ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

STANDARD ECMA-126

– ERGONOMICS –

REQUIREMENTS FOR COLOUR
VISUAL DISPLAY DEVICES

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BRIEF HISTORY

ECMA published in March 1985 Technical Report ECMA TR/22 which gives general ergonomic recommendations for VDU work places. These recommendations address not only the characteristics of the visual display terminal (VDT) but also other aspects such as the geometry of work places, arrangements, lighting, noise and ambient conditions. Most of these aspects, as well as the social, organizational and motivational characteristics of the office and business in general are under the control of the user, hence the issue of a Technical Report giving recommendations only.

The requirements for the display unit and the keyboard being entirely under the control of the manufacturers, it was decided to issue Standard ECMA-110 specifying mandatory requirements, and including an Appendix specifying methods of measurement of the parameters specified, with the exception of flicker and glare for the reasons indicated in the Standard. This Standard ECMA-110, published in December 1985, is applicable to monochromatic visual display units.

The present Standard specifies the corresponding requirements for colour visual display units.

Health aspects of visual displays in general are analyzed in Technical Report ECMA TR/33.

Adopted as an ECMA Standard by the General Assembly of ECMA on 10th December 1987.

TABLE OF CONTENTS

Page

1. SCOPE

1.1 This ECMA Standard specifies requirements for Visual Display Terminals (VDT) using colour CRT and an associated keyboard input. It is applicable to display units based on three-gun, shadow mask CRTs.

1.2 This Standard applies specifically to VDTs used intensively by a seated operator who is a skilled typist, for data entry work, data acquisition, interactive communication, or word processing.

1.3 The requirements of this Standard are restricted to those physical features of the display unit and keyboard which are entirely under the control of the manufacturer and, as such, are mandatory.

1.4 This Standard does not address those ergonomic considerations which are under the control of the user since these can be given only as recommendations. Recommendations for these considerations are to be found in ECMA TR/22.

2. FIELD OF APPLICATION

The subject of this Standard is those physical characteristics of colour CRT displays and their associated keyboards which ECMA feels are relevant to the comfort and well-being of the operator and are necessary to ensure an efficient interface between the operator and the work station.

However, these characteristics alone are not sufficient to ensure an efficient interface. For those aspects of work station design which are exclusively under the user's control, the reader is referred to Technical Report ECMA TR/22 which is complementary to this document.

3. CONFORMANCE

A VDT consisting of a colour CRT display unit and its associated keyboard shall be in conformance with this Standard if all the requirements herein are met.

The VDT shall also comply with the requirements of Standard ECMA-57.

The VDT shall conform to the acoustic noise limits prescribed at its location of use. The sound power output of the VDT shall be measured according to Standards ECMA-74 and ECMA-108.

Conformance with this ECMA Standard does not necessarily ensure compliance with all national requirements at the location of use.

4. REFERENCES

ECMA-57   Safety Requirements for Data Processing Equipment

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

ECMA-108	Measurement of High Frequency Noise Emitted by Computer and Business Equipment
ECMA-110	Ergonomics - Requirements for Visual Display Devices
ECMA/TR22	Recommendations for VDU Work Places
ECMA/TR33	Visual Displays - Health Aspects
ISO 2813	Paints and Varnishes - Measurements of specular gloss of non-metallic paint films at 20°, 60° and 85°
CIE 17	International Lighting Vocabulary, 3rd Ed.

5. DEFINITIONS

For the purpose of this Standard, the following definitions apply.

5.1 Beam Spot

The area illuminated when one or more of the three electron beams activate a single picture element.

5.2 Colour

Aspects of visible radiation by which an observer may distinguish differences between two fields of the same size, shape and structure, such as may be caused by differences in the spectral composition of the radiation concerned in the observation.

5.3 Contrast

The difference between two compared stimuli. This term is used both in a subjective and an objective sense.

i)   Subjective sense

The difference in appearance of two parts of a field of view seen simultaneously or successively.

ii)   Objective sense

The difference in luminance levels between the viewed image and its background expressed as the contrast ratio:

$$C = \frac{L_h}{L_l}$$

where:

L_h = higher luminance

L_l = lower luminance

5.4 Convergence

In a composite colour picture element, the distance between the energy centres of the primary picture elements that constitute the composite one.

5.5 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.

5.6 Illuminance

The illuminance at a point of a surface is the luminous flux incident on an element of the surface, divided by the area of that element. The unit of illuminance is the lux (1 lx = 1 lm/m²).

5.7 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/m²).

