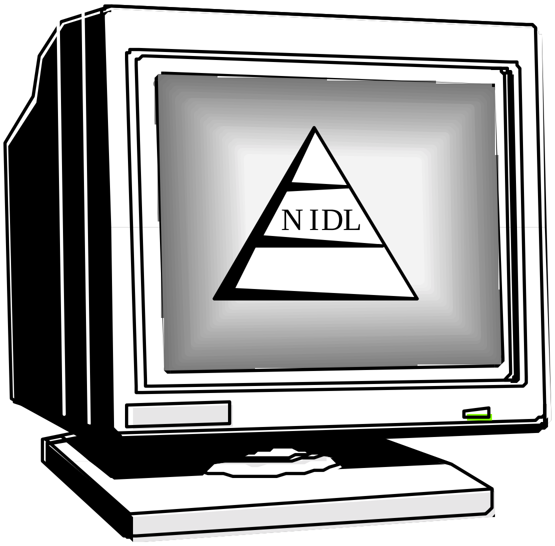

The Clinton Electronics DS2100HB-ST Monochrome CRT Monitor (21-inch CRT size, 19.0” viewable area; the selling price is $1995) is a relatively low cost, 1600 x 1280 pixel, monochrome gray scale monitor. It has good image quality and features that make it an attractive candidate display device for NIMA Imagery Exploitation Capability workstations. Based on results of our evaluation, NIDL certifies the Clinton Electronics DS2100HB-ST monochrome monitor as being suitable only for monoscopic, and not for stereo, operation in IEC workstations. NIDL rates this monochrome monitor as a “B” for monoscopic mode and “F” for stereo mode for the Image Analyst and Cartographer applications. In stereo, it can produce a 1024 x 1024 stereo image at 59 Hz per eye, but it has only 47% of the maximum luminance and only 44% of the stereo extinction ratio required by the IEC Specifications. Clinton states that the primary market for this lower cost monitor is for clinical tasks and for training purposes. It is not intended for primary diagnoses of x-ray images.

Evaluation of the Clinton Electronics DS2100HB-ST 4 x 3 Aspect Ratio, 21-Inch Diagonal Monochrome Monitor

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NIDL IEC Monitor Certification Report

The Clinton Electronics DS2100HB-ST Monochrome CRT Monitor

FINAL GRADES
Monoscopic Mode: B
Stereoscopic Mode: F

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way

The Clinton Electronics DS2100HB-ST Monochrome CRT Monitor (21-inch CRT size, 19.0" viewable area; the selling price is $1995) is a relatively low cost, 1600 x 1280 pixel, monochrome gray scale monitor. It has good image quality and features that make it an attractive candidate display device for NIMA Imagery Exploitation Capability workstations. Based on results of our evaluation, NIDL certifies the Clinton Electronics DS2100HB-ST monochrome monitor as being suitable only for monoscopic, and not for stereo, operation in IEC workstations. NIDL rates this monochrome monitor as a "B" for monoscopic mode and "F" for stereo mode for the Image Analyst and Cartographer applications. In stereo, this monitor can produce a 1024 x 1024 stereo image at 59 Hz per eye, but it has only 47% of the maximum luminance and only 44% of the stereo extinction ratio required by the IEC Specifications. Clinton states that the primary market for this lower cost monitor is for clinical tasks and for training purposes. It is not intended for primary diagnoses of x-ray images.

The Clinton Electronics DS2100HB-ST Monochrome CRT Monitor has a wide dynamic range that exceeds the 350:1 dynamic range specification in monoscopic mode. It achieves 45.5 fL for Lmax and 0.1 fL for Lmin for a dynamic range of over 450:1. Halation is very good (1.8%), and compares well to even the highest performing monochrome monitors. However, the Clinton Electronics DS2100HB-ST Monochrome CRT Monitor barely meets the minimum IEC contrast modulation requirement for 1 pixel on/1 pixel off. The contrast modulation may be somewhat higher when the luminance is reduced to the IEC minimum of 35 fL in monoscopic mode. It should be noted that this monitor has a somewhat smaller viewing area, by about 10% less, compared to the other 21 inch monochrome monitors we have tested. The Clinton Electronics DS2100HB-ST monitor somewhat exceeds the warm-up times specified for achieving stable 0.1 fL luminance readings. We noted very slight streaking in the SMPTE test pattern.

For stereo viewing, we observed a luminance value of 14 fL through the NuVision stereo screen and passive glasses. This is only 47% of the required 30 fL minimum value in stereo. The extinction ratio of 8.7:1 is only 44% of the 20:1 ratio required by the IEC specification. This may mean that stereo performance is less than experienced with some other monochrome displays. The manufacturer is planning to replace the P104 phosphor with a P45 phosphor in the CRT. This may improve the extinction ratio but not the luminance.

We calculated the dynamic range for various amounts of light falling on the face of the tube for monoscopic operation based on our measurements of reflectivity. We expect the Clinton Electronics DS2100HB-ST monitor to have a dynamic range of 158:1 with 3 fc, but only 49:1 for

10 fc falling on the screen. The amount of light falling on the screen can be minimized by using a shield to block strong overhead light to thereby increase the contrast ratio.

No field data are available on the reliability.

This monitor uses a 110^o CRT which enables a substantially smaller depth of 17 ½” compared to 20 ½” or more for other 21 inch diagonal monochrome monitors.

NIDL has evaluated more-costly alternative 1600 x 1200 pixel, landscape COTS monochrome monitors. The PIC 21si or its equivalent Siemens 21103L (stereo), the Orwin DEX2102L and the Orwin 1988 easily pass the IEC specifications in both monoscopic and stereo modes and are rated “A”. These monitors have performance that substantially exceeds that of the Clinton Electronics DS2100HB-ST Monochrome CRT Monitor, but at a higher cost. Clinton states that the primary market for this lower cost DS2100HB-ST monitor is for clinical tasks and for training purposes. It is not intended for primary diagnoses of x-ray images.

The Clinton/Orwin website is http://www.cec-displays.com/index2.htm.
The NuVision LCD stereo shutter web site is at http://www.nuvision3d.com/

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
vAddressability	1024 x 1024 min.	1600 x 1200	Pass
Dynamic Range	25.4 dB	26.3 dB	Pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.1 fL	Pass
Luminance (Lmax)	35 fL ± 4%	45.5 fL	Pass
Uniformity (Lmax)	28% max.	16%	Pass
Halation	3.5% max.	1.6%	Pass
Color Temp	Not specified	8602 K	Pass
Reflectance	Not specified	8.5%	Pass
Bit Depth	8-bit± 5 counts	8-bit	Pass
Step Response	No visible ringing	Slight Streaking	Pass
Uniformity (Chromaticity)	0.010 Δ u'v' max. ± 0.005 Δ u'v'	0.010 Δ u'v'	Pass
Pixel aspect ratio	Square H = V± 6%	Set to square	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	18.4 ins.	Pass
Cm, Zone A, 7.6 inch dia.	35% min.	36%	Pass
Cm, Zone A, 40% area	35% min.	34%	Pass
Cm, Zone B	20% min.	23%	Pass
Pixel density	72 ppi min.	109 ppi	Pass
Straightness	0.5% max ± 0.05 mm	0.3%	Pass
Linearity	1.0% max ± 0.05 mm	1.1%	Pass
Jitter	2 ± 2 mils max.	2.2 mils	Pass
Swim, Drift	5 ± 2 mils max.	2.3 mils	Pass
Warmup time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	33 mins.	Fail
Warmup time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	74 mins.	Fail
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 71.039 Hz	Pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 2048 (I)	Pass
Lmin	0.1 fL min. ± 4%	0.12 fL	Pass
Lmax	30 fL min ± 4%	14.1 fL	Fail
Dynamic range	24.77 dB min	20.8 dB	Fail
Uniformity (Chromaticity)	0.02 Δ u'v' max ± 0.005 Δ u'v'	0.010 Δ u'v'	Pass
Refresh rate	60 Hz per eye, min	59 Hz, per eye	Pass
Extinction Ratio	20:1 min	8.7:1 (n)	Fail
AMBIENT LIGHTING			
Dynamic range 22 dB (158:1)	N/A	3 fc	
Dynamic range 16.9 dB (49:1)	N/A	10 fc	

* denotes Moire cancellation turned ON
(I) denotes interlaced scanning
(n) denotes Nuvision LCD shutter panel

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The NIDL is hosted by the Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics.

