrimination significantly deteriorates in the far periphery. Variations in light level and in general movement are perceived within the much larger peripheral field of vision. This can extend up to 100^{o} on both sides of the central axis and to 55^{o} upwards and 70^{o} to 80^{o} downwards.

5.1.1.3 Line of vision

The line of vision is determined by movements of both the eyes and the head.

The optimum movement of the eye is 15^{o} in all directions, the maximum is 25^{o} upwards and 35^{o} to either side.

The inclination and rotation of the line of vision is obtained by combined movements of the head and eyes. The recommended inclination downwards for the line of vision is 30^{o} to 45^{o}, the maximum is 65^{o}. The recommended lateral rotation of the line of vision in relation to the symmetrical axis of the body is 35^{o}, the maximum is 65^{o}.

5.1.1.4 Contrast and acuity

Contrast sensitivity is the ability of the eye to perceive differences of tone and luminance. A minimum contrast ratio of 3:1 is frequently recommended for legibility. Some experiments have shown that speed and

accuracy of symbol identification can be improved with higher contrast ratios up to 40:1, however, under the typical conditions visual acuity does not increase with contrast ratios beyond about 10:1.

Visual acuity is the ability of the eye to perceive very small shapes and details. Visual acuity increases with higher luminances up to a point beyond which it decreases.

Visual acuity depends on the size of the detail and the viewing distance, i.e. the angle subtended at the eye. Under optimum conditions of contrast and illumination the smallest detail, which can be resolved, is equivalent to an angle of about 1'. The visual angle for shapes to be recognized needs to be considerably larger. The visual angle needs to be increased also under less than optimum viewing conditions.

5.1.1.5 Colour

5.1.1.5.1 Sensitivity

The eye is more sensitive to colours in the centre of the visible spectrum. In normal ambient luminance levels, the eye is operating significantly above threshold levels, therefore all colours are acceptable.

5.1.1.5.2 Preference

There is no evidence to suggest that any one colour is more "restful" than any other. Some people may have a subjective personal preference for a particular colour, but there is no consensus on these preferences.

5.1.1.5.3 Multicolour situation

Contrary to suggestions by some sources, the accommodative mechanism of the eye does not "hunt" between the different colours in a single display or between the colour of a symbol and that of its background.

Requirements for both legilility and colour discrimination are often conflicting and result in the need for a compromise. Blue on a dark background presents a problem: a deep blue gives better colour discrimination but it is not as legible as light blue. The number of colours should not exceed ten when they are required to be named and used for coding.

5.1.1.6 Flicker

The perception of periodic light variations is called flicker. Such flicker may be irritating or fatiguing. This perception is influenced by certain properties of

the light source like frequency, intensity, amplitude of the variations, size, etc. Ambient light and location of the light source in the visual field are also influencing this phenomenon, as well as differences among individuals like age and other physiological characteristics. The refresh rates generally used in VDUs are well above those which would, of themselves, contribute to the onset of flicker-induced epileptic seizures (8 Hz to 16 Hz) to which a very small number of people (1 in 10000) may be susceptible.

5.1.1.7 Jitter

The perception of periodic, geometric variations is called jitter. Such jitter may be irritating or fatiguing. This phenomenon is influenced by characteristics of the display, power supply, raster rate, etc.

5.1.1.8 Fatigue

It should be recognized that, although in some circumstances working with VDUs (like other visual tasks) can give rise to visual fatigue or eye strain, the discomfort is of a temporary nature; the present scientific evidence indicates no damage to eyesight.

5.1.1.9 Visual disabilities

5.1.1.9.1 Colour blindness

Men are more likely to have some degree of colour blindness than women. About 6% of men have some reduced ability to see a full range of colours; however, not so severe as to prevent the use of a colour display. Only 0,003% of men are completely colour blind.

With age colour perception shifts towards the red end of the spectrum, which makes blue more difficult to see.

5.1.1.9.2 Aging

Advancing age and diseases such as glaucoma reduce the eye's ability to function properly. Increased luminance levels are required to maintain legibility as aging occurs.

With age some people become more glare-sensitive, typically due to light scattering because of increased opacity of the lens and ocular media of the eye.

5.1.1.9.3 Refractive errors

The most common forms of visual disability and also the most correctable are refractive errors or the inability to focus an image on the retina.

The three main types are:

i) Presbyopia: the limitation in the range over which focusing can be achieved, typically due to aging.

ii) Hypermetropia and myopia: long or short-sightedness due to a difference between the length of the eye ball and the power of the eye's optical system.

iii) Astigmatism: variations in curvature of the cornea in different meridians.

5.1.2 Interpretation of displayed information

Besides the pure physical aspects of visual perception, as described above, the related human interpretation is essential for overall perception. Humans have certain expectations about displayed information concerning sequences, consistency and style, e.g.:

- Readability, i.e. understanding of information in context versus legibility, i.e. recognition of individual characters.
- Graphic rendition, for example the use of colour, highlighting, etc. as attributes to text and graphics.
- Character design.

5.2 Acoustical Perception

Acoustical noise can be a disturbing factor in an office environment where it can interfere with conversation or disturb concentration.

5.3 Postural Conditions

5.3.1 Body dimensions

For the purpose of designing work places and work equipment, vehicles, furniture or buildings, the individual serves as "the measure of all things". The inquiry and the statistical analysis of body dimensions is the subject of anthropometry. Body dimensions are illustrated in measurement tables. When using the tables, it is necessary to consider the various aspects of each individual case.

The design and arrangement of work places and work equipment should be determined on the basis of the body dimensions of the "tallest" and the "smallest" user since anthropometric average values cannot generally be used when determining work place dimensions. Fig. 1 illustrates this.