5.8 Luminous Flux

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

5.9 Luminous Intensity

The candela (cd) is the luminous intensity in a given direction of a source which emits monochromatic radiation of frequency 540 x 10¹² Hz and of which the radiant intensity in that direction is 1/683 watt per steradian.

5.10 Moiré

Visual effect of interference between spatial patterns.

5.11 Picture Element

The smallest portion of the screen addressable by the system. In a colour CRT display it can be composed of a number of discrete phosphor deposits even in the primary colours.

5.12 Primary Colours

A set of three colours that used alone or in suitable mix reproduce a range of colour stimuli.

Note 1

In the context of this Standard primary colours are produced when the three phosphors are excited separately.

5.13 Polarity of the Image Presentation

i) Negative polarity

Light or illuminated characters presented on a darker or unilluminated background.

ii) Positive polarity

Dark or unilluminated characters presented on a lighter or illuminated background.

5.14 Reflectance

The ratio ρ of the luminous flux reflected from a surface to the luminous flux incident on it. Reflectance may be specular or diffuse.

5.15 Reflected Luminance

The reflected luminance L is given by:

$$L = \frac{E \cdot \rho}{\pi}$$

where:

L = reflected luminance in cd/m²
ρ = surface reflectance
E = ambient illuminance in lx

6. REQUIREMENTS FOR VDTs

6.1 Work Equipment

6.1.1 Characteristics of VDT-housing

6.1.1.1 Adjustability

Keyboards of table-top units shall be separable from the screen by a distance of at least 300 mm (Fig. 1).

The inclination of the surface of the screen shall be adjustable at least between -3° and +15° from the vertical (Fig. 2).
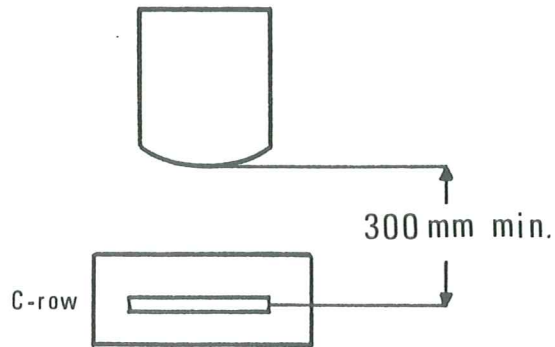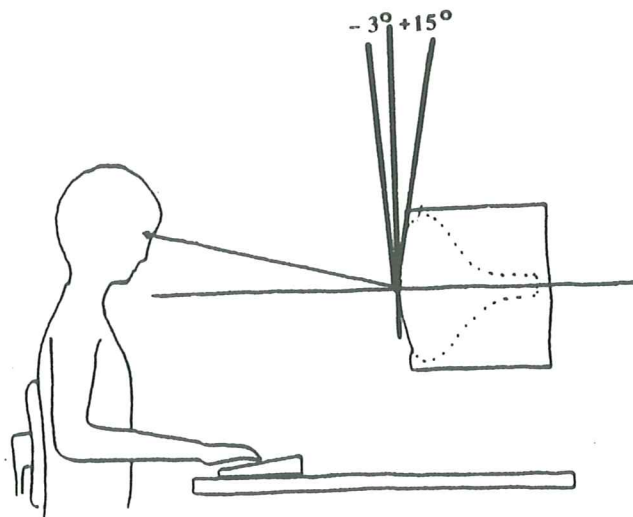
Figure 1 - Separable Keyboard (seen from the top)

Figure 2 - Tilt Angle

6.1.1.2 Surfaces

The specular reflectance of surfaces shall not exceed 45 gloss units (silky matt). The diffuse reflection factor for the front frame of the VDU screen shall be between 0,15 and 0,75. See A.1 and A.2.

6.1.2 Keyboard characteristics

6.1.2.1 Dimensions

The keyboard slope shall be in the range 5° to 18° (Fig. 3). Adjustability is not mandatory. See A.3.
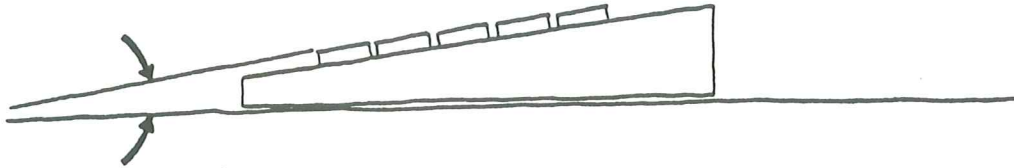