The present study evaluates a production unit of the Clinton Electronics DS2100HB-ST , monochrome CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC),* August 25, 1999.

Two companion documents that describe how the measurements are made, are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998. Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Clinton Electronics DS2100HB-ST Monochrome CRT Monitor

Manufacturer's Specifications

According to Clinton Electronics, the specifications for the Clinton Electronics DS2100HB-ST are:

The Clinton Electronics 21 inch Digital series (DS2100HB) monitor is a high-resolution display controlled by an embedded microprocessor and custom ASIC. The DS series is optimized for use as a 1000 line display for MRI, CT and other digital based modalities at high brightness. Multi-frequency scanning from 31.5 to 105kHz horizontal provides compatibility with standard VGA to custom format at flicker-free vertical rates of 50 to 150Hz. As a true multi-sync monitor, the DS series can be used with commercial desk top PC's and generic or custom medical video cards.

Clinton Electronics DS2100HB-ST

- High Resolution Landscape
- 21 Inch Flat Square
- Digital Controlled
- 11.4x15.25 Video
- 75ftL Light Output
- 1600x1280 Pixels
- RS-232 Comm Port
- Multi-Scan VGA to 1280 Lines

User controls include eleven on-screen functions via three push buttons that can he locked out to prevent unwanted manipulation. Lock-out and restoration are accomplished via the same three buttons along with a restore feature of factory pre-set values.

The DS Series comes standard with a 90% AR panel to enhance contrast modulation and a long life dispenser cathode.

The RS-232 port provides extended service capability with direct access to the microprocessor. Every function related to front of screen image quality can be adjusted to optimize and track performance.

The DS Series flexible architecture permits custom configurations to meet your imaging needs with digital accuracy and consistent quality at a competitive price.

Technical Data

Clinton Electronics DS2100HB-ST Monochrome CRT Monitor

Screen Size:		21 inch Diagonal Flat Square CRT
Active Video:		15.25 x 11.4 inches
Neck Diameter		29 mm
Deflection Angle:		110 deg Diagonal
Phosphor:		AP (PC104) std.
Transmission with AR		30% Approx.
Cathode		Long Life Dispenser
Non-Linearity		<= 10%
Raster Stability		0.05mm max jitter/swim
High voltage regulation		5% max size change
Brightness		65 fL
Video Input Signal Analog Level		0.7V p-p Typical (75 Ohms)
Sync Input Signals:	Separate	TTL levels
	Options	Full Composite, Separate Composite
Scanning Frequency	Horizontal	31 - 105 kHz
	Vertical	50 - 150 Hz
Video Amplifier Bandwidth		180 MHz
Input Power Requirements	Volts:	85 - 264 VAC continuous auto-switching
	Freq.:	47-63 Hz
	Watts:	110 watts max at 105 kHz.
	Power Factor Correction	IEC 555-2
Environment & Operating Conditions:		
Temperature	Operating:	0 to +40 deg. C
	Storage:	-40 to +65 deg. C
Humidity:	Operating:	10 to 90% non-condensing
	Storage:	5 to 95% non-condensing
Vibration:	Operating:	0.25 G Peak,. 8mm p-p Max
	Non-operating:	1.0 G Peak, 4mm p-p Max
Shock	Operating:	5 G's Peak
	Non-operating:	30 G's Peak
Safety		UL, CSA, TUV, CE - LVD, DHHS
EMI:		FCC Class B CE - EMC
Environmental		MPRII, NUTEK Energy Star
Ergonomic		ISO 9241-3
On Screen Controls		Horizontal and Vertical Size and Centering Brightness, Contrast Pin, Bow, Trap, Skew, Rotation Power On/Off (switch) Lock-Out, Restore/Pre-Sets
Dimensions		19 $^{3}/_{8}$ W x 18 $^{1}/_{2}$ H x 17 $^{1}/_{2}$ D (inches)

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimetermeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and.Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1600 x 1200 format is 26.3 dB in a dark room. It decreases to under 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

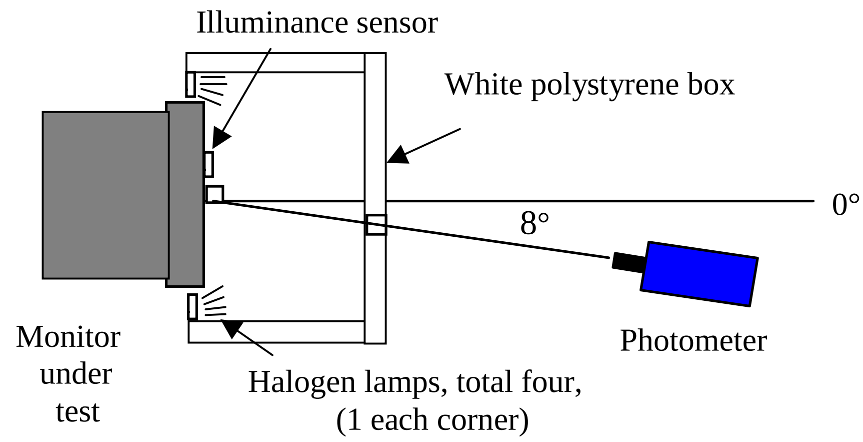
Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93} . Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are silmutaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene ice box. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: DR=10log(Lmax/Lmin)



- Top View -

Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20 fc
Reflected Luminance	1.7 fL
Faceplate Reflectance	8.5 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 26.3 dB in a dark room to less than 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.107 fL.

Ambient Illumination	Displayed Addressable Format 1600 x 1200
0 fc (Dark Room)	26.3 dB
1 fc	23.8 dB
2 fc	22.2 dB
3 fc	21.0 dB
4 fc	20.1 dB
5 fc	19.4 dB
6 fc	18.7 dB
7 fc	18.2 dB
8 fc	17.7 dB
9 fc	17.2 dB
10 fc	16.9 dB
11 fc	16.5 dB
12 fc	16.2 dB
13 fc	15.8 dB
14 fc	15.6 dB
15 fc	15.3 dB

II.2. Maximum Luminance (Lmax)

References: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.

The highest luminance for Lmax was 45.5 fL measured at screen center in 1600 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1600 x 1200	8602 K	0.284	0.314	45.5

II.3. Luminance (Lmax) and Color Uniformity

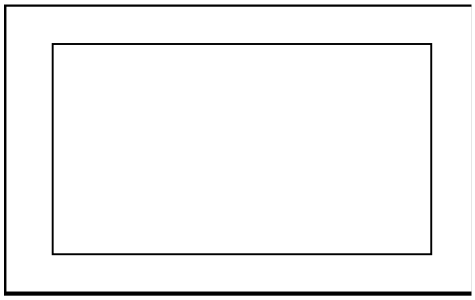
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 16% across the screen. Chromaticity variations were less than 0.010 delta u'v' units.