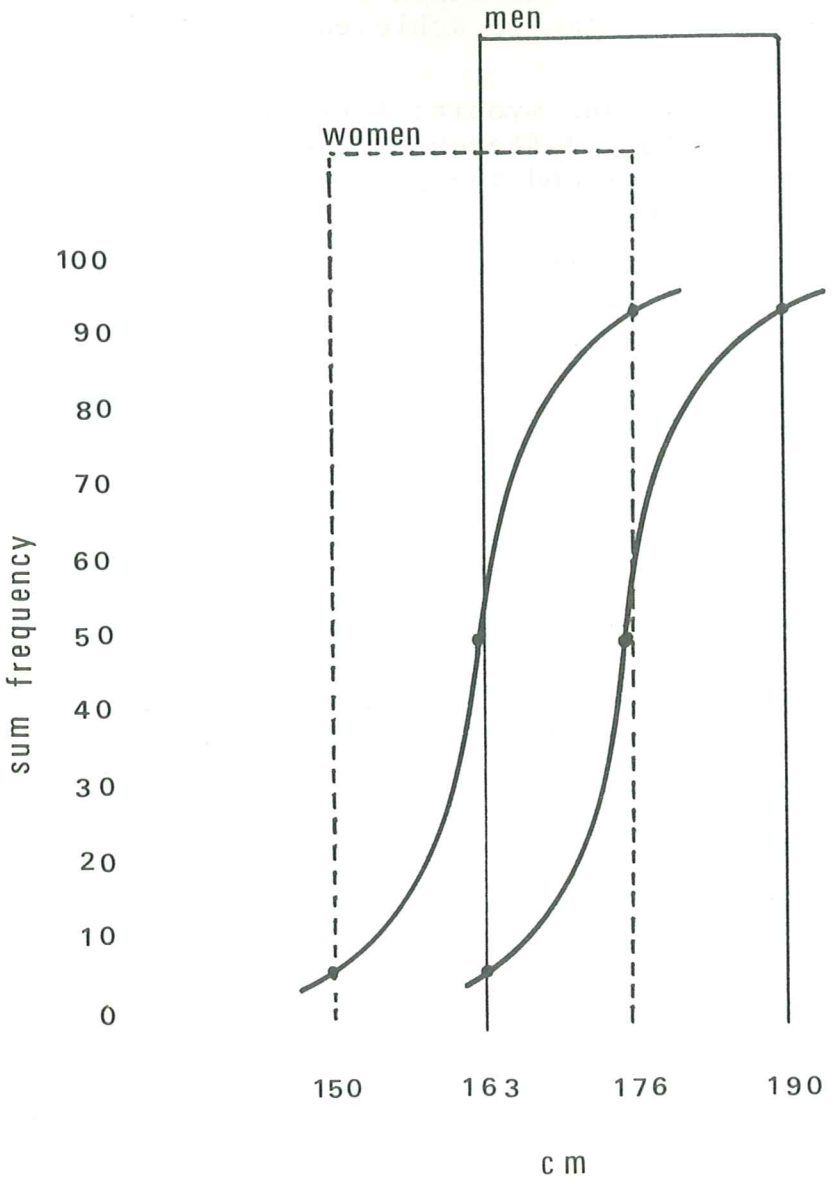

Fig. 1 - Human Heights

"Smallest" woman (only about 5% of women are smaller).

"Tallest" woman (only about 5% of women are taller) and "average" man (about 50% of men are smaller or taller resp.).

"Average" woman (about 50% of women are smaller or taller resp.) and "smallest" man (only about 5% are smaller).

"Tallest" man (only about 5% of men are taller).

The actual body posture during work is not generally the same as that from which the measurement values are derived. Changes in body posture should be considered.

Fig. 2 illustrates the differences between the reach of short women and tall men.

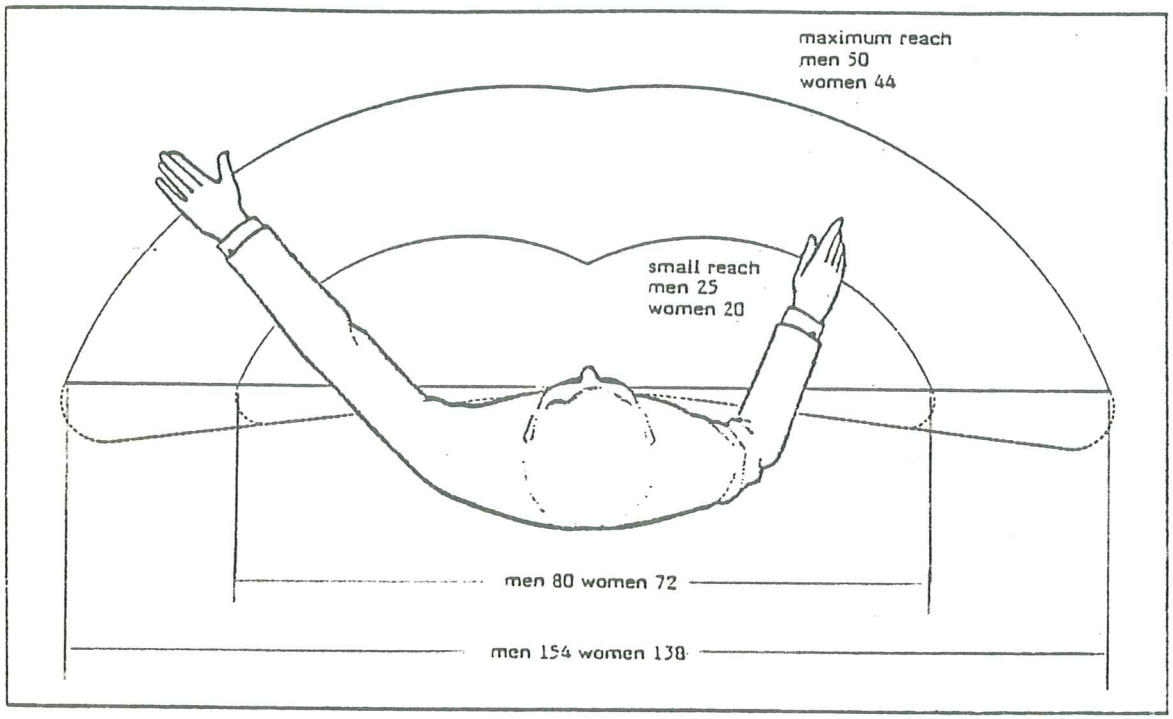

Fig. 2 - Measurements of reach in cm average working height for men and women

5.3.2 Work posture

There is no ideal sitting posture. A frequent change between different sitting postures seems to contribute most to health and well-being. An important prerequisite is sufficient space for movement at the work place and a chair that is ergonomically designed and correctly adjusted.

