The Sony GDM-FW900 24 inch, flat face monitor (22.5" viewable area; selling price $1999.99) is new both in its flat face CRT and in its improved electronics. The Sony GDM-FW900 is a distinct improvement, except for halation and linearity, over the previous model Sony GDM-W900/Sun Microsystems 365-1352-01 color monitor that NIDL had certified for IEC workstation monoscopic-mode color operation. NIDL rates this color monitor “A” in monoscopic mode and thereby certifies the 24 inch Sony GDM-FW900 color monitor as being suitable for IEC workstations in the monoscopic-mode. NIDL tested the monitor at an addressability of 1920 x 1200 pixels, as would be used in an IEC W2K PC–based workstation. Our tests show that the monoscopic contrast modulation is excellent and exceeds 48% in Zone A and 38% over the face of the whole CRT, well above the IEC minimum performance values. The FW900 can display 1024 x 1024 pixel stereo images at 56 Hz per eye (112 Hz vertical refresh rate), but this does not meet the IEC specification of 120 Hz vertical refresh rate so NIDL rates it "C" for stereo performance. NIDL demonstrated that the color CIE coordinates accurately can be reproduced over a two month's period by activating the factory reset button on the front panel. Briggs Scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 10, 40, 57 and 62, respectively.

Evaluation of the Sony GDM-FW900 16:10 Aspect Ratio, 24-Inch Diagonal Flat Face CRT Color Monitor

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CONTENTS

NIDL IEC Monitor Certification Report

The Sony GDM FW900 Color CRT Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: C

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 Sony GDM-FW900 24 inch, flat face monitor (22.5" viewable area; selling price $1999.99) is new both in its flat face CRT and in its improved electronics. It is a color monitor with excellent image quality and features that make it an excellent display device for NIMA Imagery Exploitation Capability workstations. The Sony GDM-FW900 is a distinct improvement, except for halation and linearity, over the previous model Sony GDM-W900/Sun Microsystems 365-1352-01 color monitor that NIDL had certified for IEC workstation monoscopic-mode color operation. NIDL rates this color monitor "A" in monoscopic mode and thereby certifies the 24 inch Sony GDM-FW900 color monitor as being suitable for IEC workstations in the monoscopic-mode. NIDL tested the monitor at an addressability of 1920 x 1200 pixels, as would be used in an IEC W2K PC–based workstation. Our tests show that the monoscopic contrast modulation is excellent and exceeds 48% in Zone A and 38% over the face of the whole CRT, well above the IEC minimum performance values. The reliability of the Sony GDM-FW900 monitor is expected to be excellent; it has a limited warranty of 3 years for parts, labor and the CRT. NIDL has used the previous Sony GDM-W900 version of this monitor for several years now without any failures and with continued excellent performance. The 16:10 wide aspect ratio and the 24 inch diagonal give the analyst a larger working area than a 21 inch monitor does. The 24" Flat Trinitron CRT wide screen monitor will display up to 2304 x 1440 pixels at 80 Hz. The CRT has a 0.23mm aperture grille pitch at the center increasing to 0.27mm at the edges of the screen. The manufacturer recommended addressability setting is 1920 x 1200 at 85Hz.

The color temperature can be preset to 5000, 6500, and 9300K, or can be linearly adjusted from 5000 to 11000K. A 6500K color temperature most closely resembles natural lighting and is recommended by the PQ2000 Image Quality document for viewing daylight color imagery. Other color features include: variable RGB gain/bias, the sRGB color display system. Adjusting the color temperature somewhat affects the output luminance of the monitor; 5000K, 32 fL; 6500K, 37 fL; 9300K, 38 fL. The output luminance for the 6500 and 9300K standard color temperatures are nearly identical.

NIMA has stated that color reproducibility over time is an important feature for IEC workstations. Accordingly, NIDL demonstrated that the CIE x and y coordinates can be reproduced over a period of two months by using the Sony factory default button on the front panel and adjusting Lmin to 0.1 fL. In this way, accuracy of color reproduction can be assured. NIDL recommends periodic use of the color default setting to assure accurate color reproduction over time.

The improved electronics of the FW900 allow this monitor to display 1024 x 1024 pixel stereo images at 56 Hz per eye (112 Hz vertical refresh rate), which is below the IEC specification of 60 Hz per eye but well exceeds the 46 Hz per eye of the previous W900 monitor. It is only because of its inability to meet the 120 Hz (60 Hz per eye) IEC specification that NIDL rates the GDM-FW900 as “C” in the stereoscopic mode for the Image Analyst and Cartographer application. The monitor exceeds the IEC stereo extinction ratio specification of 15:1 with the StereoGraphics CrystalEyes shutter glasses and achieves 18.7:1 at 56 Hz per eye. The stereo extinction ratio at 56 Hz per eye with the StereoGraphics ZScreen is 11.1:1. With a value of 6.9 fL at the analyst’s eye position, the Sony GDM-FW900 exceeds the IEC luminance specification in the stereoscopic mode.

The Sony GDM-FW900 version of this monitor is described in the Manufacturer’s Specifications in the section below and on the Sony website:
http://www.sonystyle.com/vaio/displays/gdm_fw900.htm.

A 21 inch version of this color monitor, the GDM-F520, is available at a price of $1699.99. It has a pitch of 0.22 mm over the entire face and 2048 x 1536 pixel maximum addressability. From the electrical specifications, it appears that this monitor may be able to achieve stereo mode operation at 1024 x 1024 addressability at 120 Hz.

The color monitors that NIDL has certified for stereoscopic mode are shown in Table I. The Sony GDM-FW900 is compared with other color CRT monitors certified by NIDL for monoscopic-mode-only operation in Table II.

Table I. NIDL IEC Color Monitor Certified for Stereoscopic-Mode Application (Have Rating B or Higher for Both Monoscopic and Stereoscopic Modes)

Monitor	IEC Spec	Corner stone	EIZO	Hitachi	Siemens	Viewsonic
Model		P1700	F980	CM814	SCM21130	P817
Certified for stereoscopic*		Y	Y	Y	Y	Y
Monoscopic		A	B	B	B	B
Stereoscopic		B	B	B	B	B
Cm, Zone A	25%	57%	37%	35%	36%	29%
Cm, Zone B	20%	52%	27%	30%	21%	40%
Refresh per eye	60 Hz	60 Hz	60 Hz	60 Hz	60.5 Hz	60 Hz
Extinction ratio, panel	No spec	10.6	12.6	11.2	11.2	10.1
IR glasses	15 to 1	21.0	14.3		18.1	
Price		$1363	$1790	$1200	< $2800	$1600

* Certified by NIDL requires achieving a rating of “B” or above for stereoscopic and for monoscopic performance relative to the IEC Working Group specifications listed in the Evaluation Datasheet. This summary is a compilation of ratings for color monitors from previously NIDL IEC monitor reports.

Table II. NIDL Certification for Imagery Exploitation Capability for Color Monitors Intended for Monoscopic-Only Applications Application
(Have Rating B or Higher for Monoscopic Mode)

Monitor Manufacturer	IEC Spec	Viewsonic 21 inch	Mitsubishi 22 inch	SONY 24 inch Tested at 1920 x 1200 addressability	
Model		PF815	2040U	24W900	GDM-FW900
Certified for monoscopic-only*		Y	Y	Y	Y
Monoscopic		A	A	A	A
Stereoscopic		C	C		C
Cm, Zone A	25%	55%	54%	51%	48%
Cm, Zone B	20%	47%	42%	35%	38%
Refresh per eye	60 Hz	55 Hz	55 Hz	46 Hz	56 Hz
Extinction ratio, panel	No spec	10.3	10.4	12.9	11.1
IR glasses	15 to 1	17.6	17.6		18.7
Price		$926	$1123	$2371	$1999

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1920 x 1200	Pass
Dynamic Range	24.7dB	24.9 dB	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	31.1 fL	Pass
Uniformity (Lmax)	20% max.	9.3%	Pass
Halation	3.5% max.	5.19 ± 0.4%	Fail
Color Temp	6500 to 9300 K	9200 K	Pass
Reflectance	Not specified	5.2%	
Bit Depth	8-bit± 5 counts	8-bit	Pass
Step Response	No visible ringing	Clean	Pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 delta u'v'	0.002 delta u'v'	Pass
Color Tracking	Not specified	Less than 0.013 delta u'v' between Lmin to Lmax	
Color Gamut Area	Not specified	27%	
Pixel aspect ratio	H = V± 6%	H = V- 4.0%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	22.265 ins.	Pass
Cm, Zone A, 7.6"	25% min.	48%V x 56%H	Pass
Cm, Zone A, 10.66"	25% min.	41%V x 59%H	Pass
Cm, Zone B	20% min.	38%V x 60%H	Pass
Pixel density	72 ppi min.	102 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.92 center 1.08 edge	Pass
Straightness	0.5% max ± 0.05 mm	0.35%	Pass
Linearity	1.0% ± 0.05 mm max.	1.56%	Fail
Jitter	2 ± 2 mils max.	3.96 mils	Pass
Swim, Drift	5 ± 2 mils max.	6.43 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. Max	33 mins.	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. Max	49 mins.	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min.	Set to 85 Hz	Pass
Average Briggs Scores, BTP #4 Delta-1, Delta-3, Delta-7, Delta-15	Not specified	Delta-1=10, Delta-3=40, Delta-7=57, Delta-15=62	
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 1024 (I) at 56 Hz)	Pass
Lmin	Not specified	0.1 fL	Pass
Lmax	6 fL min ± 4%	6.96 fL (IR at 56 Hz per eye)	Pass Pass
Dynamic range	17.7 dB min	18.2 dB (IR at 56 Hz per eye)	Pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u'v'	0.006 delta u'v' (IR at 56 Hz)	Pass
Refresh rate	60 Hz per eye, min	56 Hz, per eye	Fail
Extinction Ratio	15:1 min with CrystalEyes	18.7:1 (IR at 56Hz) 11.1 (Z, I)	Pass Pass
AMBIENT LIGHTING			
Dynamic range = 22 dB (158:1)	N/A	2 fc	
Dynamic range = 17 dB (50:1)	N/A	10 fc	