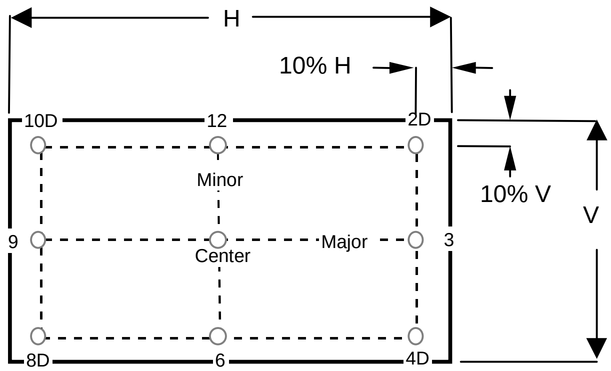
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of Δ u´v´.

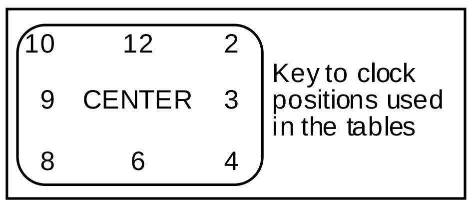
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1600 x 1200

POSITION	CCT, K	CIE x	CIE y	L, fL
center	8602	0.284	0.314	45.5
2	9651	0.276	0.303	41.1
3	9561	0.277	0.303	41.2
4	9784	0.276	0.300	39.2
6	9305	0.279	0.305	44.1
8	9343	0.279	0.304	40.8
9	9027	0.281	0.308	41.2
10	9097	0.281	0.306	38.2
12	9027	0.281	0.308	43.3



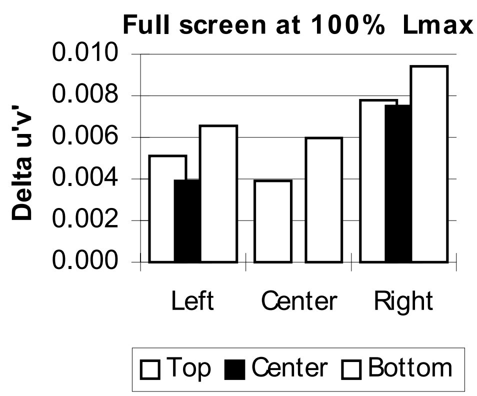


Fig.II.3-3. Spatial Uniformity of Luminance Chromaticity.
(Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 1.8% +/- 0.15% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

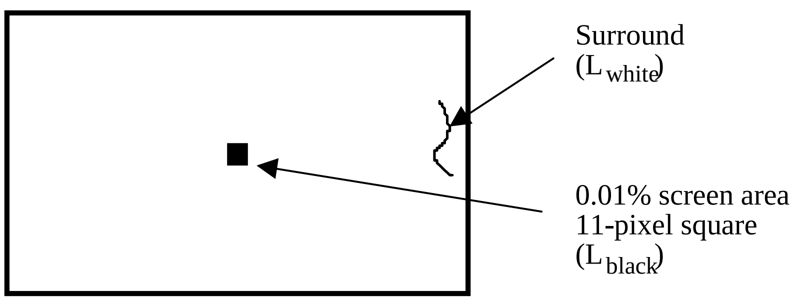


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer which is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} / (L_{white} - L_{black}) \times 100$$

Where, L_{black} = measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white} = measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	0.47fL ± 4%	0.45fL to 0.490fL
Lwhite	26.7fL ± 4%	25.6fL to 27.7fL
Halation	1.8% ± 0.15%	1.6% to 1.91%

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point is 8602K and is not specified for monochrome monitors for IEC.

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. No black level clipping nor white level saturation were observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