Figure 3 - Keyboard Slope

A low profile keyboard shall not be higher than 35 mm measured from the work surface to the centre of a key top at the C-row (Fig. 4 and 5) with the keyboard in its lowest position of angular adjustment.
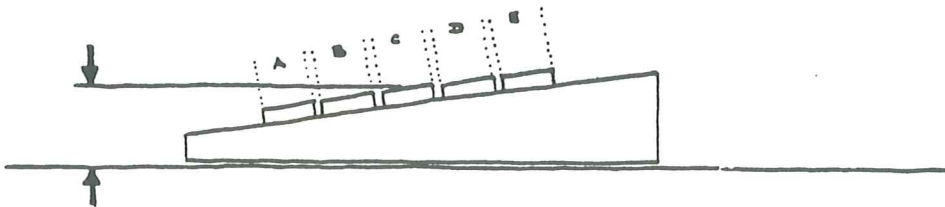

Figure 4 - Keyboard Rows

Figure 5 - Keyboard Height

6.1.2.2   Geometry and layout of keytops

The key top (the portion of the key touched by the operator) shall be concave.

The area of the key top shall be at least 113 mm², the minimum dimension being 12 mm.

The horizontal distance between keys measured centre-to-centre shall be 19 mm ± 1 mm for the alphanumeric keys and separate numerical key pad, if provided.

6.1.2.3   Key characteristics

The keys shall have a travel between 1 mm and 8 mm.

The maximum key force shall be between 0,25 N and 1,50 N with a preferred force between 0,50 and 0,60 N. The force for alphanumeric keys shall be within ± 25% of the average force.

Feedback shall be provided in one of the following ways (or in any combination of them):

- a "stop" at some distance after electrical contact has been made,

- a "trigger" point in the depression movement past which the force ceases to increase,

- an audible click.

N key roll-over shall be provided, where N = 3 or more. The N key roll-over should be consistent and applies to all alphanumeric keys.

The burst rate capability shall be at least 50 characters per second for at least 3 characters. During the burst the keys shall be recognized in the sequence of their action.

If the repeat rate of selected keys is fixed, then the repeat rate shall be (15 ± 5) characters per second after at least 0,5 s. An adjustable repeat rate is preferred.

Surface

The surface of the keys and keyboard shall have the specular and diffuse reflectance values specified in 6.1.1.2. See A.1 and A.2.

Major symbols on the key tops shall have a contrast ratio of at least 3:1 with the surface of the key top and shall be at least 2,6 mm high.

6.2   Characteristics of the Displayed Image

6.2.1   Luminance and contrast

6.2.1.1   Polarity

Either polarity is acceptable.

6.2.1.2   Higher Luminance Level

The higher luminance level shall be adjustable. The adjustement ratio shall be at least 2:1.

6.2.1.2.1   Higher Luminance Level for White

For the brightest available white with all three guns active, the value of the luminance at the top limit of the adjustment shall be at least 45 cd/m² measured in a dark environment as specified in A.4.1.

6.2.1.2.2   Higher Luminance Level for Colour

For the two highest available colour combinations with one of the guns not active, the value of the luminance at the top limit of the adjustment shall be at least 35 cd/m² measured in a dark environment as specified in A.4.1.

6.2.1.3   Lower Luminance Level

For any alphanumeric character displayed, the CRT shall be capable of achieving a contrast ratio of the higher luminance to the lower luminance of at least 3:1. This requirement has to be met at an ambient illuminance of 250 lx measured perpendicularly to the plane of the screen as specified in A.4.2 and A.5.

6.2.2   Flicker

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

Note 2

This clause is part of the standard because it is essential that VDUs should be flicker-free. However, for the time being no objective conformance test can be specified, as scientific investigations presently in progress have not allowed a reliable test method to be identified.

6.2.3   Glare

Specular glare is a function of sharpness and maximum luminance of a reflected image. Specular glare should be minimized.

Note 3

The design/manufacturing methods for reducing glare (if appropriate) include etched surfaces, optical coatings, micromesh filters, polarizers, hoods, etc. These methods are application dependent and, as such, ECMA does not consider a conformance requirement to be appropriate for inclusion in this specification.

Attention is drawn to TR/22 Clause 7.4 for user methods of reducing glare.

6.2.4 Moiré

In order to avoid moiré effects, the diameter of the beam spot size shall be equal to, or greater than, twice the distance between phosphor deposits of the same colour.