Inadequate work posture can lead to fatigue, backache, stiffness, neckache, headache, sore arms and wrists, etc. All of these decrease both quality of work life and productivity. Such inadequate work place design could aggravate physical impairments already present.

A seated posture of the operator which will minimize fatigue, especially for prolonged situations can be achievable as follows.

The feet should be placed flat on the floor or a footrest with the lower leg approximately vertical. The thighs should be approximately horizontal with the weight taken on the buttocks, not the thighs. If the thighs are compressed, particularly behind the knees, such compression restricts blood flow to the lower legs. The trunk should be vertical, and the body weight on the spine supported by a backrest at the lumbar region.

The upper arms should hang from the shoulder joint comfortably straight down at the sides. The forearms should be positioned less than 90°, up to 70° with the elbow joints taking the load, not the upper arm muscles. The wrists should be flexed no more than 20°. Finally, the head should be inclined downwards, but no more than about 15° to 20°. Nor should the head need to be turned, except occasionally.

There are other postures found to be comfortable, such as provided by arm rests (palm rests) or by tilted seat pans.

The different body dimensions have a direct influence on:

- height of seat,
- table height,
- height of footrest for a table not height-adjustable,
- leg space under the tabletop,
- height and arrangement of the visual objects,
- height and arrangement of objects being manually operated,
- area of motion at the work place.

A good VDU height is determined by the seated eye height with the head tilted comfortably down no more than 20°, at a comfortable viewing distance. The comfortable range of vertical eye movement relative to the head adds another 15° down from horizontal. Finally, the actual position of interest can be anywhere on the screen.

5.4 Psychological Conditions

Absence of emotional stress is one of the major conditions for feeling comfortable, in all office situations. The emotional stress felt by the individual during work depends on the type and duration of strain as well as on one's experience and skills. It is also influenced by the desires and attitude towards the work. Emotional stress may result in: fatigue which results in a reduction of performance, weakness of concentration and increased frequency of errors, boredom which, in most cases, occurs with short and repetitive work tasks, frustration, which becomes evident if activities are a source of annoyance or are performed only with great reluctance.

6. RECOMMENDATIONS

6.1 Office Environment

The following sections describe some general principles as to how to design the components of the work place to meet the ergonomic needs of the people performing their tasks in that work place for extended periods of time. The goal is to provide for good worker satisfaction by designing to meet the prolonged comfort and productivity needs of a wide range of workers in a wide variety of settings.

The data presented is considered to be a sufficient description of work place design parameters for the situations and tasks under consideration. The three prime elements of the work place which affect the worker are the task, the work station and the environment. The last two are treated here. This material cannot be exhaustive (e.g. the dimensions given throughout any all-encompassing work such as this one can never be more than a first-order approximation) because the nature of good ergonomic design is to tailor these elements together for the unique situation of interest. Because then, situations differ, the work place design or user should solicit local expertise.

6.1.1 Geometry of work place

Independent of the floor space occupied by the work place, operators themselves require a certain floor space.

6.1.1.1 Working space

Seated operators require from 750 mm to 1000 mm (front to back) of seating space to give clearance to move the chair back to exit from the work place.

A further 900 mm wide aisle behind that space should be allowed for circulation around the work place behind the operator. Operators who are seated side by side should not be closer than 1000 mm, centre-to-centre.

6.1.1.2 Office space

A general recommendation is to provide 7 m^2 to 10 m^2 floor space per worker, depending somewhat on the particular work station equipment involved.

6.1.1.3 Work surface

The width of the working table is most often determined by the dimensions of the required working equipment and by its arrangement. If it is also necessary to take handwritten notes, an area of at least 600 mm width must be provided.

In order to extend reach, an angled working table could be used. The decision as to which side should be angled depends on whether the operator is left-handed or right-handed or on the direction of the work flow. An empty space should be provided beneath the keyboard and working area to provide sufficient room for the user's knees and feet. Sharp edges should be avoided.

6.1.1.4 Height-adjustable chairs

Regardless of whether the table is adjustable or not, a height-adjustable chair is required. Footrests adjustable in height and inclination are not required unless the

height adjustment of the chair does not make for a comfortable posture. The footrest must be securely positioned on the floor and its surface should be large enough and slip-proof.

6.1.1.5 Adjustments

The primary means to achieve a comfortable seat position for prolonged work is a properly adjusted chair (with a footrest, if needed). Next in importance, fixed-height work places can, usually, be made equally comfortable through the use of adjustments in the equipment in the work place. Finally, in a sometimes more complex way, work places can be made equally comfortable for prolonged use through the use of fully adjustable office furniture such as tables, desks, stands, etc. Obviously, combinations of the above three techniques provide more adjustments to achieve the same result.