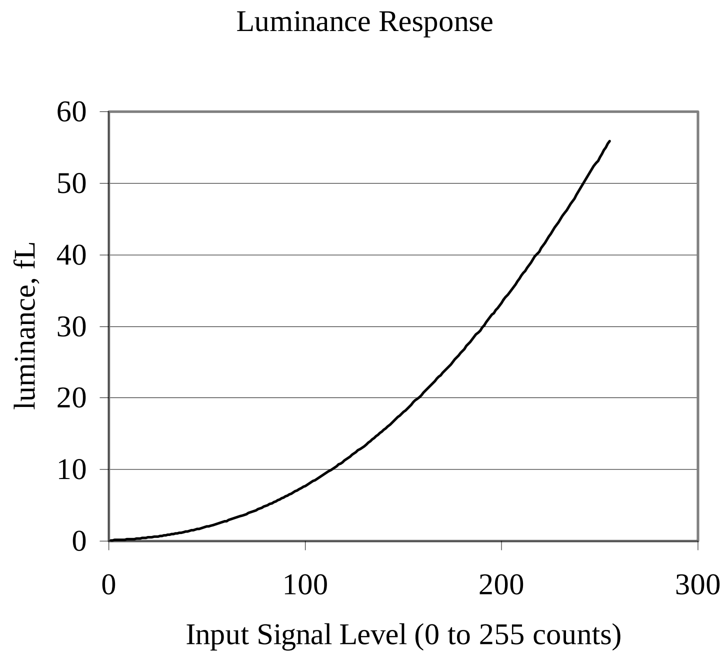


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.104	0	0
39	1	0.118	0.014	4
39	2	0.126	0.008	2
39	3	0.137	0.011	2
40	4	0.15	0.013	3
40	5	0.164	0.014	3
41	6	0.178	0.014	2
41	7	0.194	0.016	3
41	8	0.209	0.015	3
42	9	0.226	0.017	3
42	10	0.245	0.019	3
42	11	0.264	0.019	3
43	12	0.285	0.021	3
43	13	0.306	0.021	3
43	14	0.329	0.023	3
44	15	0.352	0.023	3
44	16	0.384	0.032	4
44	17	0.411	0.027	3
45	18	0.438	0.027	3
45	19	0.466	0.028	3
45	20	0.497	0.031	3
46	21	0.527	0.03	3
46	22	0.558	0.031	3
46	23	0.593	0.035	3
47	24	0.627	0.034	3
47	25	0.663	0.036	3
48	26	0.699	0.036	3
48	27	0.738	0.039	4
48	28	0.776	0.038	2
49	29	0.818	0.042	4
49	30	0.862	0.044	3
49	31	0.905	0.043	3
50	32	0.953	0.048	3
50	33	0.997	0.044	3
50	34	1.046	0.049	3
51	35	1.097	0.051	3
51	36	1.144	0.047	3
51	37	1.195	0.051	3
52	38	1.252	0.057	3
52	39	1.306	0.054	3
52	40	1.363	0.057	3
53	41	1.422	0.059	3
53	42	1.479	0.057	3
53	43	1.541	0.062	3
54	44	1.599	0.058	2
54	45	1.664	0.065	3
55	46	1.728	0.064	3
55	47	1.796	0.068	3
55	48	1.881	0.085	4
56	49	1.948	0.067	3
56	50	2.023	0.075	3
56	51	2.094	0.071	2
57	52	2.167	0.073	3
57	53	2.247	0.08	3
57	54	2.324	0.077	3
58	55	2.402	0.078	3
58	56	2.481	0.079	2
58	57	2.563	0.082	3
59	58	2.652	0.089	3
59	59	2.732	0.08	3
59	60	2.814	0.082	2
60	61	2.908	0.094	3
60	62	2.998	0.09	3
60	63	3.097	0.099	3
61	64	3.196	0.099	2
61	65	3.289	0.093	3
62	66	3.377	0.088	2
62	67	3.479	0.102	3
62	68	3.581	0.102	3
63	69	3.686	0.105	3
63	70	3.791	0.105	2
63	71	3.897	0.106	3
64	72	3.987	0.09	2
64	73	4.101	0.114	3
64	74	4.206	0.105	2
65	75	4.326	0.12	3
65	76	4.433	0.107	2
65	77	4.547	0.114	3
66	78	4.659	0.112	2
66	79	4.787	0.128	3
66	80	4.924	0.137	3
67	81	5.046	0.122	2
67	82	5.181	0.135	3
67	83	5.309	0.128	2
68	84	5.417	0.108	2
68	85	5.548	0.131	3
69	86	5.691	0.143	2
69	87	5.802	0.111	2
69	88	5.948	0.146	3
70	89	6.088	0.14	2
70	90	6.217	0.129	3
70	91	6.357	0.14	2
71	92	6.506	0.149	2
71	93	6.649	0.143	3
71	94	6.789	0.14	2
72	95	6.935	0.146	2
72	96	7.107	0.172	3
72	97	7.265	0.158	2
73	98	7.416	0.151	3
73	99	7.571	0.155	2
73	100	7.719	0.148	2
74	101	7.847	0.128	2
74	102	8.023	0.176	2
74	103	8.193	0.17	3
75	104	8.362	0.169	2
75	105	8.517	0.155	2
76	106	8.702	0.185	2
76	107	8.864	0.162	2
76	108	9.033	0.169	2
77	109	9.205	0.172	3
77	110	9.384	0.179	2
77	111	9.547	0.163	2
78	112	9.754	0.207	2
78	113	9.944	0.19	2
78	114	10.13	0.186	3
79	115	10.31	0.18	2
79	116	10.49	0.18	2
79	117	10.69	0.2	2
80	118	10.86	0.17	2
80	119	11.04	0.18	2
80	120	11.24	0.2	2
81	121	11.45	0.21	2
81	122	11.63	0.18	2
81	123	11.84	0.21	2
82	124	12.05	0.21	2
82	125	12.26	0.21	2
83	126	12.46	0.2	2
83	127	12.67	0.21	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts Target levels 128 to 255.

Background	Target	L, fL	Diff, fL	Diff, JND
83	128	12.87	0.2	2
84	129	13.06	0.19	2
84	130	13.27	0.21	2
84	131	13.49	0.22	2
85	132	13.74	0.25	2
85	133	13.97	0.23	2
85	134	14.18	0.21	2
86	135	14.41	0.23	2
86	136	14.63	0.22	1
86	137	14.86	0.23	2
87	138	15.08	0.22	2
87	139	15.32	0.24	2
87	140	15.53	0.21	2
88	141	15.78	0.25	2
88	142	16.02	0.24	2
88	143	16.26	0.24	2
89	144	16.57	0.31	2
89	145	16.81	0.24	2
90	146	17.04	0.23	1
90	147	17.32	0.28	2
90	148	17.55	0.23	2
91	149	17.81	0.26	2
91	150	18.05	0.24	2
91	151	18.27	0.22	1
92	152	18.55	0.28	2
92	153	18.78	0.23	2
92	154	19.09	0.31	2
93	155	19.36	0.27	2
93	156	19.63	0.27	1
93	157	19.87	0.24	2
94	158	20.14	0.27	2
94	159	20.42	0.28	1
94	160	20.72	0.3	2
95	161	20.99	0.27	2
95	162	21.26	0.27	2
95	163	21.53	0.27	1
96	164	21.83	0.3	2
96	165	22.09	0.26	2
97	166	22.38	0.29	1
97	167	22.67	0.29	2
97	168	22.97	0.3	2
98	169	23.17	0.2	1
98	170	23.56	0.39	2
98	171	23.81	0.25	1
99	172	24.07	0.26	2
99	173	24.43	0.36	2
99	174	24.72	0.29	1
100	175	25.02	0.3	2
100	176	25.41	0.39	2
100	177	25.68	0.27	1
101	178	25.97	0.29	2
101	179	26.31	0.34	1
101	180	26.53	0.22	2
102	181	26.87	0.34	1
102	182	27.26	0.39	2
102	183	27.58	0.32	2
103	184	27.81	0.23	1
103	185	28.14	0.33	1
104	186	28.54	0.4	2
104	187	28.89	0.35	2
104	188	29.12	0.23	1
105	189	29.45	0.33	1
105	190	29.87	0.42	2
105	191	30.15	0.28	2

Background	Target	L, fL	Diff, fL	Diff, JND
106	192	30.62	0.47	2
106	193	30.91	0.29	1
106	194	31.26	0.35	2
107	195	31.64	0.38	1
107	196	31.84	0.2	1
107	197	32.28	0.44	2
108	198	32.54	0.26	1
108	199	32.95	0.41	2
108	200	33.28	0.33	1
109	201	33.71	0.43	2
109	202	34.06	0.35	1
109	203	34.42	0.36	2
110	204	34.76	0.34	1
110	205	35.17	0.41	2
111	206	35.52	0.35	1
111	207	35.84	0.32	1
111	208	36.34	0.5	2
112	209	36.62	0.28	1
112	210	37.07	0.45	2
112	211	37.45	0.38	1
113	212	37.74	0.29	1
113	213	38.18	0.44	2
113	214	38.53	0.35	1
114	215	38.91	0.38	1
114	216	39.37	0.46	2
114	217	39.75	0.38	1
115	218	40.13	0.38	2
115	219	40.44	0.31	1
115	220	40.92	0.48	1
116	221	41.33	0.41	2
116	222	41.65	0.32	1
116	223	42.15	0.5	1
117	224	42.55	0.4	2
117	225	42.92	0.37	1
118	226	43.34	0.42	1
118	227	43.84	0.5	2
118	228	44.19	0.35	1
119	229	44.57	0.38	1
119	230	44.98	0.41	1
119	231	45.41	0.43	2
120	232	45.77	0.36	1
120	233	46.23	0.46	1
120	234	46.64	0.41	2
121	235	47.08	0.44	1
121	236	47.49	0.41	1
121	237	47.84	0.35	1
122	238	48.39	0.55	2
122	239	48.83	0.44	1
122	240	49.27	0.44	1
123	241	49.72	0.45	2
123	242	50.14	0.42	1
123	243	50.61	0.47	1
124	244	51.08	0.47	1
124	245	51.49	0.41	1
125	246	51.92	0.43	2
125	247	52.42	0.5	1
125	248	52.86	0.44	1
126	249	53.15	0.29	1
126	250	53.62	0.47	1
126	251	54.11	0.49	1
127	252	54.67	0.56	2
127	253	55.02	0.35	1
127	254	55.51	0.49	1
128	255	55.92	0.41	1

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

Very slight video streaking was observed in the SMPTE test pattern.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