For special applications for which sharpness is more important than avoiding moiré effect (e.g. text processing, CAD/CAM) the diameter of the beam spot can be equal to 1,2 to 2 times the distance between the phosphor deposits of the same colour.

6.2.5 Beam Spot Characteristics

6.2.5.1 Beam Spot Size

The minimum width and height of a beam spot shall be equal to the distance between adjacent picture elements when measured according to A.6. This is to ensure that when a line of adjacent picture elements is illuminated, the beam spots will form a continuous line with no gaps.

The maximum width and height of a beam spot shall be equal to twice the distance between adjacent picture elements less the distance between adjacent rows of phosphor deposits when measured according to A.6. This is to ensure that there is a visible gap between adjacent characters and between adjacent lines within characters.

6.2.5.2 Size uniformity of the primary beam spots

The widths and heights of the beam spots for the primary colours measured individually at the same screen address as specified in A.6 shall not differ from each other by more than 10 %.

6.2.6 Character presentation

6.2.6.1 Character height/dot matrix

A character matrix consisting of seven picture elements in the vertical direction and five picture elements in the horizontal direction shall be the minimum to be used for digits and capital letters.

The height shall be increased upward by at least two picture elements positions if diacritical marks are to be used. When displaying small letters, the height shall be increased downward by at least two picture elements position to accommodate the descenders of the small letters. The minimum height of a capital letter shall be 2,9 mm regardless of screen size and picture elements matrix. See. A.7.

6.2.6.2 Character and stroke width proportions

The character width shall be between 50% and 80% of the character height. See A.7.

The stroke width shall be between 8% and 20% of the character height. See A.7.

6.2.6.3 Character spacing

For dot matrix displays, the character spacing in either direction shall be at least one row or column of picture elements.

6.2.6.4 Distortion

6.2.6.4.1 Luminance variation

The variation in luminance shall be assessed by measuring the luminance at five points (centre and four corners), see A.8.1. The ratio of the maximum luminance to the minimum luminance shall not be greater than 2,0.

6.2.6.4.2 Geometric variation of the screen

Distortions of lines and columns shall be avoided. The perimeter line and column locations shall not vary by more than 2% of the respective total display width or height, respectively. See A.8.2.

6.2.6.4.3 Character size variation

The height and width of a character shall not differ by more than 10% from the average height and width of all characters. This variation shall be measured as specified in A.8.3 at five character positions, viz. at the centre and the four corners of the screen.

6.2.6.4.4 Character stability

Location changes of a character in the frequency range between 0,1 Hz and 30 Hz shall not be greater than 0,1 mm in either the horizontal or the vertical direction. See A.6.4.

6.2.6.5 Colour uniformity

Throughout the screen there shall be no noticeable difference for any given colour.

Note 4

This requirement is part of the Standard because it is essential that VDUs present uniform colours. However, for the time being, no objective conformance test can be specified, as scientific investigations have not yet produced a reliable criterion.

6.2.6.6 Convergence

The distance between the centres of the beam spots for each primary colours at the same screen address shall not exceed, in both horizontal and vertical direction, 0,4 mm in the central zone and 0,6 mm in the peripheral zone of the screen. See A.9.

These figures apply for a 356 mm screen. For other sizes, these values shall be changed proportionally.

APPENDIX A

METHODS OF MEASUREMENT

The methods of measurement specified in this Appendix shall be used for checking conformance to the clauses of this Standard. They are applicable to colour CRT displays both with positive and negative polarity. Simplified methods have been specified with the aim of avoiding expensive and time-consuming measurements.

All measurements and evaluations shall be preceded by the following steps:

i) Position the CRT with the axis of the tube set in the direction in which the measurements and evaluations are to be made.

ii) Switch on the CRT and allow a warm-up period of at least 20 minutes.

iii) After switching on, activate any integral, manual de-magnetization device.

A.1 Diffuse Reflection Factor

The diffuse reflection factor of opaque surfaces can easily be judged by means of a diffuse reflection factor chart.

Note A.1

Such charts are commercially available, for example from:

Verlag W. Girardet
D-4300 ESSEN
Germany

Part Number: 0725
From Handbuch für Beleuchtung (ISBN: 3-7736-0725-3)

A.2 Specular Reflectance

The specular reflectance of external surfaces, including key-caps and excluding CRT screen shall be measured by means of a 60° glossmeter calibrated against a Reference Glass Mirror, according to International Standard ISO 2813.