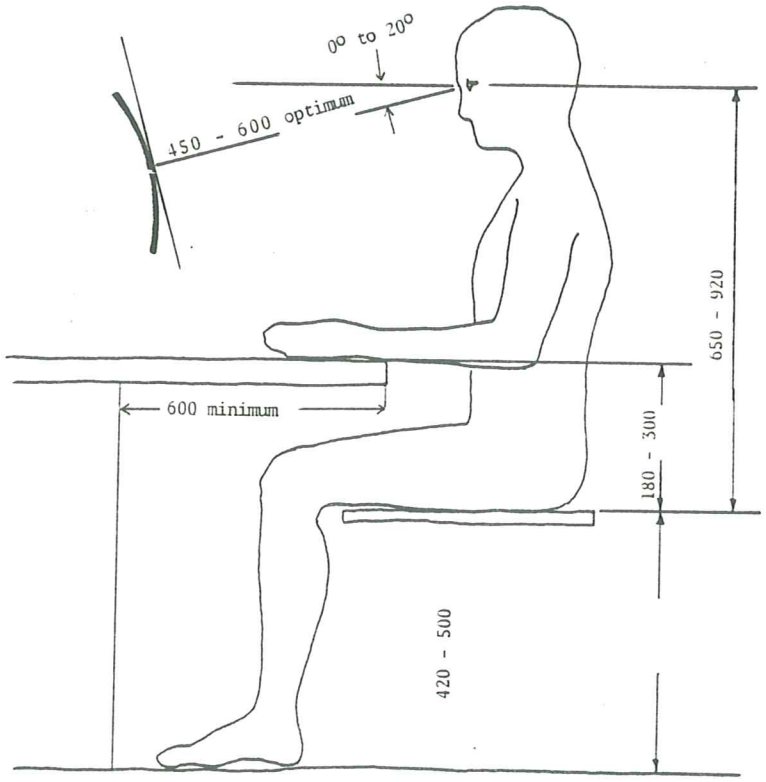

Fig. 3 - Recommended Work Station Adjustment Ranges

Specific to a computer terminal work station consisting of a VDU and keyboard, there are three key dimensions in work place design which will permit comfortable, seated posture for prolonged work:

i) Vertical distance between seat pan and keyboard C-row (Fig. 7).

To accommodate various populations from 5th percentile women to 95th percentile men seated as described above, the distance between the seat pan and keyboard C-row should be adjustable from 180 mm to 300 mm. This adjustment is most easily accomplished with an adjustable height chair.

ii) Viewing distance from eye to reading surfaces.

The viewing distance to both screen and document will range normally between 450 mm and 600 mm, but may be as much as 300 mm to 700 mm. This adjustment is accomplished by setting the document holder adjacent next to the screen so that both are within the same depth of field, and by moving the chair and/or screen to a comfortable viewing distance. This adjustment can be easily accomplished, provided the screen is not positioned too far back on the work surface.

iii) Relative heights of screen and eye.

Given the wide range of possible screen locations, a tilt and/or height adjustment facility may be desirable.

iv) Table height.

If the height of the table is not adjustable, then a height of about 720 mm is recommended.

6.1.2 Arrangements

6.1.2.1 Arrangement of the work place

The VDU should be positioned in such a way that disturbing reflections and glare from light surfaces are avoided on the screen (e.g. from windows, glass walls of neighbouring rooms or lamps). The work place should be positioned between the rows of lamps and the line of vision should substantially be parallel to these rows. The operator should be protected from peripheral disturbances in the field of vision.

6.1.2.2 Work place design

The frequency of use of the various parts of the work equipment (VDU keyboard and source documents) is important for the work place design. In particular, the following activities must be taken into consideration:

- Visual contact with the primary working equipment
- Data input using keyboard
- Movement of source documents
- Handwriting.

It is important to reduce fatigue due to neck and/or eye movements to and from the source document and screen.

Arrangement of the workplace and VDU

Accordingly, the working equipment must be positioned within the user's reach and field of vision:

- Working equipment that is used frequently should be placed within the central field of vision to minimize head movement.
- Working equipment that is used only occasionally can be located further away but not necessarily within the central field of vision.
- If several items of working equipment are looked at equally often, e.g. source documents and VDU, they should both be located in the central field of vision and preferably at the same distance.

The depth of the working table must be such that, where possible there is the same distance to VDU and source documents.

6.1.2.3 The keyboard

The keyboard is of high importance in the design of work station, not only to achieve easy and error-free operation, but also to reduce the fatigue of the operator.

The work place layout should be such as to permit the operator to place the keyboard in a position best suited to the particular job in hand, taking due account of his/her postural comfort. There should be a space of at least 50 mm in depth on which to rest the palm.

6.1.2.4 Source documents

It is important that source documents should be readily legible. This is considerably influenced by the quality of the paper, by the quality of presentation and by the grouping and formatting of data.

6.1.3 Lighting and surfaces

6.1.3.1 Illumination

The illumination shall be sufficiently bright, uniform and free of glare and flicker. The required intensity of illumination depends on the visual task to be performed. In work places with visual display units, an intensity of illumination in the range of 300 lux to 500 lux measured on the table is normally sufficient.
This illumination can be achieved by a combination of general lighting and lighting with personal adjustment.

Do not face any large, brightly-lit surfaces while reading, i.e. a window.

Direct lighting on a CRT screen is undesirable since it may introduce reflections and glare. However, direct lighting on other reading surfaces will permit lowered ambient lighting conditions and avoid unnecessary glare.

Properly positioned, indirect lighting can produce evenly diffuse illumination. Systematically removing a strongly competing light source from the direct line of sight increases performance as the angle increases. It is recommended that such lighting be kept at least 50° from the direct line of sight, e.g. by using grids or prisms.

Work surfaces should be matt, neutral in colour, and reflect no more than 20% to 50% of incident light in the direction of the operator. Surfaces adjacent to the work station should also be matt.

There are two prime reading surfaces in the work place: paper and screen. The contrast in printed material is due to the difference in the reflectance of light by the characters and by the background. These contrast levels can be quite high. For print on paper the contrast should not be less than 1:6 for satisfactory legibility.

The contrast between reading surfaces and surround is important. Assuming an absence of specific glare sources, contrast can be specified in two different ways: by luminance ratios or by surface reflectances.

A pragmatic rule for surface reflectances is that they should generally decrease from ceiling (80% to 90%) to floor (20% to 40%).

Another pragmatic rule is that when using monochromatic displays, a complementary colour to that of the phosphore chosen should be used for the main surfaces of the room.