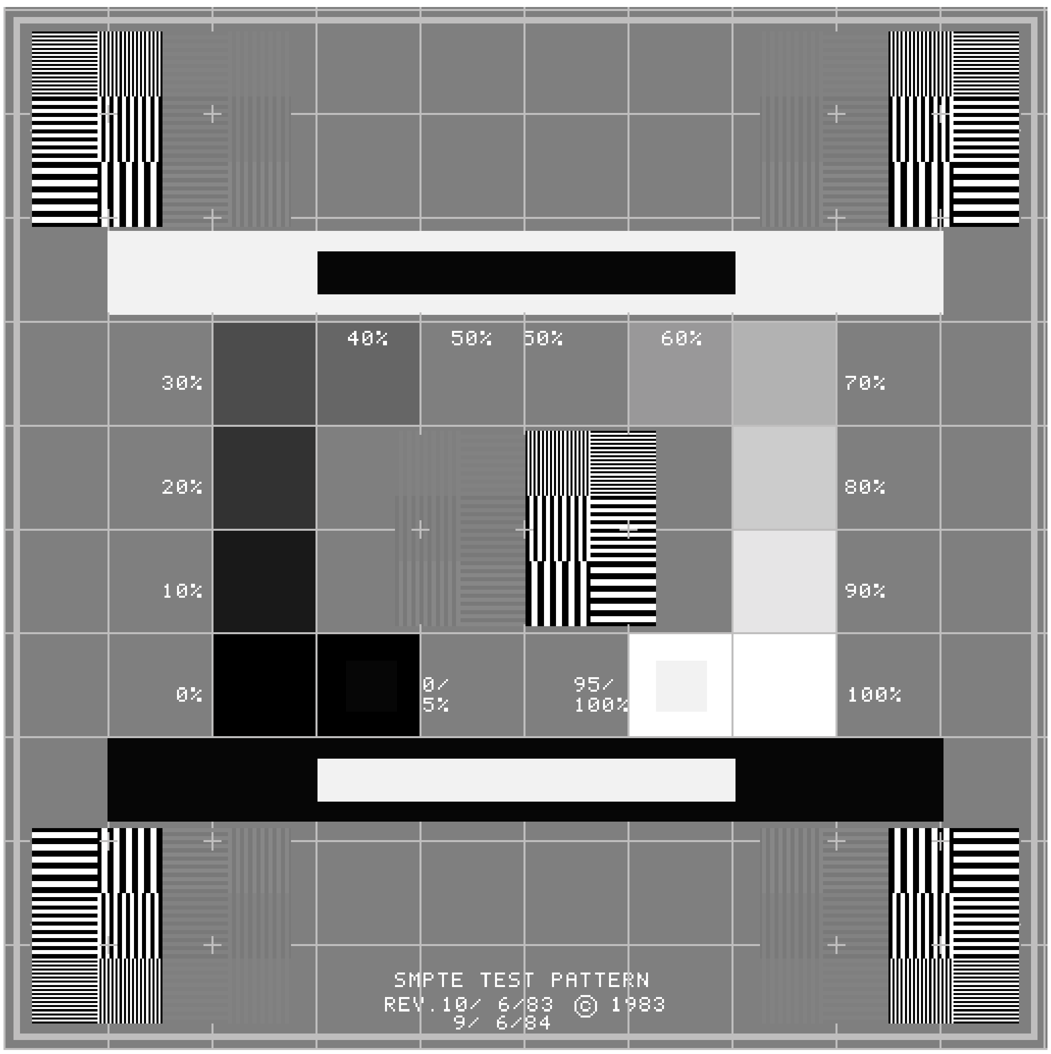


Figure II.8-1. SMPTE Test Pattern .

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." Most of these artifacts, except for slight streaking, were not observed in the Clinton Electronics DS2100HB-ST monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200x 71 Hz, and 1024 x 1024 x 118 Hz.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200	1024 x 1024

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 0.6%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	1600 x 1200
H x V Image Size (inches)	14.715 x 10.969
H x V Pixel Spacing (mils)	9.20 x 9.14 mils
H x V Pixel Aspect Ratio	H = V - 0.6%

II.11. Screen Size (Viewable Active Image)

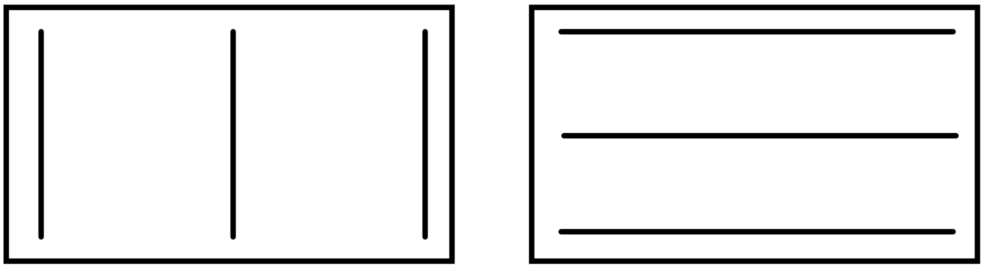
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size as tested was 18.35 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any over-scanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Mode
Addressability (H x V)	1600 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	14.715 x 10.969 18.354

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 34% in Zone A, and exceeded Cm = 23% in Zone B.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

Procedure: The maximum video modulation frequency for each 1600 x 1200 format was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax..

Zone A is defined as a 24 degree subtense circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 51% in Zone A, and is equal to or greater than 35% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

Table II.12-1. Contrast Modulation
Corrected for lens flare and Zone Interpolation

Zone A 7.6-inch diameter circle for 24-degree subtense at 18-inch viewing distance

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	63%	29%			26%	53%			72%	39%
			68%	41%	40%	52%	71%	45%		
Major	61%	24%	66%	36%	71%	49%	70%	36%	68%	24%
			64%	38%	58%	48%	68%	40%		
Bottom	54%	23%			52%	48%			63%	27%

Zone A 9.07-inch diameter circle for 40% area

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	63%	29%			26%	53%			72%	39%
			67%	39%	34%	53%	71%	44%		
Major	61%	24%	65%	34%	71%	49%	69%	34%	68%	24%
			63%	36%	55%	48%	67%	38%		
Bottom	54%	23%			52%	48%			63%	27%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was set to 109 ppi for the 1600 x 1200-line addressable format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
Addressability (H x V)	1600 x 1200
H x V Image Size (inches)	14.715 x 10.969
H x V Pixel Density, ppi	109 x 109

II.14. Moire

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Not applicable to monochrome monitors.

II.15. Straightness

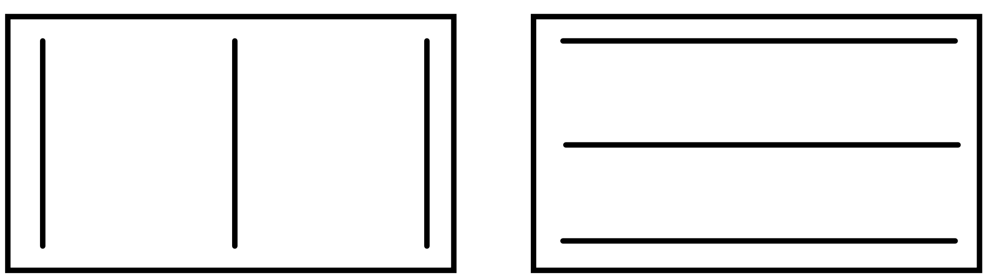
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.3% of the image width or height.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