(IR) Denotes StereoGraphics CrystalEyes IR Eyewear (I) Denotes interlaced scanning
(Z) Denotes StereoGraphics ZScreen and passive glasses

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 Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Sony GDM-FW900 color 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.*
- *VESA Flat Panel Display Measurements Standard, Version 2.0, June 1, 2001.*

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 Manufacturer's Specifications for the Sony GDM-FW900 Color CRT Monitor

Please refer to the Sony web page for further information on the GDM-FW900 CRT monitor.
http://www.sonystyle.com/vaio/displays/gdm_fw900.htm.

Features

- **Virtually flat wide screen format to minimize geometric distortion and glare**
- **24 inch diagonal (22.5 inch viewable)**
- **Aperture grill CRT**
- **Up to 2304 x 1440 pixel addressability at 80 Hz**

Sony GDM-FW900 Specifications per manufacturer. Please refer to the Sony web page for current information on the GDM-FW900 CRT monitor. http://www.sonystyle.com/vaio/displays/gdm_fw900.htm.

Specifications

• CRT	Super fine pitch 24 inch wide HD Trinitron
• Active display area	22.5 inch diagonal, 18.98 inch (H), 12.18 inch (V)
• Aperture grill pitch	0.23 to 0.27 mm
• Screen treatment	High contrast AR coating
• Horizontal scan range	30 kHz to 121 kHz
• Vertical scan range	48 Hz to 160 Hz
• Recommended resolution	1920 x 1200 @ 85 Hz
• Preset resolutions	640 x 480 @ 60 Hz to 2304 x 1440 @ 80 Hz VESA
• Preset timings	Factory 25, user 10
• Color temperature presets	5000K, 6500K, 9300K, sRGB, variable RGB gain/bias
• Signal inputs	Analog RGB, 75 Ohms, 0.7 V peak to peak
• Input connectors	15 pin mini D sub
• Weight	92 pounds
• Power requirements	90 to 264 V AC 50/60 Hz
• Operating power	170 W max
• Operating temperature	10C to 40C
• Operating humidity	10 to 80% non condensing
• Regulation compliance	See web page
• Front panel digital controls	See web page
• On-screen display controls	See web page
• Warranty	Parts, labor and CRT 3 years

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 Colorimeter
- 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

Computers used in these measurements included:

- Sun Microsystems Ultra 60 workstation with dual 360 MHz processors and creator 3D graphics card for displaying Briggs targets.

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

- StereoGraphics ZScreen 19-inch LCD shutter with passive polarized eyeglasses.
- StereoGraphics CrystalEyes IR Eyewear.

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 contrast ratio measured in 1920 x 1200 format is 309:1 (24.9 dB dynamic range) in a dark room. It decreases to 151:1 (21.8 dB) in 2 fc diffuse ambient illumination. The absolute threshold for IEC is 158:1 (22 dB).

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 simultaneously 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 icebox. 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: Contrast ratio is a linear expression of Lmax to Lmin. Dynamic range expresses the contrast ratio in log units, dB, which correlates more closely with the sensitivity of the human vision system.

Define contrast ratio by: CR = Lmax/Lmin

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

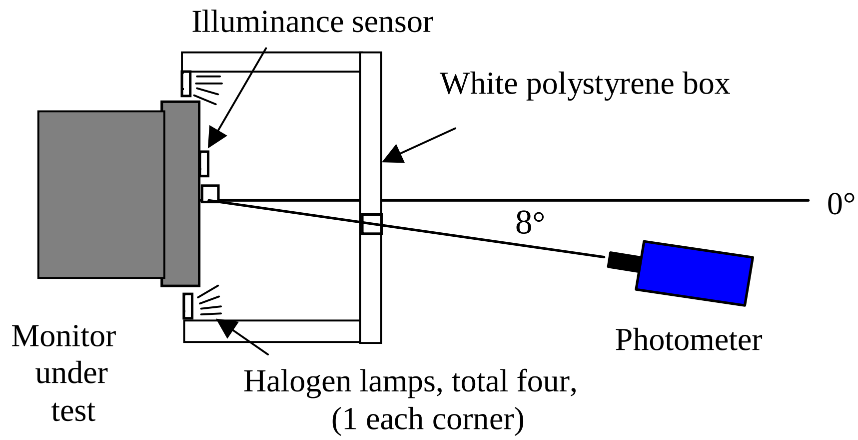


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate
VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	31.1 fc
Reflected Luminance	1.055 fL
Faceplate Reflectance	5.2 %

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 contrast ratio decreases from 309:1 (24.9 dynamic range) in a dark room to 151:1 (21.8 dB) in 2 fc diffuse ambient illumination. The absolute threshold for IEC is 158:1 (22 dB).

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 = 0.10.

Ambient Illumination	Contrast Ratio	Dynamic Range, dB
0 fc (Dark Room)	309 :1	24.9 dB
1 fc	204 :1	23.1 dB
2 fc	151 :1	21.8 dB
3 fc	120 :1	20.8 dB
4 fc	102 :1	20.1 dB
5 fc	87 :1	19.4 dB
6 fc	76 :1	18.8 dB
7 fc	68 :1	18.3 dB
8 fc	60 :1	17.8 dB
9 fc	55 :1	17.4 dB
10 fc	51 :1	17.1 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 31.1fL measured at screen center in 1920 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). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

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
1920 x 1200	9200K	0.285	0.294	31.1 fL

II.3. Luminance (Lmax) and Color Uniformity

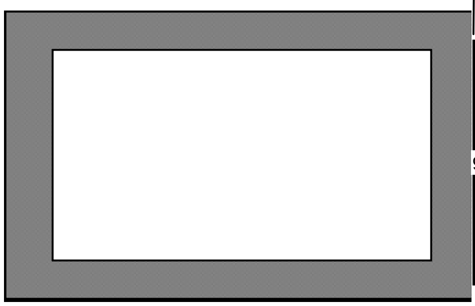
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 9.3% across the screen. Chromaticity variations were 0.0021 delta u'v' units or less.

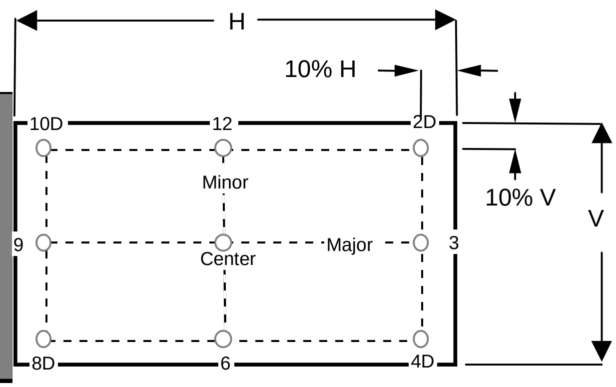
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

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 Δu´v´.

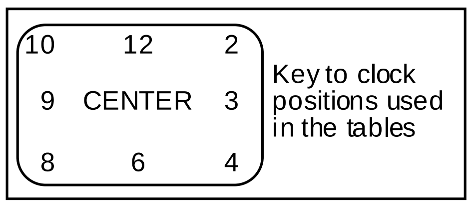
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

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.