The surfaces meeting the characteristics (planarity and dimensions) needed for proper operation of the instrument chosen shall be measured directly. In the case of surfaces too small and/or too curved (e.g. keycaps) the measurement shall be performed on a sample surface of suitable planarity and dimensions but treated exactly as the surface under consideration.

A.3 Keyboard Slope

The slope of the keyboard shall be the angle between the horizontal plane and a line drawn through the centres of key rows B and D.

A.4 Luminance

The luminance of character and background (either with positive or negative polarity) for the purpose of 4.4.1 shall be measured in terms of mean value (mean luminance).

A.4.1 Higher luminance level (L_h)

The higher luminance level represents, either the mean background luminance in case of positive polarity, or the mean character luminance in case of negative polarity.

The measurement of the higher luminance level Lh for the purpose of 6.2.1.2.1 and 6.2.1.2.2 shall be made in an unilluminated room, by means of a narrow-angle luminance probe. A full matrix (i.e. a cursor) of at least 5 x 5 picture elements shall be activated in the brightest available white or colour at the centre of the screen, as shown in Fig. A.1.
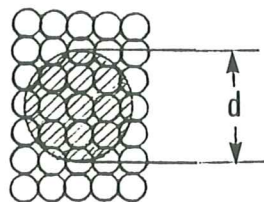

Figure A.1

The diameter d of the circular area "seen" by the luminance probe shall be contained within the full matrix, but it shall completely cover a block of at least 3 x 3 picture elements. The maximum diameter d shall be 10 mm. This is achievable by setting the proper distance from the probe to the surface of the screen, taking into account the visual angle of the probe itself.

In case of positive polarity, the result will be the background luminance L_b.

In case of negative polarity, the result will be assumed to be the luminance L_c of the character.

A.4.2 Lower luminance level (L_{la})

The lower luminance level represents either the mean character luminance in case of positive polarity, or the mean background luminance in case of negative polarity.

The measurement of the lower luminance level L_{la} shall be made at the level of ambient illuminance on the screen specified in 6.2.1.3. When measuring the lower luminance level in presence of ambient illuminance, attention shall be paid:

- to avoid shading the measured area with the luminance probe,

- to avoid effects of specular reflections.

A.4.3 Contrast

Higher luminance level for the purpose of calculating contrast (L_{ha}) shall be measured in the presence of ambient illumination as specified in 6.2.1.3, using the narrow-angle luminance probe and with the illuminance probe removed. The contrast ratio Cr shall be:

$$Cr = \frac{L_{ha}}{L_{la}}$$

A.5 Ambient Illuminance

The ambient illuminance on the screen shall be measured by means of a flat luxmeter head, applied to the surface itself, so as to reduce errors due to the thickness of the head.

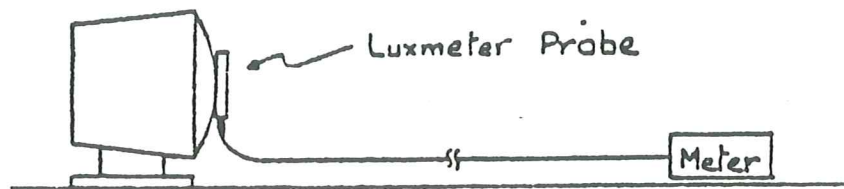The ambient illuminance shall be measured perpendicularly to the screen surface (see Figure A.2).

Figure A.2

The present measurement applies to A.4.2. For this purpose, controlled illuminance shall be obtained by diffuse indirect lighting, avoiding specular reflections.

A.6 Beam Spot Size

The size of the beam spot shall be evaluated by the operator using a microscope with a graticule, a magnification power of typically 20 times and a field of view sufficient to cover the area of interest. Since the dimension of the beam spot can vary with the luminance value, the screen shall be set up to produce a luminance of 45 cd/m² on the brightest available white.

When the phosphor structure is made up of discrete phosphor elements, the edge shall be evaluated as follows:

- the beam spot shall be considered to finish at the edge of the last fully illuminated deposit if no further deposit is illuminated;

- if a peripheral deposit is partially illuminated, then the beam spot shall be considered to finish halfway between that deposit and the last fully illuminated deposit.

When the phosphor deposit is continuous, the edge shall be judged by the operator.