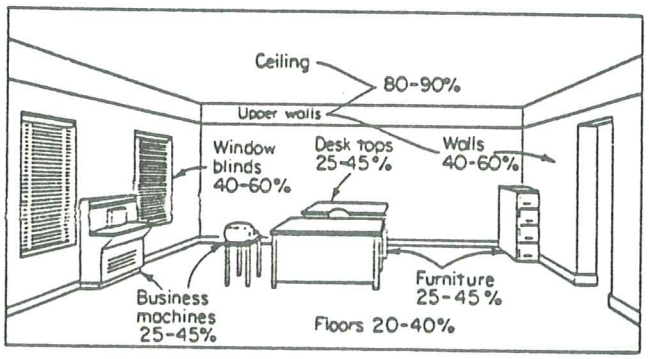

Fig. 4 - Reflectances recommended for room and furniture surfaces

Attention is focused more closely on the working area if it is brighter than its surroundings.

With daylight illumination the intensity should be regulated. Some reductions may be achieved by use of neutral coloured curtains. A better method is to use window shades which allow the intensity to be regulated easily.

Lighting units should be arranged in rows parallel to the windows. If these rows can be separately switched on, the brightness distribution can be adapted to the prevailing conditions.

6.1.4 Acoustical noise

Unwanted noise generated by equipment may be reduced, e.g. by noise protection covers, in which case due attention must be given to any consequential safety impact such as overheating. Noise reflections may be reduced by curtains, sound-absorbing partition walls and textile floor materials.

6.1.5 Temperature, humidity and ventilation

Ventilation requirements for VDU work place operation are not generally different from those which apply to non-VDU installations, except to emphasize avoiding low humidity to diminish static electricity.

6.2 Work Equipment

6.2.1 Characteristics of VDU-housing

6.2.1.1 Dimensions

The size of the display screen depends on the amount of information to be displayed, and this in turn depends on the task to be performed. For word processing, it might be useful to display a whole page. For other applications, a few lines might be sufficient.

6.2.1.2 Adjustability

In most cases keyboards of table-top units should be separable from the screen. Depending on the task, the keyboard and the screen can then be positioned in ergonomically favourable positions.

The inclination of the surface of the screen should be adjustable at least between -3^{o} and $+15^{o}$ from the vertical to avoid visual disturbances such as reflection, and to achieve the correct reading angle (Fig. 5).

Under some circumstances it may also be desirable to provide height adjustment to control the angle between the line of sight and screen surface. While 90^{o} (normal) is optimal, a variation of $\pm 20^{o}$ is usually acceptable (Fig. 6).

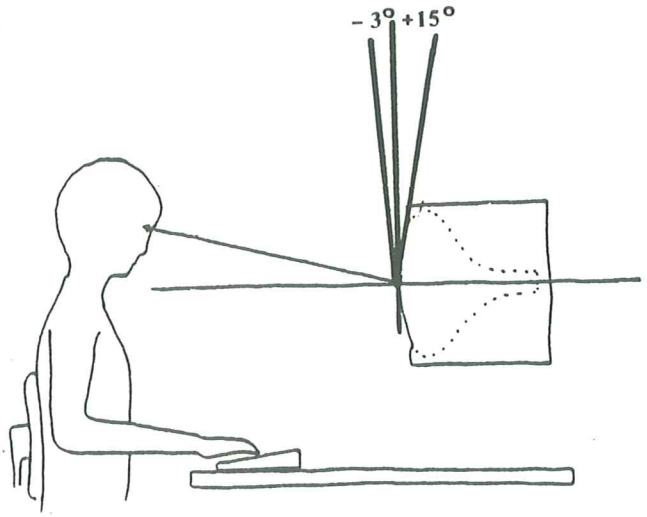

Fig. 5 - Tilt angle

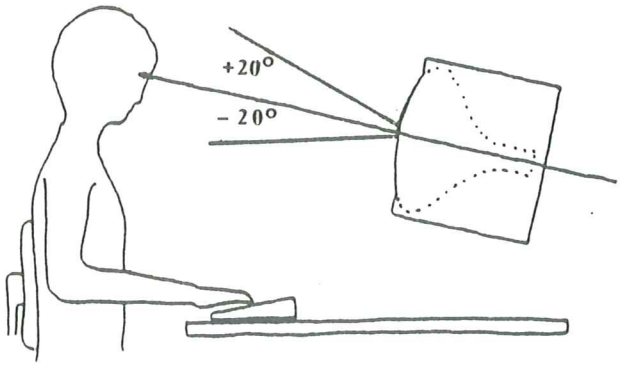

Fig. 6 - Viewing angle

6.2.1.3 Surfaces

To prevent reflections, silky matt surfaces are recommended. The diffuse reflection factor for the front frame of the VDU screen should be between 15% and 75%.

6.2.2 Keyboard characteristics

6.2.2.1 Dimension and weight

Keyboards should be light enough to give easy movement, but should sit firmly on the work surface and not slide or tip during operation.

Keyboard height from the desk surface is measured to the C-row. The exact choice of this height depends on a number of parameters, e.g. seat pan height, keyboard slope, etc. However, low height (low profile) or provision of a palm rest is recommended.