1920 x 1200

POSITION	CCT	CIE x	CIE y	L, fL
center	9200	0.285	0.294	31.1
2	9253	0.284	0.295	29.1
3	9531	0.282	0.293	28.5
4	9119	0.285	0.296	29.3
6	9390	0.283	0.294	30.1
8	9200	0.285	0.294	28.3
9	9066	0.286	0.295	28.2
10	9337	0.284	0.293	28.7
12	9433	0.283	0.293	30.5



1920 x 1200

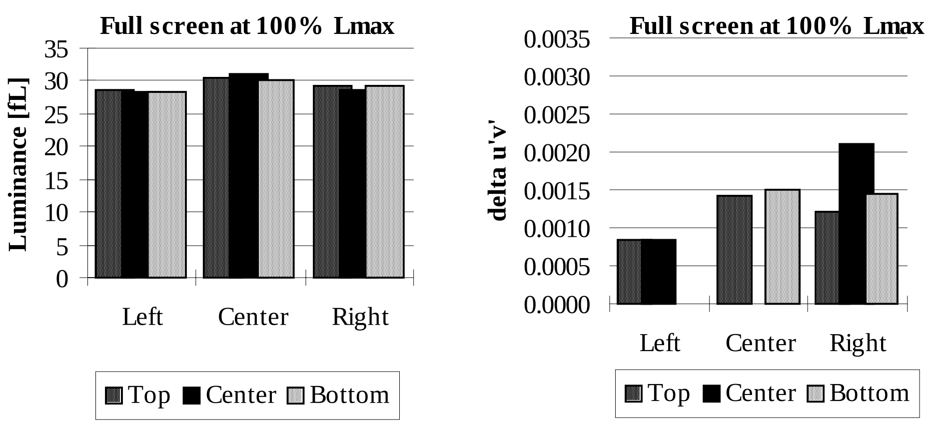


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity at Lmax.
(Delta u'v' of 0.004 is just visible.)

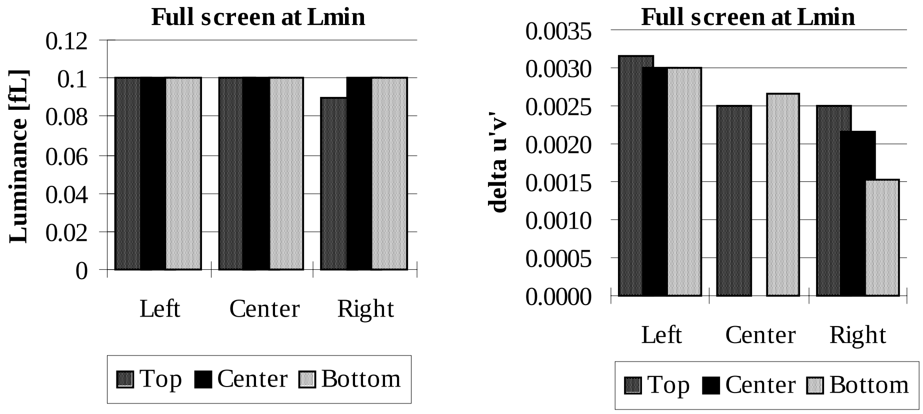


Fig.II.3-4. Spatial Uniformity of Luminance and Chromaticity at Lmin. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

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

Halation was 5.19% +/- 0.4% n 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:

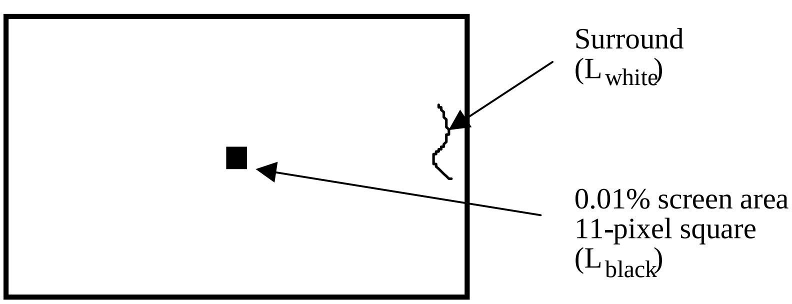


Figure II.4-1 *Test pattern for measuring halation.*

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 that 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 1920 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	1.015 fL ± 4%	0.974 fL to 1.056 fL
Lwhite	19.54 fL ± 4%	18.76 fL to 20.32 fL
Halation	5.19% ± 0.4%	4.79% to 5.63%

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 9200 K and lies within the boundaries accepted by IEC.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute Δu'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x,y) by the VESA/McCamy formula: CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517, where n = (x-0.3320)/(0.1858 - y). [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +
   - 0.244063.

- If CCT > 7000, then xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +
- 0.237040.
- In either case, yd = -3.000 xd^2 + 2.870 xd -0.275.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - (u',v') = (4x,9y)/(3 + 12y - 2x)
   - (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

6. Evaluate delta-u'v' between (u,v) and (ud,vd):
   - delta-u'v' = sqrt[(u' - u'd)^2 + (v' - v'd)^2].

7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise it passes the test.

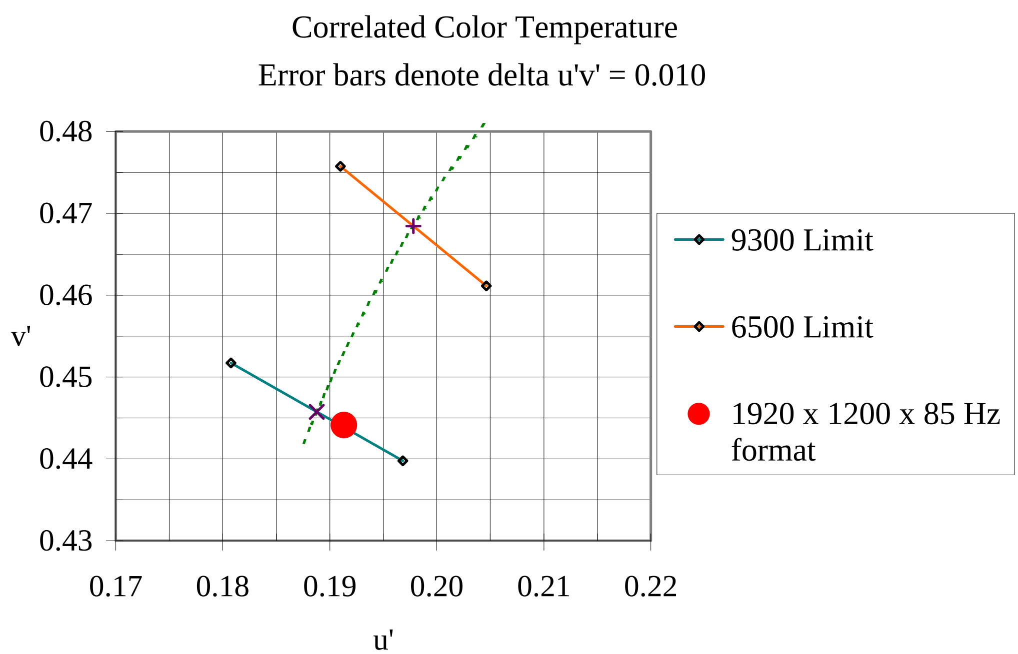


Figure II.5-1 *CCTs of measured white points are within the boundaries required by IEC.*

Table II.5-1 Δu’v’ Distances between measured white points and CIE coordinate values from D_{65} to D_{93}.

	1920 x 1200
CIE x	0.285
CIE y	0.294
CIE u'	0.191
CIE v'	0.444
CCT	9200 K
delta u'v'	0.003

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. Neither black level clipping nor white level saturation was 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. Figure II.6-2. Shows the perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) 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.

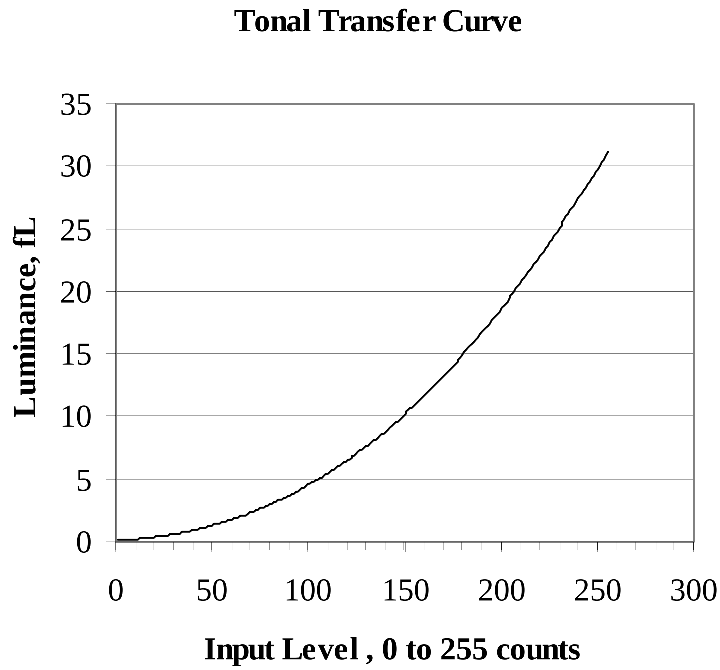


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

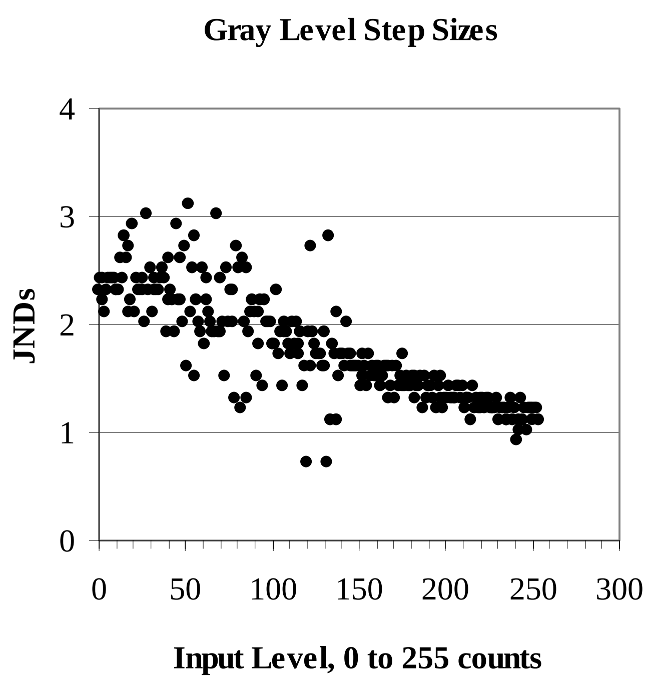


Figure II.6-2. Perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) as a function of input counts.