A scale drawing of the phosphor structure on the screen can be useful as an aid to recording the observation. See Figure A.3 for an example, in case of a dot matrix display and of a slotted mask display.
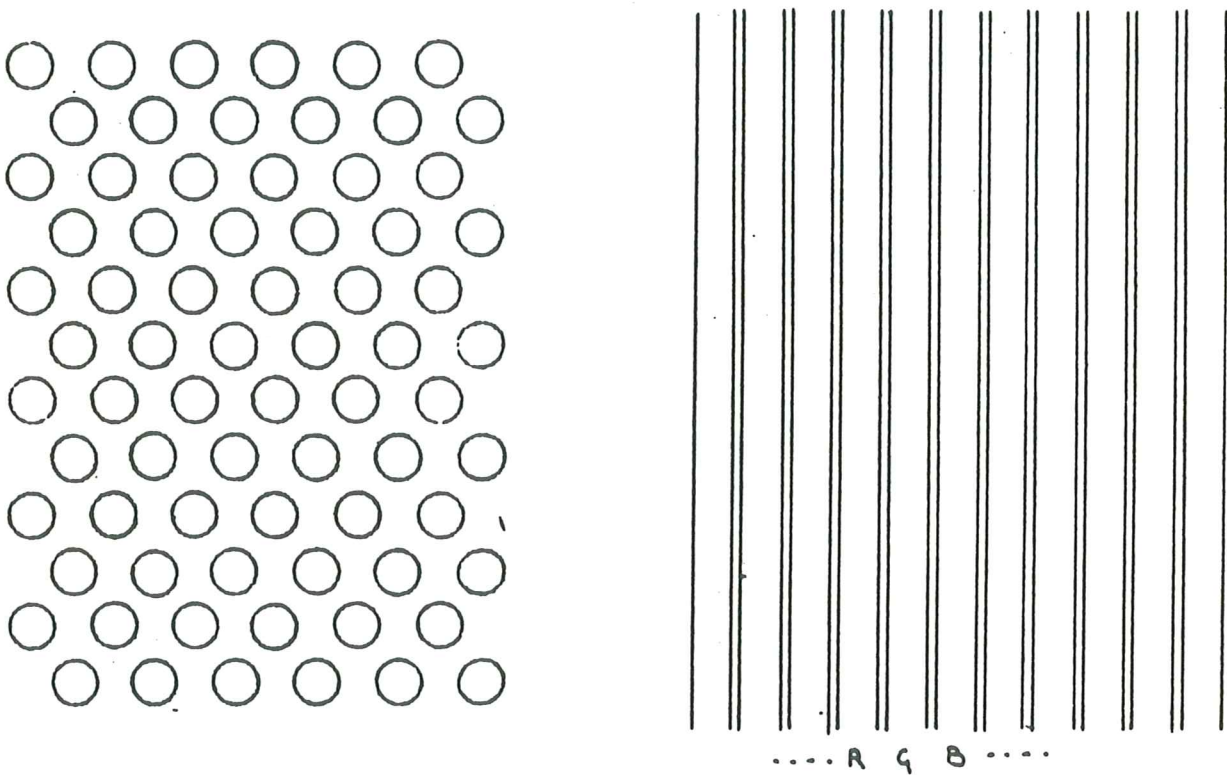
Figure A.3