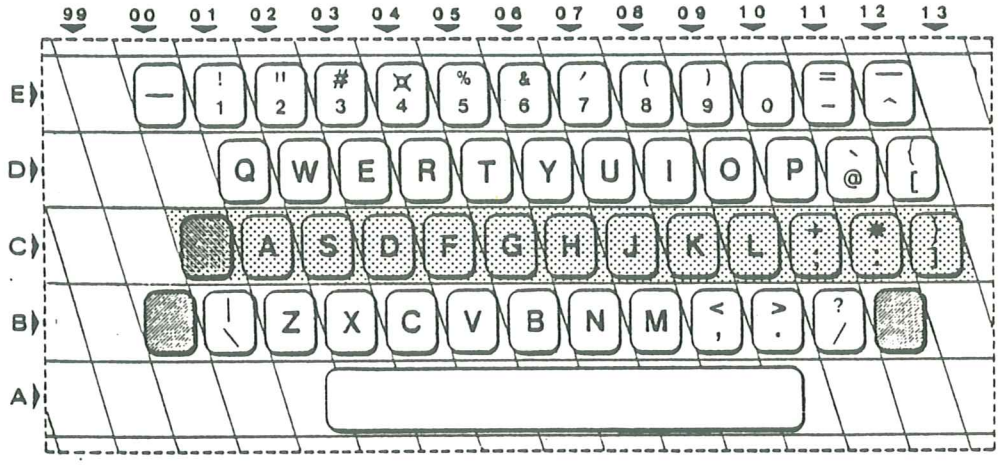

Fig. 7 - Keyboard rows

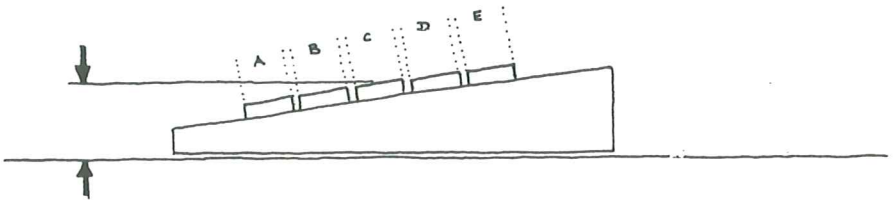

Fig. 8 - Keyboard height

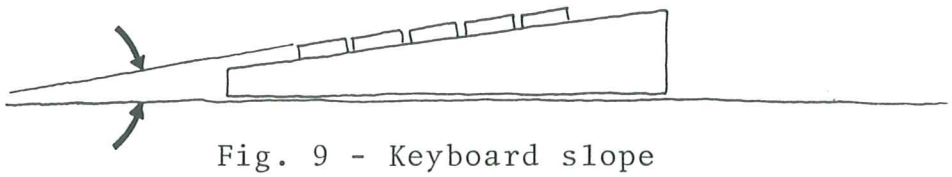

Fig. 9 - Keyboard slope

Keyboard slopes of 5^{o} to 18^{o} have all been found to be comfortable. Adjustability of slope, though desirable, is not mandatory.

6.2.2.2 Geometry and layout of keytops

The profile of the key pad may be stepped, sloped or dished (i.e. concave), all these arrangements are satisfactory.

The key top (the portion of the key touched by the operator) should be slightly concave to aid the accurate location of the operator's fingers.

Fig. 10 - Stepped keyboard

Fig. 11 - Dished keyboard

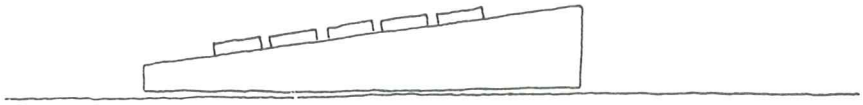

Fig. 12 - Sloped keyboard

Dimension of the key top, for a square-topped key, should be between 12 mm and 15 mm for the alphanumeric and numerical key pads. Where the key top is not square, then an area of at least 100 mm^2 should be provided.

The distance between keys measured centre-to-centre should be 19 mm ± 1 mm for the alphanumeric keys and separate numerical key pad, if provided. However, future keyboard developments may well reduce these dimensions. The size of function keys and other special keys may be different as well as their positioning on the keyboard.

Keyboard layouts are the subject of other standards. When there is a requirement for considerable numeric input, a separate key pad (either integral or detachable from the alphanumeric keyboard) is an advantage.

6.2.2.3 Key characteristics

The travel of the keys should be between 0,5 mm and 8 mm (though the optimum would seem to be between 1 mm and 5 mm), and the force between 0,25 N and 1,5 N. A low key force is less fatiguing than a high key force.

The combination of key force and travel should not be such that easy accidental actuation is possible.

Optimum efficiency for touch typing relies on the tactile feedback to the typist that the key has been depressed. This can be provided by the fact that the key comes up against a "stop" at the end of its travel some distance after it has made electrical contact. Also, a "trigger" point in the depression movement past which the force ceases to increase or actually reduces with further depression could be used.

Another form of feedback, as an alternative or in addition to a trigger feature which may be provided, is an audible click when a key is depressed. This facility should be optional and adjustable in intensity.

A useful optional feature is N key roll-over which permits a second key or any number of keys to be depressed, and released during the time a first key was also depressed. The keys will be recognized in the sequence of their action. The N in N key roll-over should be consistent throughout the entire alphanumeric area.

A burst rate capability of 50 characters per second for a few characters, should be possible.

For characters which are used repeatedly, like underline, the key may be held down and the character will be entered at a fixed rate starting after a fixed delay after the first character. Both the repeat rate and time to start may be adjustable as an optional feature.

6.2.2.4 Colour and surface

The keys must be easily distinguishable one from another by easily identified symbols on the keys. This may be provided by both the symbol shape and the colour contrast between the symbols and the body of the key. Different blocks of keys may be given different colours or tones to aid orientation.

The surface of the keys and keyboard should be matt to reduce specular reflection. The diffuse reflectance should be in the range 15% to 75%. The symbols on the key tops must be simple, consistent and easily read for quick identification of the keys. The symbols must be durable, i.e. resistent to wear and abrasion, including cleaning.

7. CHARACTERISTICS OF DISPLAYED IMAGE

7.1 Limitations

Visual display units, when properly designed, have no unique luminance properties that would limit their use by normally sighted people. The visual demands are the same as for any similar visual task.

7.2 Luminance Levels

Displays are very frequently used in office environments and the visual task often includes reference to source documents.

Using the formula stated in 3.16 and assuming paper has a surface reflectivity of approximately 70%, the luminance of paper may be calculated for a wide range of ambient luminance levels of the work space. This in turn provides a basis for display luminance levels.