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

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.102	0	0.0	61	64	2.002	0.056	2.2
39	1	0.111	0.009	2.3	61	65	2.054	0.052	2.1
39	2	0.121	0.01	2.4	62	66	2.108	0.054	2.0
39	3	0.131	0.01	2.4	62	67	2.157	0.049	1.9
40	4	0.141	0.01	2.2	62	68	2.207	0.05	1.9
40	5	0.151	0.01	2.1	63	69	2.289	0.082	3.0
41	6	0.162	0.011	2.3	63	70	2.343	0.054	1.9
41	7	0.174	0.012	2.4	63	71	2.412	0.069	2.4
41	8	0.187	0.013	2.4	64	72	2.467	0.055	1.9
42	9	0.2	0.013	2.4	64	73	2.526	0.059	2.0
42	10	0.214	0.014	2.4	64	74	2.572	0.046	1.5
42	11	0.228	0.014	2.3	65	75	2.648	0.076	2.5
43	12	0.242	0.014	2.3	65	76	2.709	0.061	2.0
43	13	0.257	0.015	2.3	65	77	2.781	0.072	2.3
43	14	0.274	0.017	2.6	66	78	2.855	0.074	2.3
44	15	0.291	0.017	2.4	66	79	2.921	0.066	2.0
44	16	0.311	0.02	2.8	66	80	2.965	0.044	1.3
44	17	0.331	0.02	2.6	67	81	3.057	0.092	2.7
45	18	0.347	0.016	2.1	67	82	3.143	0.086	2.5
45	19	0.369	0.022	2.7	67	83	3.186	0.043	1.2
45	20	0.387	0.018	2.2	68	84	3.278	0.092	2.6
46	21	0.412	0.025	2.9	68	85	3.351	0.073	2.0
46	22	0.431	0.019	2.1	69	86	3.399	0.048	1.3
46	23	0.453	0.022	2.4	69	87	3.494	0.095	2.5
47	24	0.475	0.022	2.3	69	88	3.566	0.072	1.9
47	25	0.497	0.022	2.3	70	89	3.648	0.082	2.1
48	26	0.521	0.024	2.4	70	90	3.733	0.085	2.2
48	27	0.545	0.024	2.3	70	91	3.818	0.085	2.1
48	28	0.567	0.022	2.0	71	92	3.879	0.061	1.5
49	29	0.599	0.032	3.0	71	93	3.952	0.073	1.8
49	30	0.625	0.026	2.3	71	94	4.042	0.09	2.1
49	31	0.655	0.03	2.5	72	95	4.136	0.094	2.2
50	32	0.679	0.024	2.1	72	96	4.194	0.058	1.4
50	33	0.709	0.03	2.4	72	97	4.29	0.096	2.2
50	34	0.738	0.029	2.3	73	98	4.381	0.091	2.0
51	35	0.768	0.03	2.3	73	99	4.471	0.09	2.0
51	36	0.799	0.031	2.3	73	100	4.562	0.091	2.0
51	37	0.831	0.032	2.4	74	101	4.646	0.084	1.8
52	38	0.866	0.035	2.5	74	102	4.734	0.088	1.8
52	39	0.901	0.035	2.4	74	103	4.819	0.085	1.8
52	40	0.929	0.028	1.9	75	104	4.93	0.111	2.3
53	41	0.967	0.038	2.6	75	105	5.017	0.087	1.7
53	42	1.001	0.034	2.2	76	106	5.108	0.091	1.9
53	43	1.038	0.037	2.3	76	107	5.179	0.071	1.4
54	44	1.073	0.035	2.2	76	108	5.285	0.106	2.0
54	45	1.105	0.032	1.9	77	109	5.382	0.097	1.9
55	46	1.155	0.05	2.9	77	110	5.487	0.105	1.9
55	47	1.193	0.038	2.2	77	111	5.584	0.097	1.8
55	48	1.231	0.038	2.2	78	112	5.676	0.092	1.7
56	49	1.279	0.048	2.6	78	113	5.787	0.111	2.0
56	50	1.317	0.038	2.0	78	114	5.887	0.1	1.8
56	51	1.368	0.051	2.7	79	115	5.998	0.111	2.0
57	52	1.399	0.031	1.6	79	116	6.1	0.102	1.7
57	53	1.461	0.062	3.1	79	117	6.201	0.101	1.8
57	54	1.504	0.043	2.1	80	118	6.315	0.114	1.9
58	55	1.556	0.052	2.5	80	119	6.402	0.087	1.4
58	56	1.587	0.031	1.5	80	120	6.494	0.092	1.6
58	57	1.648	0.061	2.8	81	121	6.541	0.047	0.7
59	58	1.697	0.049	2.2	81	122	6.657	0.116	1.9
59	59	1.743	0.046	2.0	81	123	6.824	0.167	2.7
59	60	1.786	0.043	1.9	82	124	6.931	0.107	1.6
60	61	1.846	0.06	2.5	82	125	7.054	0.123	1.9
60	62	1.889	0.043	1.8	83	126	7.168	0.114	1.8
60	63	1.946	0.057	2.4	83	127	7.285	0.117	1.7

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

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
83	128	7.397	0.112	1.7	106	192	17.1	0.18	1.4
84	129	7.514	0.117	1.7	106	193	17.29	0.19	1.4
84	130	7.623	0.109	1.6	106	194	17.48	0.19	1.3
84	131	7.737	0.114	1.6	107	195	17.68	0.2	1.5
85	132	7.868	0.131	1.9	107	196	17.86	0.18	1.2
85	133	7.921	0.053	0.7	107	197	18.05	0.19	1.4
85	134	8.122	0.201	2.8	108	198	18.24	0.19	1.3
86	135	8.204	0.082	1.1	108	199	18.45	0.21	1.5
86	136	8.339	0.135	1.8	108	200	18.63	0.18	1.2
86	137	8.464	0.125	1.7	109	201	18.83	0.2	1.3
87	138	8.628	0.164	2.1	109	202	19.02	0.19	1.3
87	139	8.706	0.078	1.1	109	203	19.23	0.21	1.4
87	140	8.826	0.12	1.5	110	204	19.42	0.19	1.3
88	141	8.963	0.137	1.7	110	205	19.62	0.2	1.3
88	142	9.092	0.129	1.7	111	206	19.82	0.2	1.3
88	143	9.226	0.134	1.6	111	207	20.03	0.21	1.3
89	144	9.386	0.16	2.0	111	208	20.25	0.22	1.4
89	145	9.526	0.14	1.7	112	209	20.47	0.22	1.4
90	146	9.662	0.136	1.6	112	210	20.68	0.21	1.3
90	147	9.804	0.142	1.7	112	211	20.9	0.22	1.4
90	148	9.942	0.138	1.6	113	212	21.09	0.19	1.2
91	149	10.08	0.138	1.6	113	213	21.31	0.22	1.3
91	150	10.22	0.14	1.6	113	214	21.52	0.21	1.3
91	151	10.36	0.14	1.6	114	215	21.74	0.22	1.3
92	152	10.49	0.13	1.4	114	216	21.93	0.19	1.1
92	153	10.64	0.15	1.7	114	217	22.16	0.23	1.4
92	154	10.78	0.14	1.5	115	218	22.37	0.21	1.2
93	155	10.93	0.15	1.6	115	219	22.6	0.23	1.3
93	156	11.06	0.13	1.4	115	220	22.8	0.2	1.2
93	157	11.22	0.16	1.7	116	221	23.03	0.23	1.3
94	158	11.37	0.15	1.5	116	222	23.25	0.22	1.2
94	159	11.52	0.15	1.6	116	223	23.48	0.23	1.3
94	160	11.67	0.15	1.5	117	224	23.7	0.22	1.2
95	161	11.82	0.15	1.5	117	225	23.93	0.23	1.3
95	162	11.98	0.16	1.6	118	226	24.16	0.23	1.3
95	163	12.14	0.16	1.6	118	227	24.39	0.23	1.2
96	164	12.28	0.14	1.4	118	228	24.61	0.22	1.2
96	165	12.44	0.16	1.5	119	229	24.84	0.23	1.2
97	166	12.6	0.16	1.6	119	230	25.07	0.23	1.2
97	167	12.77	0.17	1.6	119	231	25.31	0.24	1.3
97	168	12.91	0.14	1.3	120	232	25.53	0.22	1.1
98	169	13.08	0.17	1.6	120	233	25.76	0.23	1.2
98	170	13.24	0.16	1.4	120	234	25.99	0.23	1.2
98	171	13.41	0.17	1.6	121	235	26.23	0.24	1.2
99	172	13.56	0.15	1.3	121	236	26.45	0.22	1.1
99	173	13.74	0.18	1.6	121	237	26.68	0.23	1.1
99	174	13.9	0.16	1.4	122	238	26.92	0.24	1.2
100	175	14.07	0.17	1.5	122	239	27.17	0.25	1.3
100	176	14.26	0.19	1.7	122	240	27.41	0.24	1.1
100	177	14.43	0.17	1.4	123	241	27.66	0.25	1.2
101	178	14.6	0.17	1.4	123	242	27.84	0.18	0.9
101	179	14.78	0.18	1.5	123	243	28.06	0.22	1.1
101	180	14.94	0.16	1.4	124	244	28.29	0.23	1.0
102	181	15.12	0.18	1.4	124	245	28.55	0.26	1.3
102	182	15.3	0.18	1.5	125	246	28.79	0.24	1.1
102	183	15.48	0.18	1.5	125	247	29.05	0.26	1.2
103	184	15.65	0.17	1.3	125	248	29.27	0.22	1.0
103	185	15.83	0.18	1.4	126	249	29.54	0.27	1.2
104	186	16.01	0.18	1.4	126	250	29.8	0.26	1.2
104	187	16.2	0.19	1.5	126	251	30.06	0.26	1.2
104	188	16.36	0.16	1.2	127	252	30.31	0.25	1.1
105	189	16.55	0.19	1.5	127	253	30.59	0.28	1.2
105	190	16.73	0.18	1.3	127	254	30.85	0.26	1.2
105	191	16.92	0.19	1.4	128	255	31.12	0.27	1.1