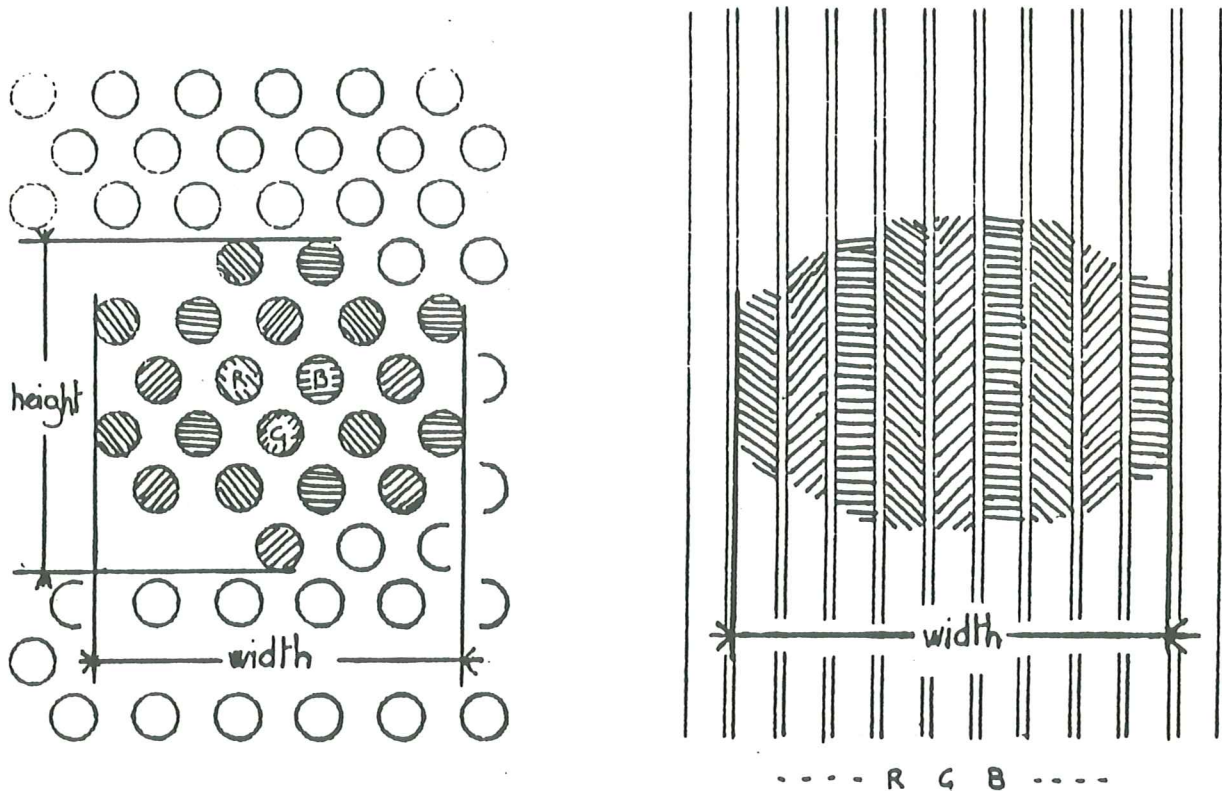In Figure A.4 are shown two examples of measurement.

Figure A.4

With this procedure, the maximum horizontal and vertical diameters of the beam spot shall be evaluated.

A.7 Character Dimensions

Character dimensions shall be measured from edge to edge. The higher luminance level shall be set as in A.6. The evaluation shall be made on capital letter H or E, which involve all the external rows and columns of the matrix, and activated in the brightest available white. The edges of the character and the stroke shall be evaluated according to A.6. Both in case of positive and negative polarity, the values are measured as shown in Figure A.5.
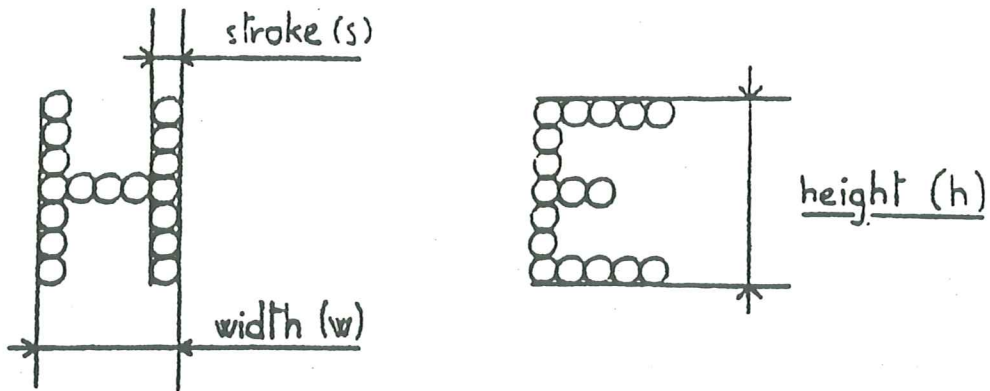
Figure A.5

The present method applies to Clauses 6.2.6.1, 6.2.4.6.2 and 6.2.6.4.3.

A.8 Distortion

A.8.1 Luminance variation

The higher luminance level shall be measured according to A.4.1 on a full matrix (i.e. a block cursor) activated at the centre and the corners of the screen in the brightest available white.(See Fig. A.7). The optical axis of the luminance probe shall be perpendicular to the screen surface at the point of measurement.

The ratio:

$$\frac{L_h max}{L_h min} \leq 2,0$$

shall comply with the 6.2.6.4.1.

A.8.2 Geometric variations of the screen

The geometric distortion of peripheral rows and columns may be judged by means of a transparent mask held against the screen and viewed in a direction parallel to the axis of the table. Dimensions and tolerances shall comply with 6.2.6.4.2.