Since the visual task depends upon recognizing a difference in luminance levels or contrast, a higher and lower luminance level is required. Each is discussed below.

7.2.1 Higher luminance level

The higher luminance level of a centrally viewed pattern establishes the adaptation level of the eye.

There is some advantage to having a balance between the higher luminance levels of centrally viewed surfaces which are frequently viewed in sequence. If there is a considerable difference between the higher luminances of the two sequentially viewed patterns, then there may be a very temporary loss of contrast sensitivity that may hamper the perception of the second surface being viewed.

Fig. 13 describes these relationships as follows:

- Source document luminance (cd/m^2) is shown for a range of illuminance from 300 ℓx to 1000 ℓx of the work space.
- A 3:1 ratio above and a 1:3 ratio below the source document is shown.
- The shaded area illustrates that any VDU with a fixed luminance in the range from 75 cd/m^2 to 200 cd/m^2 can be used satisfactorily in a work space with an illuminance of 300 ℓx to 900 ℓx.

  Adjustable luminance can be used to extend the range of acceptable work space illuminance conditions.

Fig. 13 is not intended as a recommendation of work space illuminance levels since the minimum would be determined by the total visual task being performed and the maximum would be the level in which the display could maintain an adequate contrast ratio.

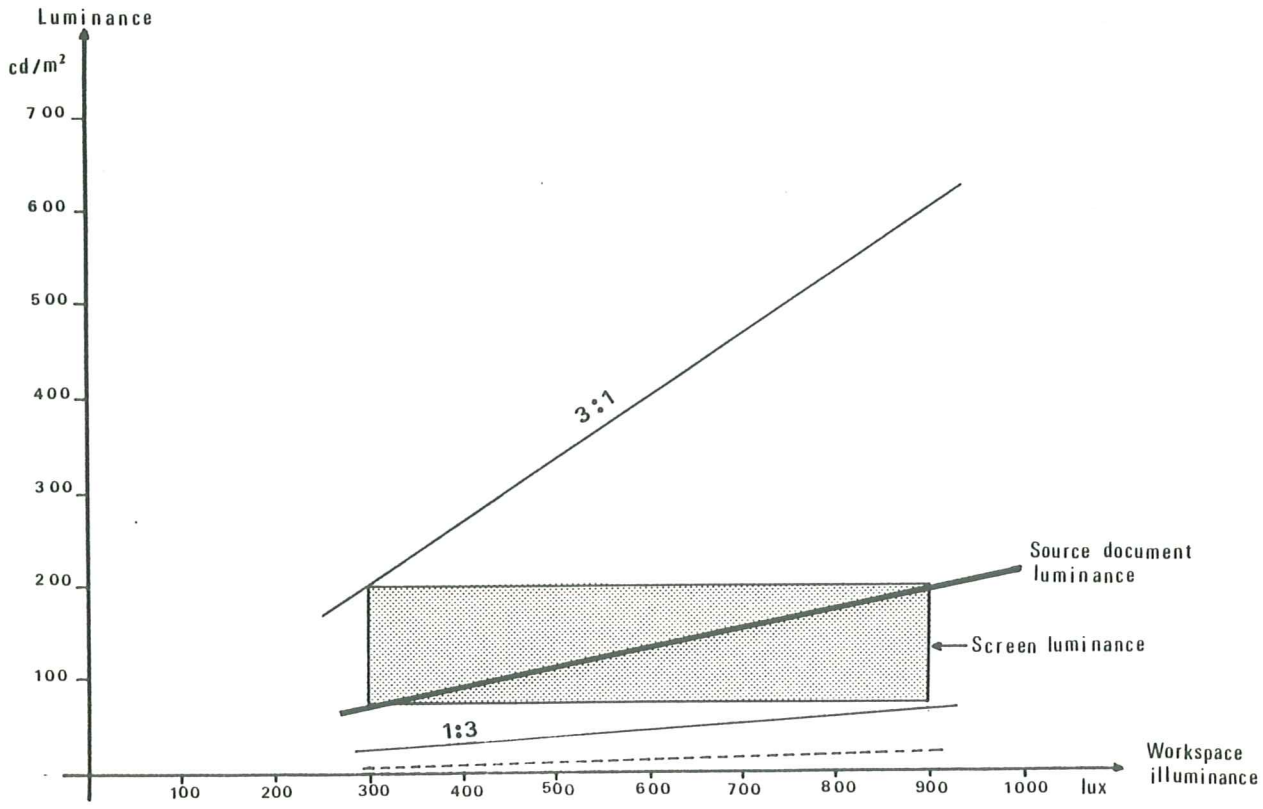

Fig. 13 - 1:3 and 3:1 display luminance levels relative to source document luminance levels in a range of work space illuminance from 300 ℓx to 1000 ℓx

7.2.2 Lower luminance level

A lower luminance level is required to provide contrast to the higher luminance level. In the case of displays, contrast is the ratio of luminance levels between the viewed image and its background.

For fairly large surfaces within the general visual field a lower luminance level within a 10:1 ratio to the source document is recommended.

A minimum contrast ratio of 3:1 is recommended for legibility.

Since paper typically reflects 70% to 80% of the light falling on it, all other surfaces could have a reflectivity of not less than 7% to 8% and maintain the 10:1 ratio over a variety of ambient conditions.

The dotted line on Figure 13 indicates the minimum lower luminance level for a 10:1 ratio relative to the source document luminance level. The range is 7 cd/m^2 at 1000 ℓx.

Under normal working conditions the eye adapts to the highest luminance level within a fairly narrow field of view. Therefore, maintaining the 3:1 ratio between the higher luminance level and the source document is more important than the 10:1 ratio to the lower luminance level.

Under normal ambient luminance conditions, CRT displays are typically capable of achieving high enough higher luminance levels to maintain adequate contrast relative to the lower luminance levels.

Using a 400 ℓx ambient condition as an example, the desired lower luminance level would be 9 cd/m^2. The higher luminance level could be from 30 cd/m^2 to 270 cd/m^2.