II.8. Luminance Step Response

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

No video artifacts were observed.

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.

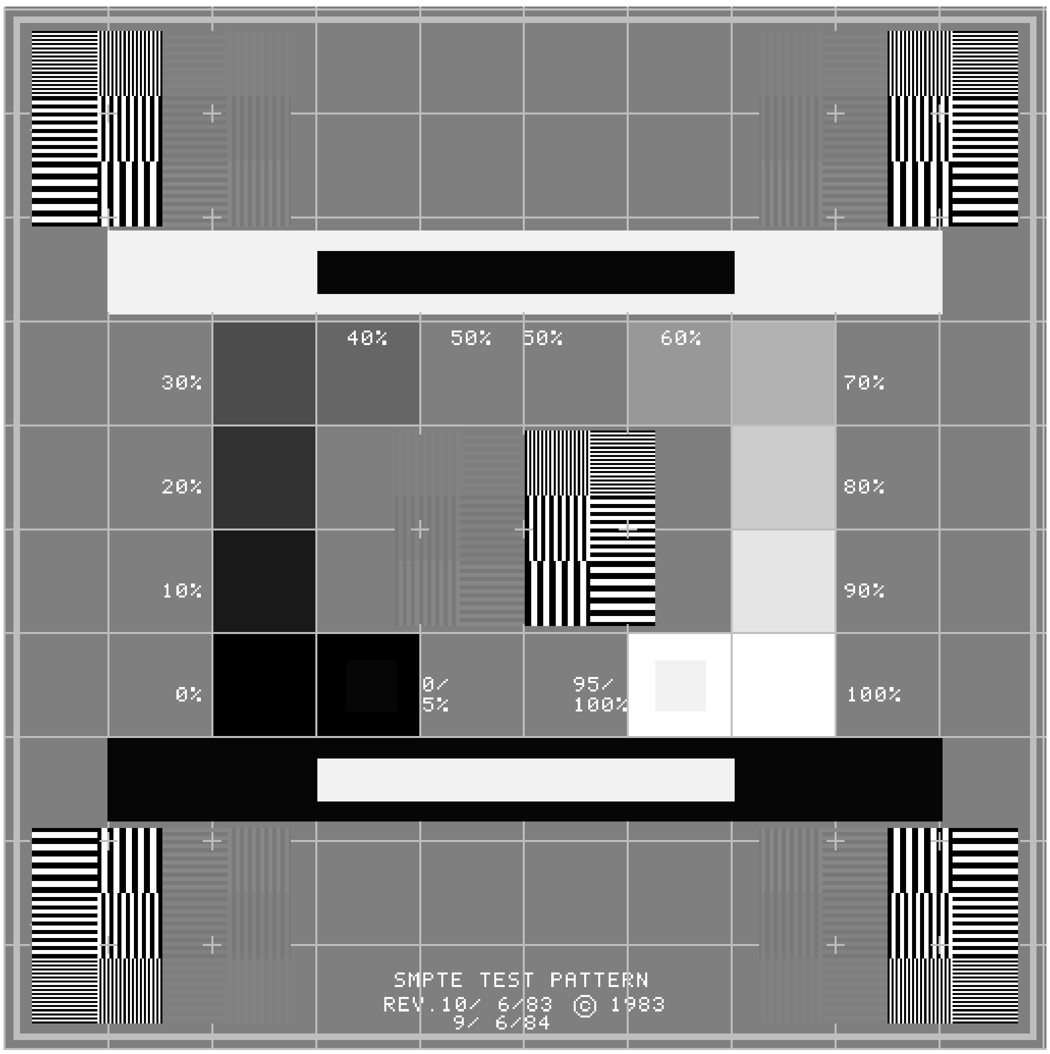


Figure II.8-1. SMPTE Test Pattern.

Data: Define passes 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." None of these artifacts was observed in the Sony GDM-FW900 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): 1920 x 1200 x 85 Hz, and 1024 x 1024 x 112 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 85 Hz refresh rate which exceeds the 72 Hz minimum required by IEC for monoscopic mode and 120 Hz for stereoscopic mode, the minimum required by IEC. All perimeter lines were confirmed to be visible with no irregular jaggies on diagonals.

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
1920 x 1200 x 85 Hz	1024 x 1024 x 112 Hz

II.10. Pixel Aspect Ratio

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

Pixel aspect ratio is within 4.0%.

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)	**400 x 400 target**	**1920 x 1200 full image**
H x V Image Size (inches)	3.798 x 3.955	18.870 x 11.818
H x V Average Pixel Spacing (mils)	9.50 x 9.89 mils	9.83 x 9.85 mils
H x V Pixel Aspect Ratio	H = V - 4.0%	H = V - 0.20%

II.11. Screen Size (Viewable Active Image)

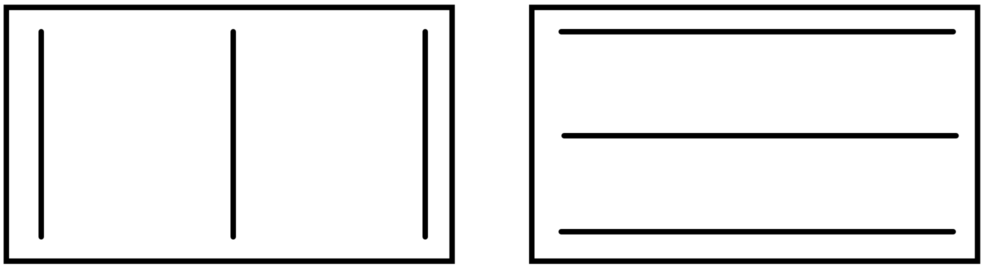
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size for 1920 x 1200 format was 22.265 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)	1920 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	18.870 x 11.818 22.265

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 = 48% in Zone A of diameter 7.6 inches, and 41% for Zone A diameter of 10.66 inches (40% of image area). Cm exceeded 38% in Zone B. Moiré cancellation circuitry was turned OFF for this measurement.

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

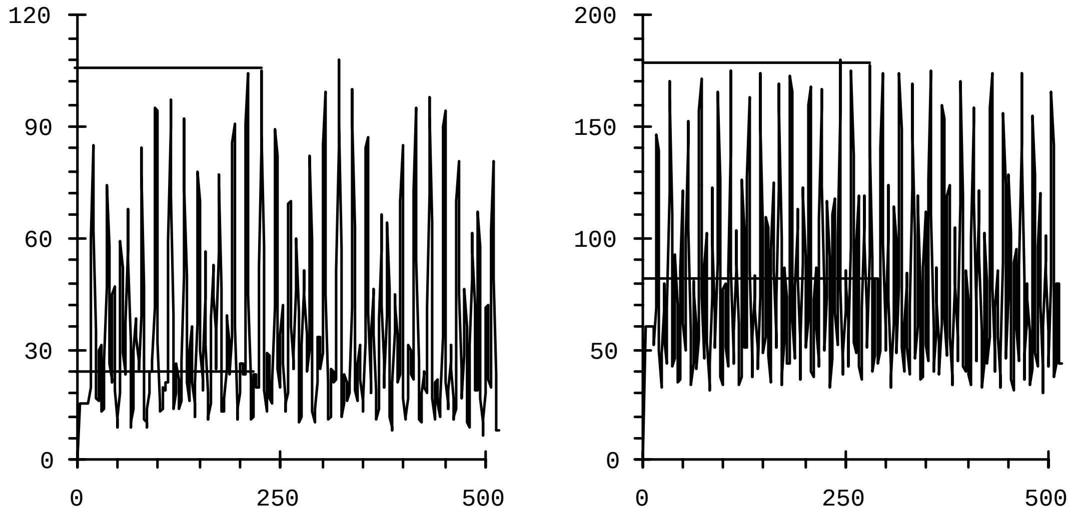
Procedure: The maximum video modulation frequency for each format (1024 x 1024, 1920 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen 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 subtended 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 56% in Zone A, and is equal to or greater than 52% in Zone B.