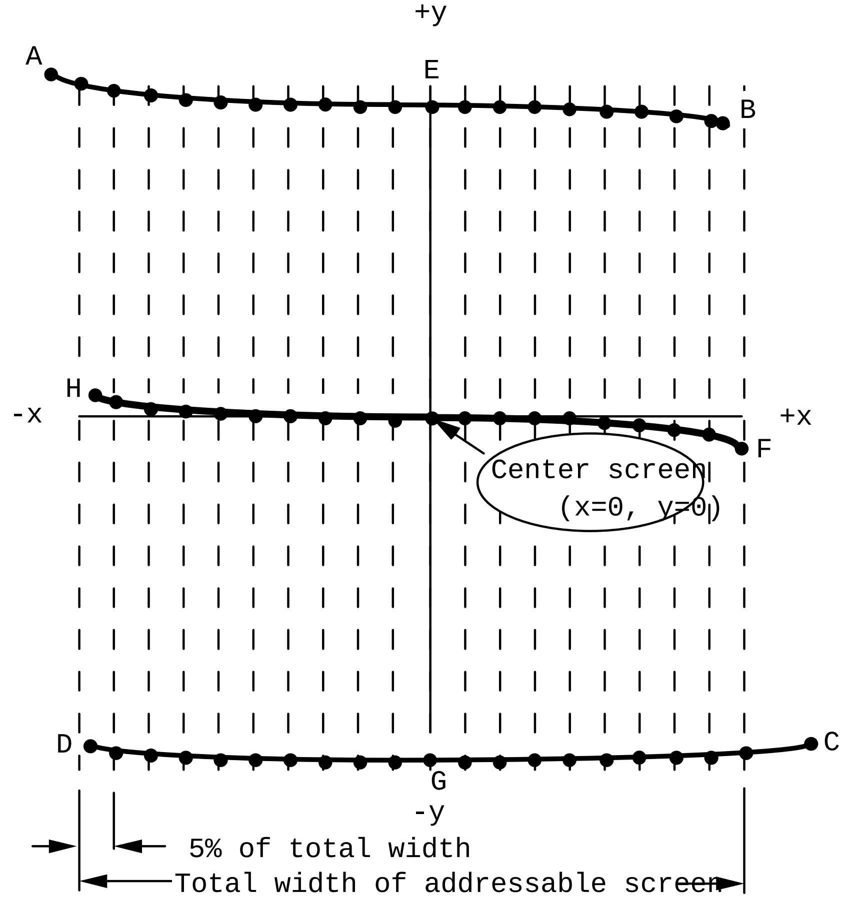


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness
Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7343	5489	-7300	-5524	-7334	-3	9	5551	-7345	5505	7401	5385
-6615	5501	-6615	-5533	-6615	-3	7	4968	-7351	4968	7406	4968
-5880	5506	-5880	-5538	-5880	-4	8	4416	-7352	4416	7407	4416
-5145	5510	-5145	-5538	-5145	-5	7	3864	-7351	3864	7407	3864
-4410	5516	-4410	-5534	-4410	-3	7	3312	-7350	3312	7408	3312
-3675	5522	-3675	-5530	-3675	-1	6	2760	-7348	2760	7408	2760
-2940	5528	-2940	-5526	-2940	0	4	2208	-7350	2208	7410	2208
-2205	5533	-2205	-5520	-2205	2	4	1656	-7350	1656	7413	1656
-1470	5537	-1470	-5515	-1470	5	4	1104	-7348	1104	7416	1104
-735	5539	-735	-5512	-735	7	4	552	-7345	552	7418	552
0	5540	0	-5512	0	8	1	0	-7344	0	7422	0
735	5541	735	-5513	735	10	2	-552	-7344	-552	7428	-552
1470	5543	1470	-5515	1470	11	0	-1104	-7345	-1104	7437	-1104
2205	5546	2205	-5519	2205	11	0	-1656	-7346	-1656	7448	-1656
2940	5549	2940	-5525	2940	11	0	-2208	-7346	-2208	7460	-2208
3675	5554	3675	-5530	3675	11	0	-2760	-7341	-2760	7466	-2760
4410	5560	4410	-5532	4410	11	0	-3312	-7338	-3312	7475	-3312
5145	5567	5145	-5533	5145	10	1	-3864	-7332	-3864	7482	-3864
5880	5575	5880	-5536	5880	8	3	-4416	-7326	-4416	7487	-4416
6615	5581	6615	-5538	6615	5	7	-4968	-7319	-4968	7491	-4968
7305	5584	7465	-5533	7399	0	10	-5471	-7305	-5508	7495	-5486

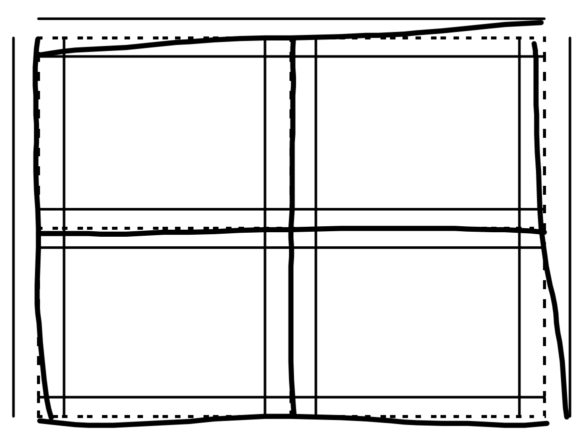


Figure II.15-3 Waviness of Clinton Electronics DS2100HB-ST Monochrome monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for the1600 x 1200 format was set to 71 Hz.
Vertical refresh rate for the 1024 x 1024 stereo format was set to 118 Hz, limited by the monitor.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	1600 x 1200	1024 x 1024
Vertical Scan Horizontal Scan	71 Hz 87.8 kHz	118 Hz 127 kHz

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio was averaged 8.7 to 1 (7.9 left, 9.6 right) at screen center. Luminance of white varied by up to 10.6% across the screen. Chromaticity variations of white were less than 0.010 delta u'v' units.