Using the contrast formula stated in 3.10.2, ratios could range from 2,5 to 30 and meet all other criteria for the higher and lower luminance levels.

7.3 Flicker

Visual display units should be designed so as not to flicker, i.e., any periodic light variation should not be perceived.

Cathode ray tube (CRT) displays are illuminated by an electron beam striking a phosphor surface which in turn causes the phosphor to emit visible light. Office work stations use in general raster CRTs where the electron beam scans repeatedly very quickly over the entire surface, exciting small points typically of 0,3 mm to 1 mm in diameter. The time taken for the beam to return to the same spot and reilluminate it is known as the refresh rate.

The ability of the phosphor to remain illuminated between refresh cycles is known as persistence. Short-persistence phosphors lose their luminance level much faster than long-persistence phosphors and will appear to flicker unless refreshed at a higher rate.

7.4 Glare

Highly polished or very smooth surfaces act like mirrors. Curved surfaces distort images in accordance with the laws of physics for curved mirrors.

Glare technically includes reflected light sources. However, many people use the term to mean any reflected image. Sharp focused images due to the smoothness of the surface are called specular images.

The best method of eliminating specular glare is through careful placement of the CRT relative to the windows and light sources. The use of swivel and tilt adjustment on the CRT can also help considerably. Other techniques are:

etched surfaces
optical coatings
micro-mesh filters
polarizers
hoods

7.5 Colour

7.5.1 Colour selection

Provided adequate luminosity is achieved any colour within the visible spectrum can be used, except that deep blue or violet should be avoided for fine detail since the acuity of the eye is poor for these colours.

7.5.2 Contrast

For good legibility aim for high luminance contrast between a symbol and its background, independent of colour. However, good resolution should be maintained. Thus symbol and background of equal luminosity should be avoided even if they are of different colours.

7.5.3 Multicolour displays

For multicolour displays all the above criteria apply. In addition the distance between colours on the chromaticity chart should be such that they are clearly distinguishable.

Fairly high lower level luminances, when achieved by using screen backgrounds that reflect the ambient luminance level, have the effect of reducing colour separation. If the background is significantly lightened, colours will become pale or pastel and therefore more similar to each other and colour contrast will be reduced.

7.6 Positive/Negative Polarity

Negative Polarity

Light or illuminated characters on a dark or unilluminated background.

Positive Polarity

Dark or unilluminated characters on a light or illuminated background.

Either polarity is acceptable from an ergonomic viewpoint.

In the case of CRTs, where contrast is obtained by generating emitted light, the following should be considered.

7.6.1 Glare

Reflected luminance sources appear more prominently in negative backgrounds. However, text legibility is degraded in both polarities if the reflected image is in the text area.

As some people become more glare-sensitive with age, large light sources such as positive polarity CRTs can increase the effect unless compensated for by placement and lower luminance levels.

7.6.2 Luminance levels

Acceptable upper and lower luminance levels are similar for both polarities. Direct light sources should not be located within a range of visual angles that would have a worker looking at them most of the time. For this reason reduced upper luminance levels for positive polarity displays are recommended.

7.6.3 Flicker

The typical CRT screen occupies a large portion of the visual field. Therefore when it is used in positive polarity, the combination of phosphor persistence and refresh rate must be more carefully matched to get above the expected critical fusion frequency for fairly large light sources.

7.6.4 Colour

As stated above, any colour is acceptable.

7.6.5 Character design

Positive displays require wider character stroke widths than the equivalent negative polarity displays. Among other reasons, this is due to the fact that the eye reacts primarily to luminance and emphasizes it through a process called lateral inhibition.

7.7 Character Presentation

This guideline specifies typical values for intensive use. Other formats may be desired for special situations.

7.7.1 Character height/dot matrix

For CRTs a 5 x 7 dot matrix is the minimum usable; however, a 7 x 9 (or larger) matrix is preferable.

The subtended angles of displayed characters listed below are for capital letters. Measurements are made at right angles to the screen surface. Character dimensions are measured from edge to edge at the mean ratio between high and low luminance levels.

For conditions where the legibility of individual characters is important:

a) For low-resolution characters (5 x 7): 20' minimum, corresponding to a minimum height of 2,9 mm at a viewing distance of 500 mm.

b) For high-resolution characters: 17' minimum, corresponding to a minimum height of 2,5 mm at a viewing distance of 500 mm.

c) Letters must be displayed with properly formed descenders, ascenders and diacritical marks, thus a matrix with a sufficient resolution must be provided.

For conditions where the readability of text for contextual meaning is important:

d) For low-resolution characters (5 x 7): 18' minimum, corresponding to a minimum height of 2,6 mm at a viewing distance of 500 mm.

e) For high-resolution characters: 16' minimum, corresponding to a minimum height of 2,3 mm at a viewing distance of 500 mm.

7.7.2 Character and Stroke Width Proportions

The character width should be between 60% and 80% of the character height.

The stroke width should be between 1/6 and 1/10 of the character height.

7.7.3 Spacing

Unless proportional spacing is used, the minimum space between characters should be equal to one stroke width. Small letters and narrow capital letters which do not fill the matrix would have correspondingly larger spaces between characters unless proportional spacing is used.

The minimum free space between lines should be equal to one stroke width.

7.8 Distortion

7.8.1 Luminance variation

For CRTs, a luminance variation of less than 2:1 within a half degree visual cone and less than 3:1 from centre to edge of the display is recommended.

7.8.2 Geometric variation

Over the entire display surface character width and height should not vary by more than 10%. The character shape or font appearance should not differ disturbingly from character cell to character cell. Visible disturbances caused by single or multiple echoes in line direction (ghost images) are to be avoided.

Distortions of lines and columns should be avoided. The perimeter line and column locations should not vary by more than 1% of the respective total display width or height, respectively.

7.8.3 Jitter

Frequent location changes of a character should not be greater than 0,7' (0,1 mm at 500 mm viewing distance).