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

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadow mask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

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

Moiré Cancellation OFF

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches 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	39%	56%			46%	63%			54%	51%
			57%	52%	53%	58%	63%	50%		
Major	71%	52%	69%	51%	67%	50%	67%	49%	68%	47%
			64%	53%	48%	56%	61%	52%		
Bottom	57%	58%			38%	60%			48%	55%

Zone A = 10.66-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	39%	56%			46%	63%			54%	51%
			54%	53%	48%	62%	61%	50%		
Major	71%	52%	69%	51%	67%	50%	60%	51%	54%	51%
			62%	54%	41%	59%	58%	52%		
Bottom	57%	58%			38%	60%			48%	55%

II.13. Pixel Density

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

Pixel density was 102 ppi as tested for the 1920 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
H x V Addressability, Pixels	1920 x 1200
H x V Image Size, Inches H x V Pixel Density, ppi	18.870 x 11.818 102 x 102 ppi

II.14. Moiré

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

Phosphor-to-pixel spacing ratio is 0.92 at screen center and 1.08 at the edge of the screen for the 1920 x 1200 format. Moiré compensation circuitry was not evaluated.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

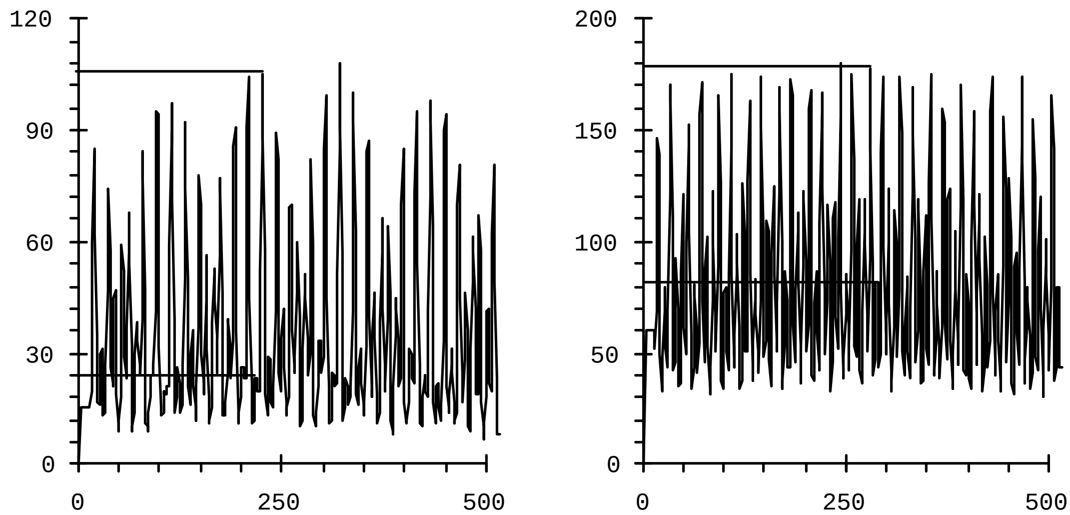
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1920 x 1200
Phosphor Pitch, horizontal	0.23 mm center to 0.27 mm edge
Pixel Spacing, horizontal	9.83 mils (0.2497 mm)
Phosphor-to-Pixel-Spacing	0.92 center to 1.08 edge

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of about 0.6 pixels or less is required for adequate visibility of image information without interference from the phosphor structure.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.14-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

In Figure II.14-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Even though the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moiré on either monitor when grayscale imagery was displayed.

II.15. Straightness

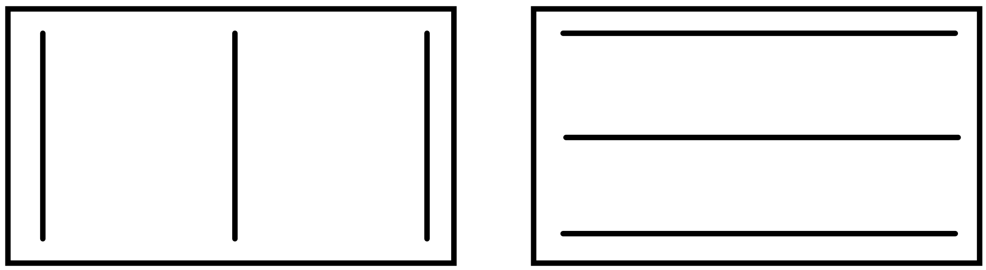
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.35% 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.

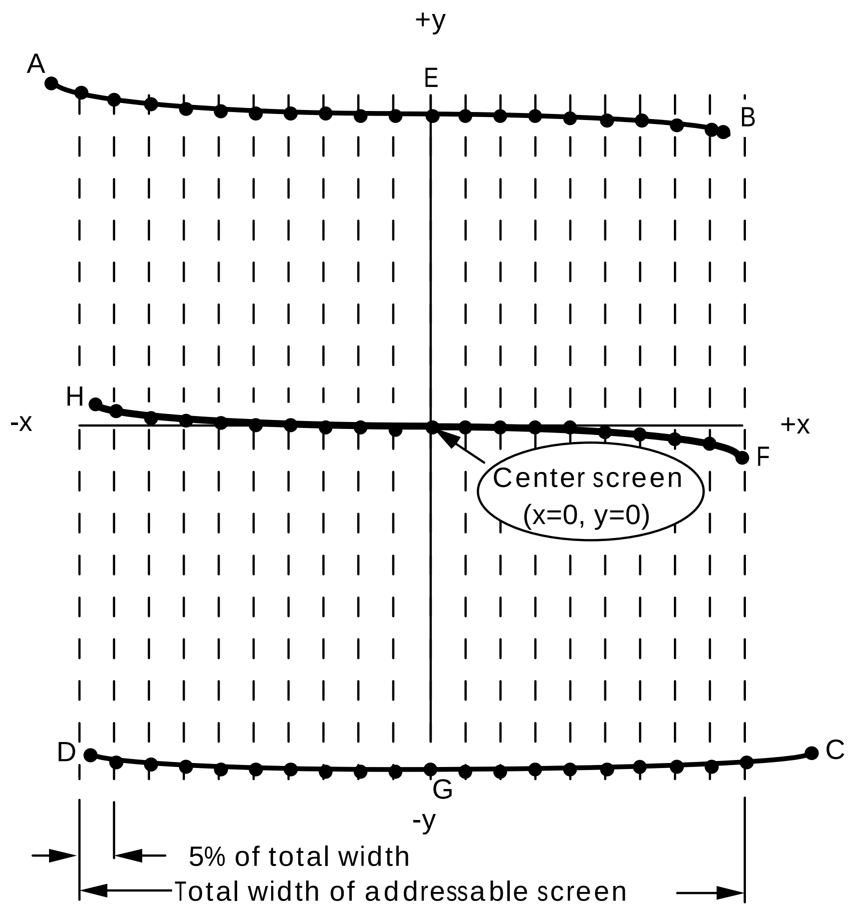


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

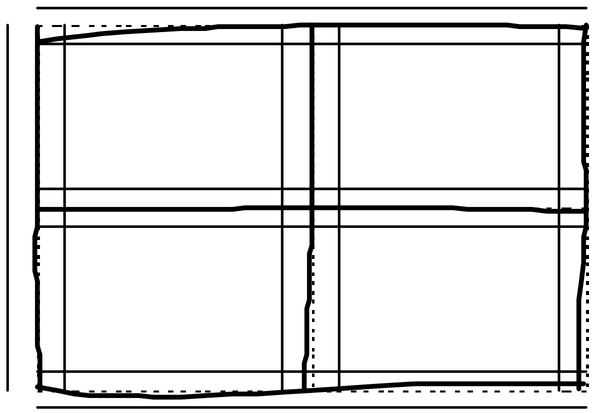
Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video 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
-9422	5876	-9415	-5912	-9427	-7	1	5926	-9422	5876	9459	5920
-8100	5892	-8100	-5929	-8100	-5	-3	5400	-9425	5400	9448	5400
-7200	5899	-7200	-5936	-7200	-4	-1	4800	-9426	4800	9449	4800
-6300	5907	-6300	-5940	-6300	-3	0	4200	-9427	4200	9451	4200
-5400	5913	-5400	-5941	-5400	-3	0	3600	-9427	3600	9451	3600
-4500	5917	-4500	-5941	-4500	-3	1	3000	-9427	3000	9451	3000
-3600	5919	-3600	-5938	-3600	-2	1	2400	-9427	2400	9452	2400
-2700	5923	-2700	-5934	-2700	-2	1	1800	-9427	1800	9454	1800
-1800	5925	-1800	-5929	-1800	-1	1	1200	-9427	1200	9456	1200
-900	5926	-900	-5924	-900	0	0	600	-9427	600	9457	600
0	5927	0	-5918	0	0	0	0	-9428	0	9457	0
900	5928	900	-5913	900	1	-2	-600	-9429	-600	9455	-600
1800	5930	1800	-5908	1800	1	-3	-1200	-9430	-1200	9452	-1200
2700	5931	2700	-5903	2700	1	-5	-1800	-9430	-1800	9446	-1800
3600	5931	3600	-5900	3600	0	-7	-2400	-9428	-2400	9440	-2400
4500	5931	4500	-5898	4500	-1	-10	-3000	-9426	-3000	9436	-3000
5400	5931	5400	-5897	5400	-3	-13	-3600	-9425	-3600	9434	-3600
6300	5929	6300	-5898	6300	-5	-15	-4200	-9422	-4200	9434	-4200
7200	5926	7200	-5900	7200	-7	-17	-4800	-9419	-4800	9433	-4800
8100	5922	8100	-5901	8100	-9	-20	-5400	-9416	-5400	9434	-5400
9459	5920	9432	-5901	9456	-11	-24	-5918	-9415	-5912	9432	-5901