A.8.3 Character size variation

These measured heights and widths shall be compared with the averaged height h and the averaged width w calculated as follows:

$$h = \frac{n}{N} \cdot H$$

$$w = \frac{m}{M} \cdot W$$

where:

H : total height of the active area of the screen
W : total width of the active area of the screen
n : number of beam spots lines in the character
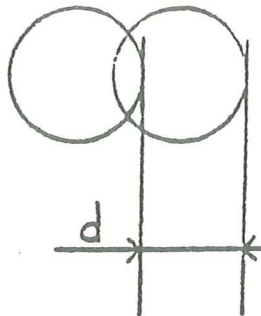m : number of beam spots columns in the character
N : total number of beam spots lines in the active area
M : total number of beam spots columns in the active area

The present method applies to 6.2.6.4.3.

A.8.4 Character stability

Changes of character position in any direction shall be measured in terms of beam spot movement, according to Figure A.6.

Between dot edges

Figure A.6

The measurement shall be made at the centre and at the corners of the screen (See Fig. A.7). The present method applies to 6.2.6.4.

A.9 Convergence

The convergence error shall be measured by means of a Convergence Error Measurement Gauge.

Note A.2

Such gauges are commercially available from RCA Picture Tube Division under part number PIX 507G.

A number of cross patterns of suitable dimensions shall be activated at the nine locations shown in Figure A.7, and the vertical and horizontal distances between the lines of the primary colours shall be measured. The highest value found in both directions for each shall comply with 6.2.6.7.
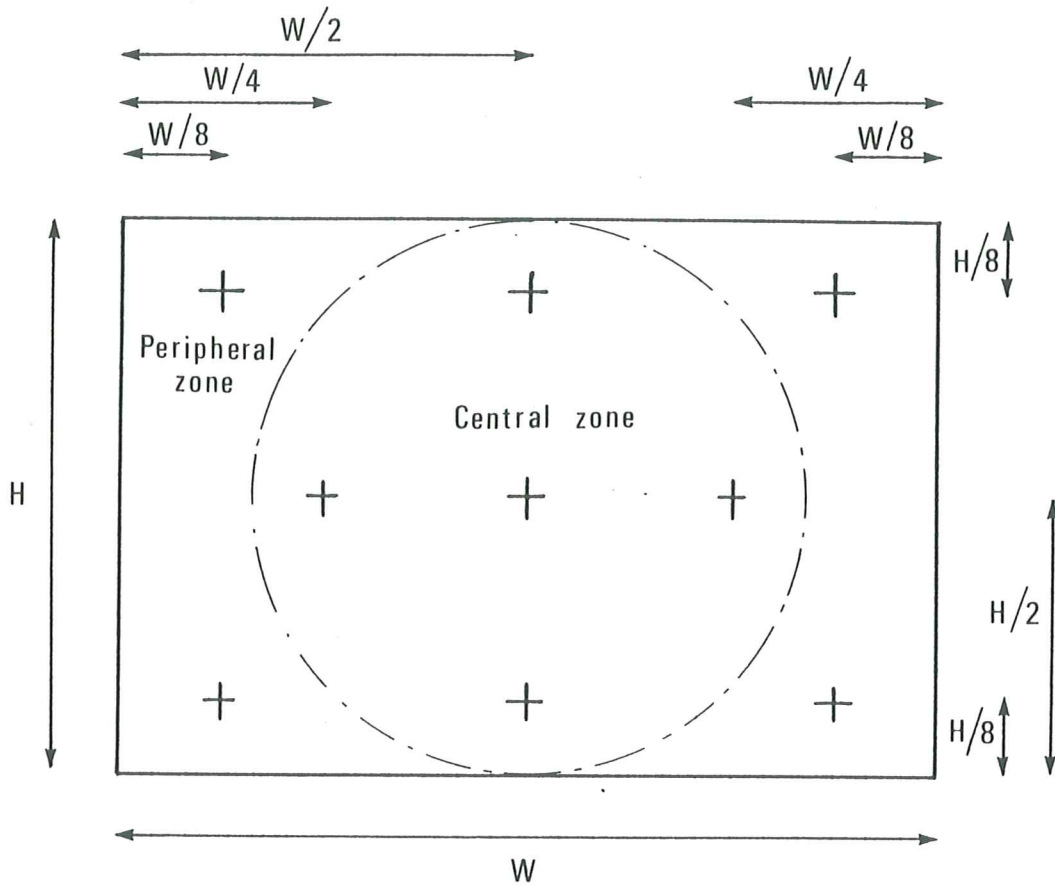
Figure A.7

H = total height of the active area of the screen
W = total width of the active area of the screen
+ = measurement point