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

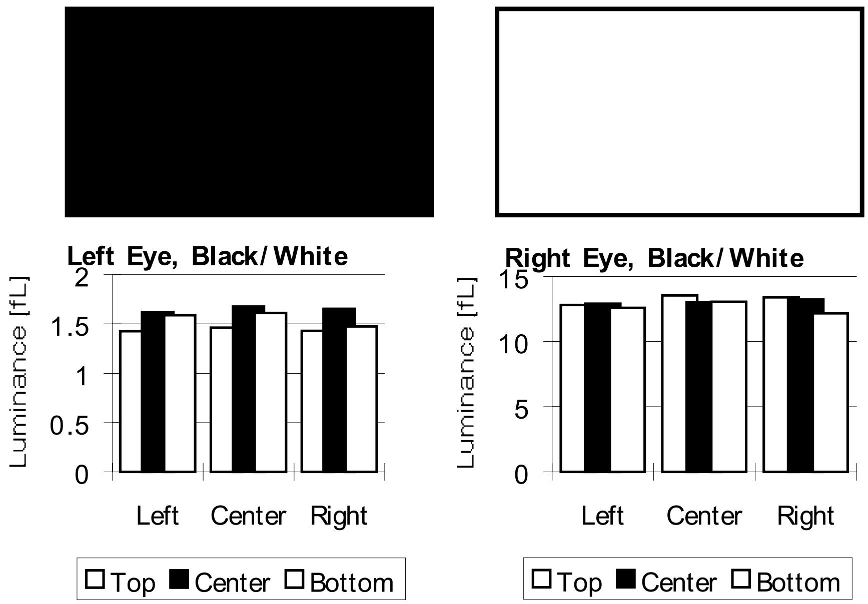


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

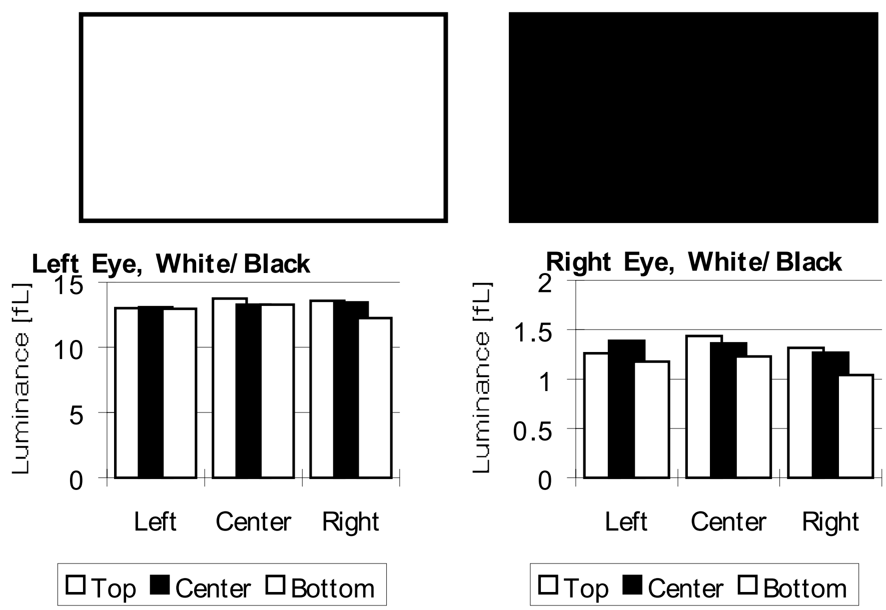


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

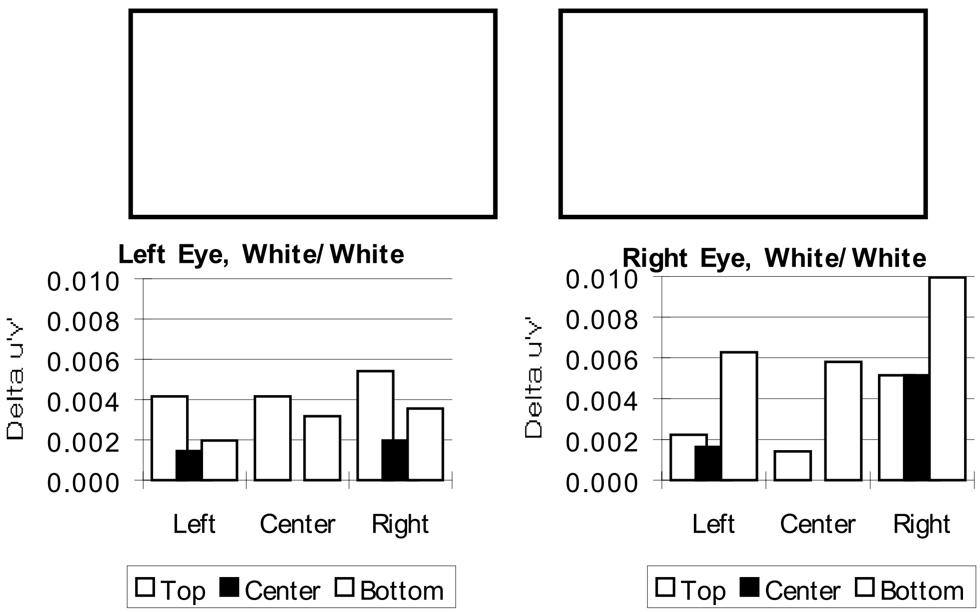


Fig.II.17-4 Spatial Uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 1.1 % of full screen.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

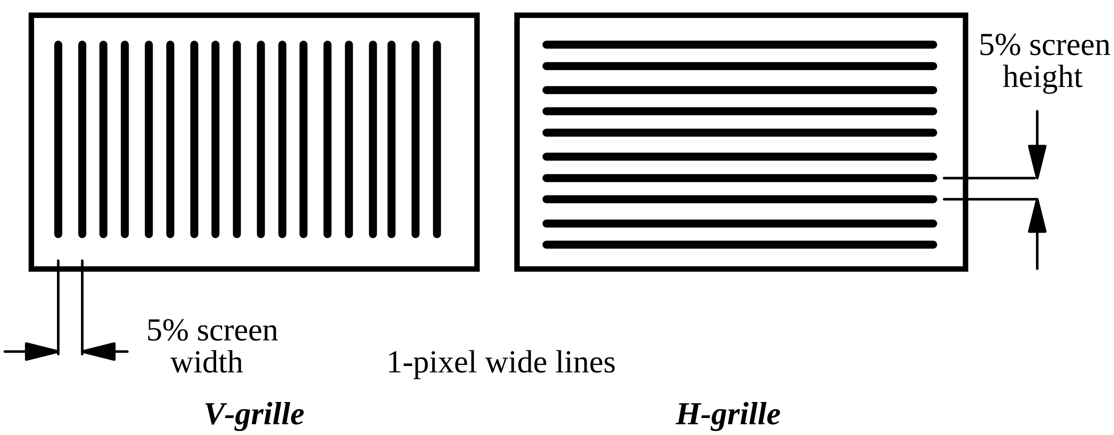


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

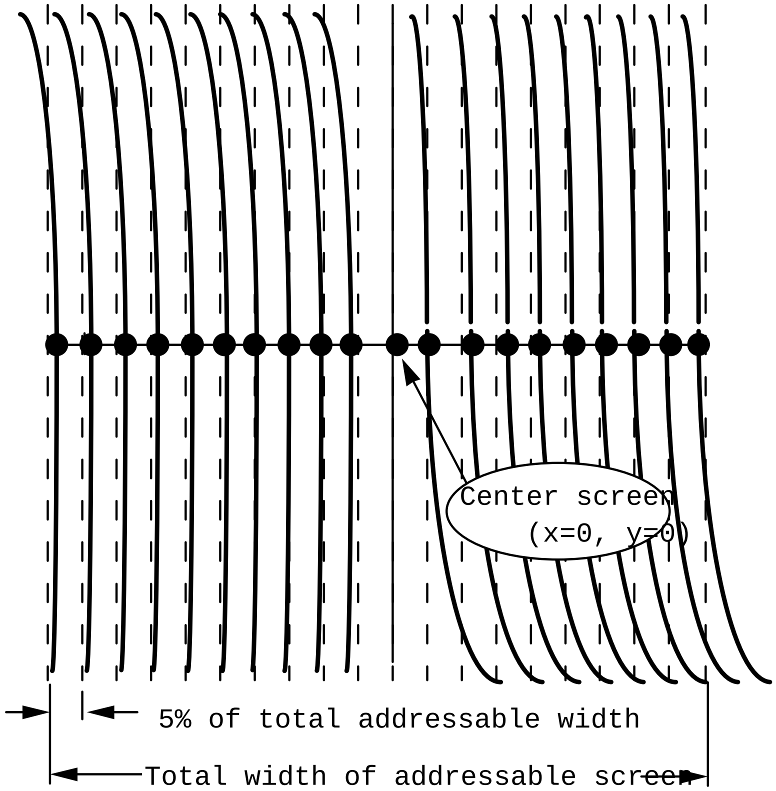


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

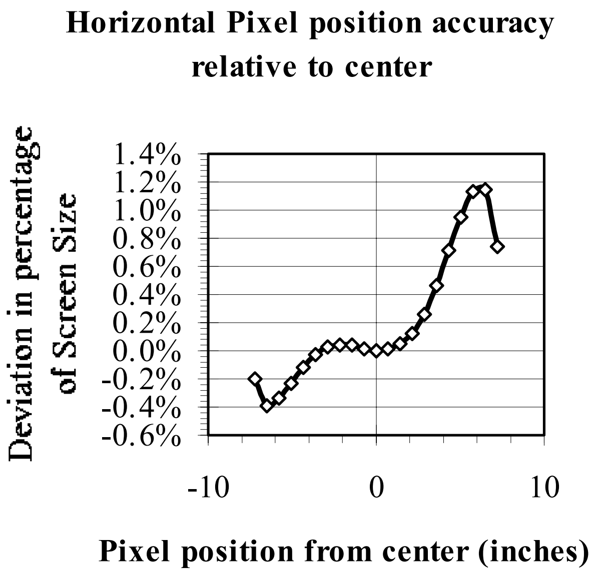
Data: Tabulate x,y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impacts the absolute position of each pixel on the screen and is, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figure II.18-3.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	0.4%	1.1%	0.6%	0.2%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	**Right Side**	**Top**	**Bottom**
-7259	7338	5439	-5384
-6564	6674	4903	-4855
-5833	5949	4362	-4315
-5095	5200	3813	-3772
-4355	4442	3261	-3230
-3619	3683	2710	-2687
-2888	2930	2162	-2147
-2163	2187	1617	-1609
-1440	1453	1076	-1073
-721	725	538	-537
0	0	0	0