1920 x 1200

Figure II.15-3 Waviness of Sony GDM-FW900 color monitor in 1920 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 1920 x 1200 format was set to 85 Hz. Vertical refresh rate for the 1024 x 1024 stereo format was 112 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	1920 x 1200	1024 x 1024 interlace
Vertical Scan Horizontal Scan	85.0 Hz 107.100 kHz	112 Hz 120.568 kHz

II.17. Extinction Ratio

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

Stereo extinction ratio using StereoGraphics LC shutter glasses averaged 18.7 to 1 (18.7 left, 18.7 right) at screen center, and 12.3 to 1 along the bottom of the screen when tested in 1024 x 1024 x 112 Hz (56 Hz per eye) mode. Luminance of white varied by up to 8.1% across the screen. Chromaticity variations of white were less than 0.006 delta u'v' units.

Stereo extinction ratio using the StereoGraphics ZScreen and passive polarized glasses averaged 11:1 (11.7 left, 10.3 right) at screen center. Luminance of white varied by up to 8.8 % across the screen. Chromaticity variations of white were less than 0.007 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 commercially available StereoGraphics CrystalEyes 3 Stereoscopic Visualization Eyewear and ENT Emitter. Stereoscopic-mode measurements were also made using a commercially-available StereoGraphics ZScreen with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and at least 30 fL Lmax for monochrome monitors and at least 6 fL Lmax for color monitors (no ambient) at the analyst's eye position, e.g., through the ZScreen and passive glasses. Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

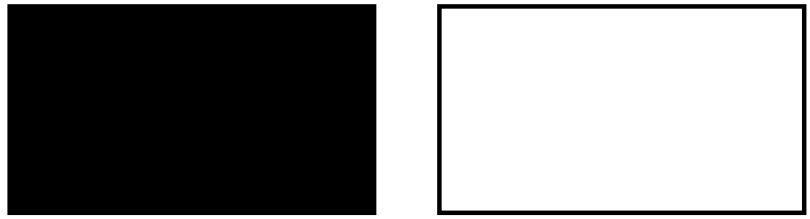
Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

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

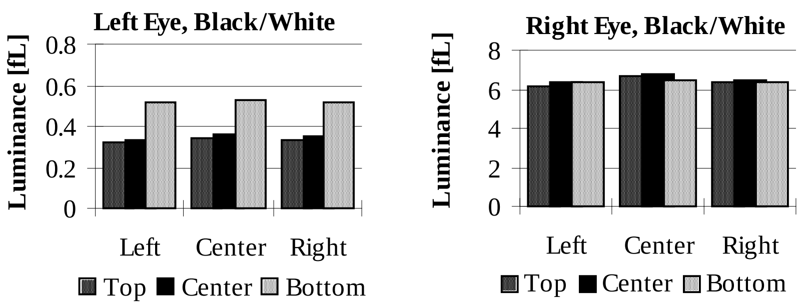
Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

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.



StereoGraphics CrystalEyes Active Glasses



StereoGraphics ZScreen LC Shutter with Passive Glasses

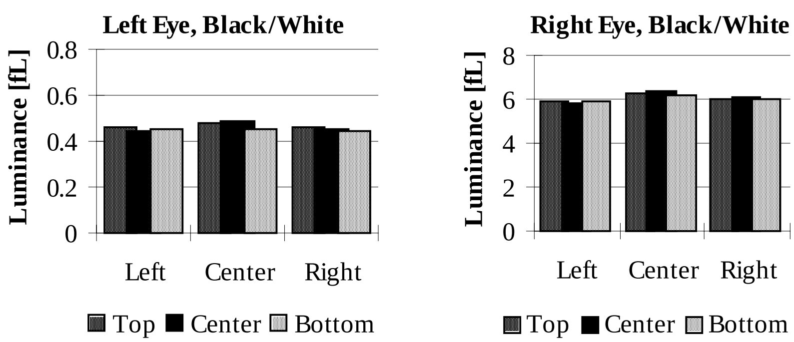
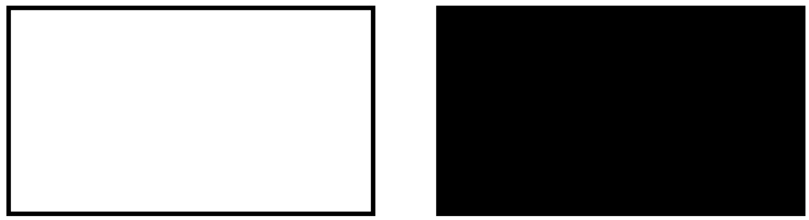
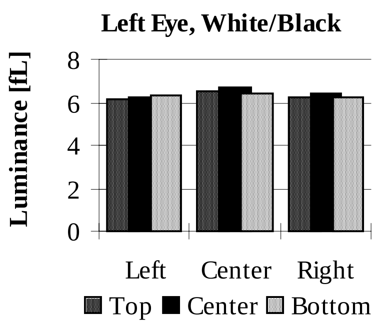
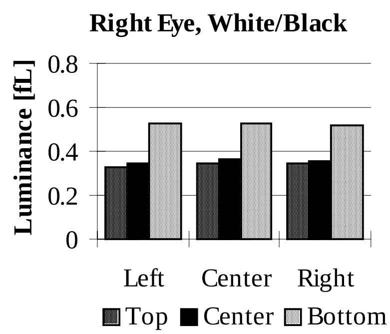


Fig.II.17-1.1 Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

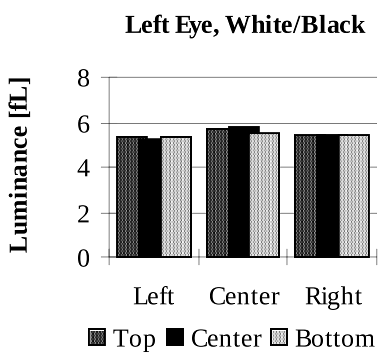


StereoGraphics CrystalEyes Active Glasses





StereoGraphics ZScreen LC Shutter with Passive Glasses



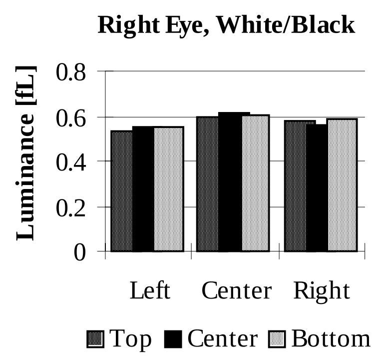
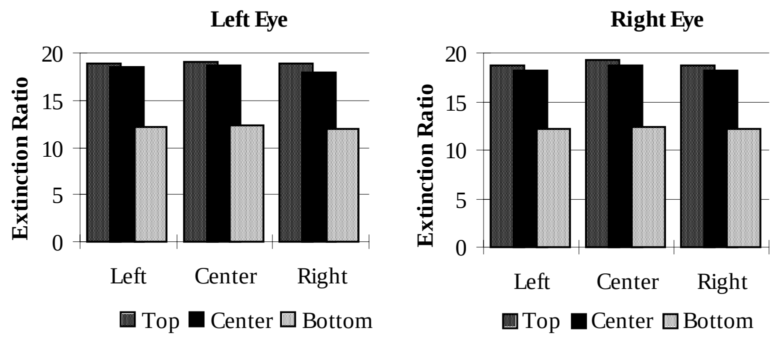