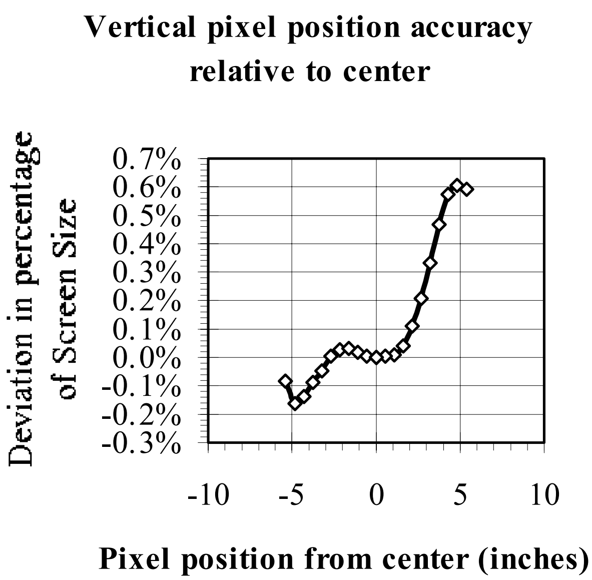


Fig. II.18-5 Horizontal and vertical linearity characteristics.

II.19. Jitter/Swim/Drift

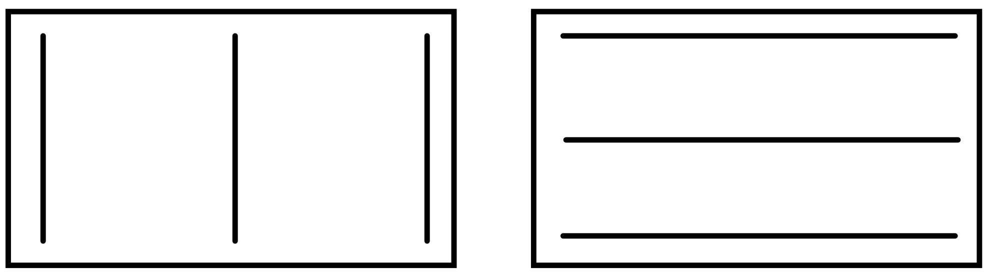
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift were 2.2 mils and 2.3 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depend upon the amplitude and frequency of the motions which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-

1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

		H-lines	V-lines	
10D corner	Max Motions			
	Jitter	2.03	2.33	
	Swim	2.08	2.43	
	Drift	2.09	2.49	
Black Tape	Max Motions			
	Jitter	0.142	0.122	
	Swim	0.16	0.182	
	Drift	0.199	0.183	
Less Tape Motion				maximums
	Jitter	1.89	2.21	2.21
	Swim	1.92	2.25	2.25
	Drift	1.89	2.31	2.31

II.20 Warmup Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 74 - minute warmup was necessary for luminance stability of Lmin = 0.1 fL +/- 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1280 x 1024 format in graphical form. The luminance remains very stable after 49 minutes.

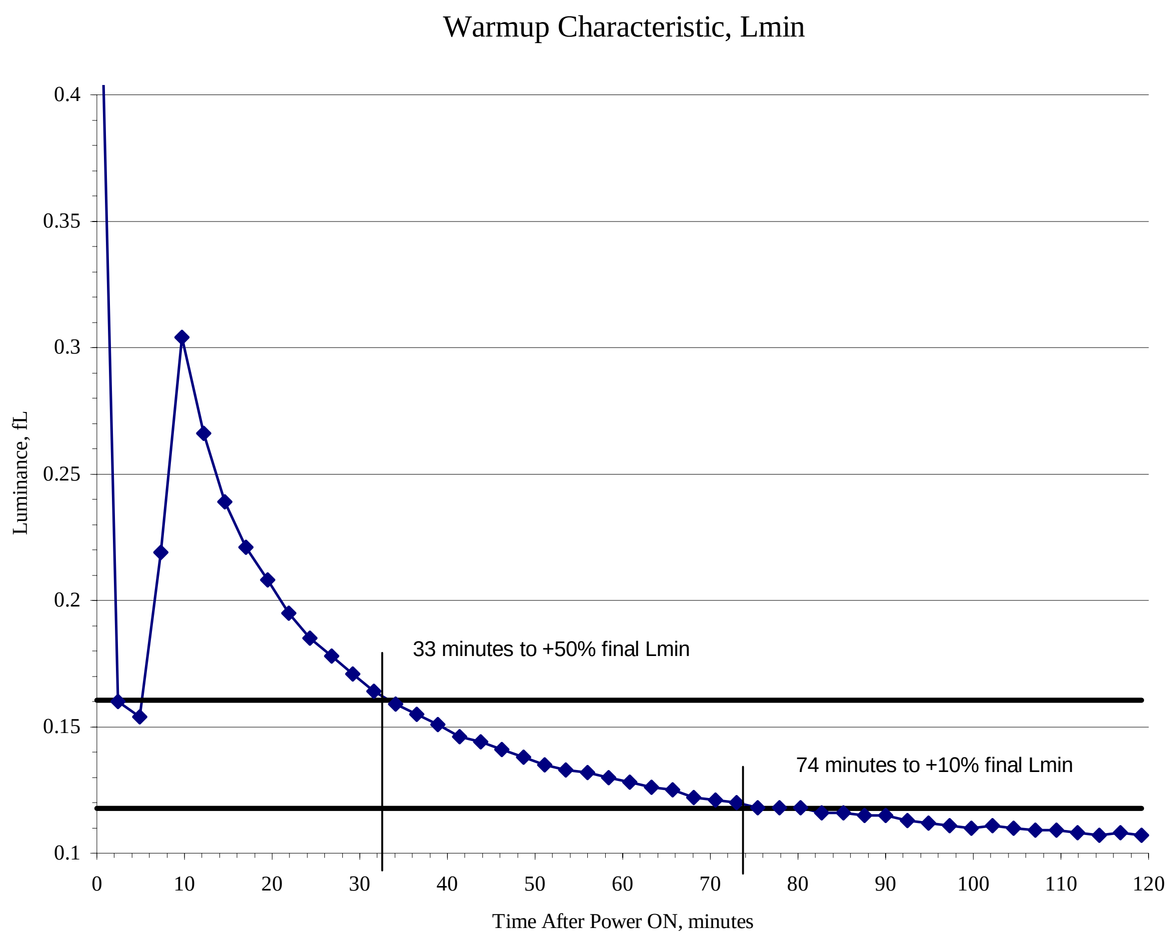


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).