Fig.II.17-1.2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

StereoGraphics CrystalEyes Active Glasses



StereoGraphics ZScreen LC Shutter with Passive Glasses

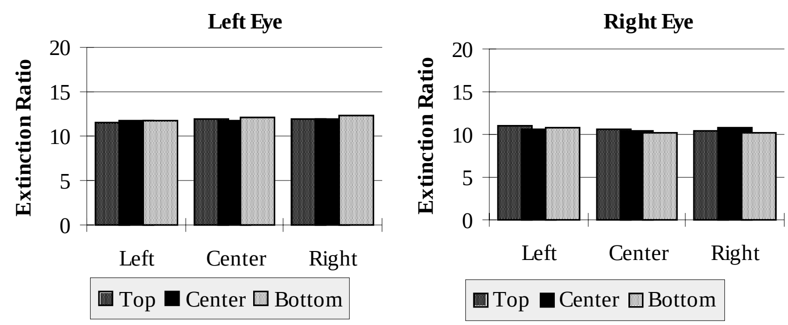
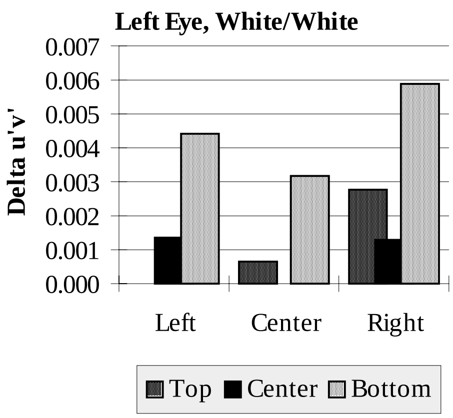
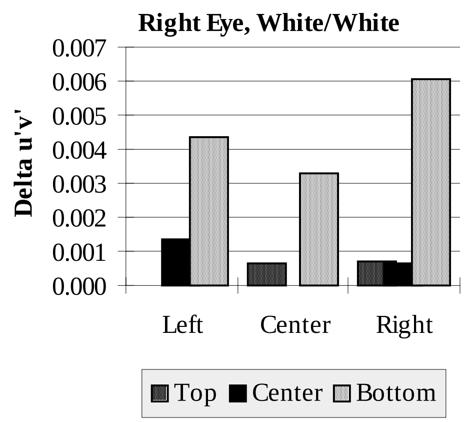


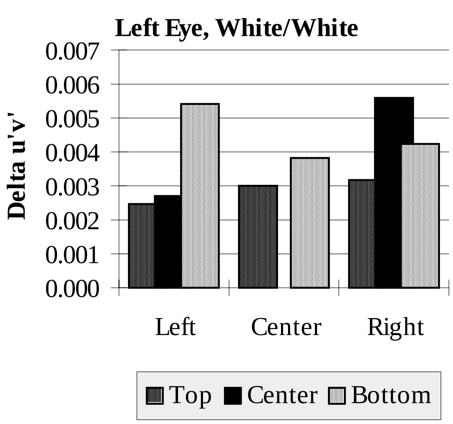
Fig.II.17-1.3. Spatial Uniformity of extinction ratio in stereo mode.

StereoGraphics CrystalEyes Active Glasses





StereoGraphics ZScreen LC Shutter with Passive Glasses



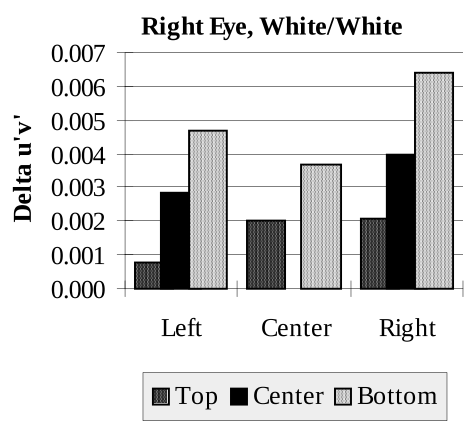


Fig.II.17-1.4 Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

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

The maximum nonlinearity of the scan was 1.56% 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.

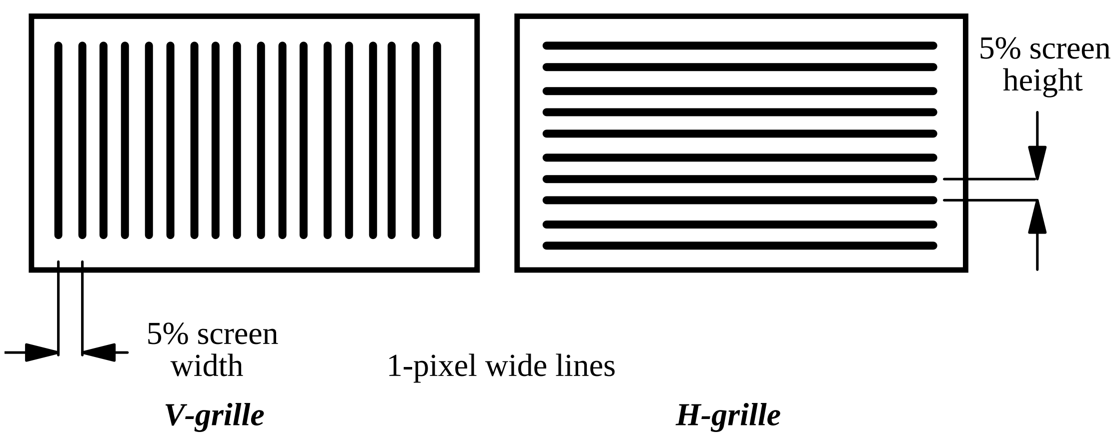


Figure II.18-1. *Grille patterns for measuring linearity*

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.

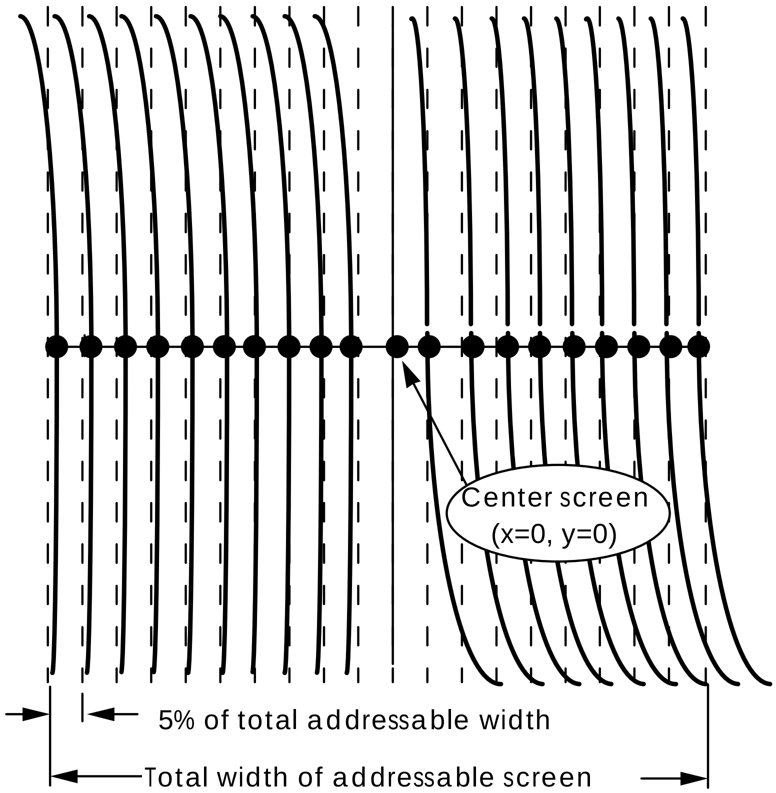


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

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 impact the absolute position of each pixel on the screen and are, 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 Figures II.18-3 and II.18-4.

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

Format	Left Side	Right Side	Top	Bottom
1920 x 1200	-1.43%	1.56%	-0.39%	0.33%

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
-9338	9362	5829	-5817
-8383	8409	5224	-5234
-7421	7444	4638	-4654
-6461	6480	4059	-4074
-5509	5522	3480	-3495
-4567	4574	2904	-2916
-3635	3640	2326	-2335
-2717	2720	1749	-1754
-1808	1811	1168	-1171
-906	908	585	-586
0	0	0	0

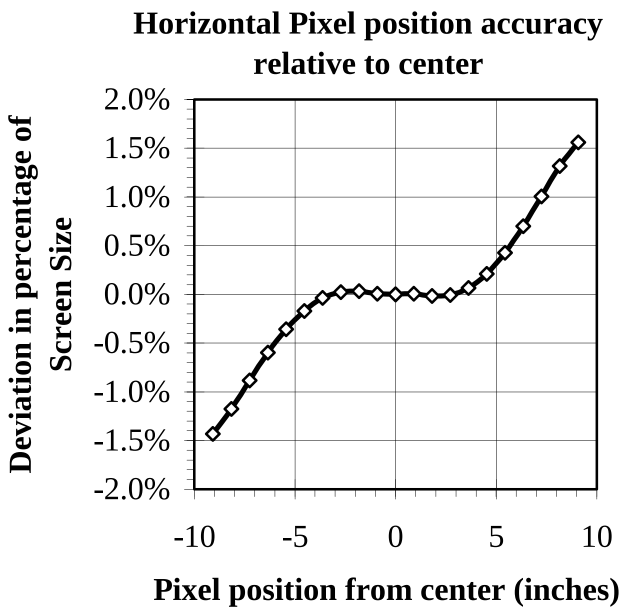


Fig. II.18-3 Horizontal linearity characteristic.

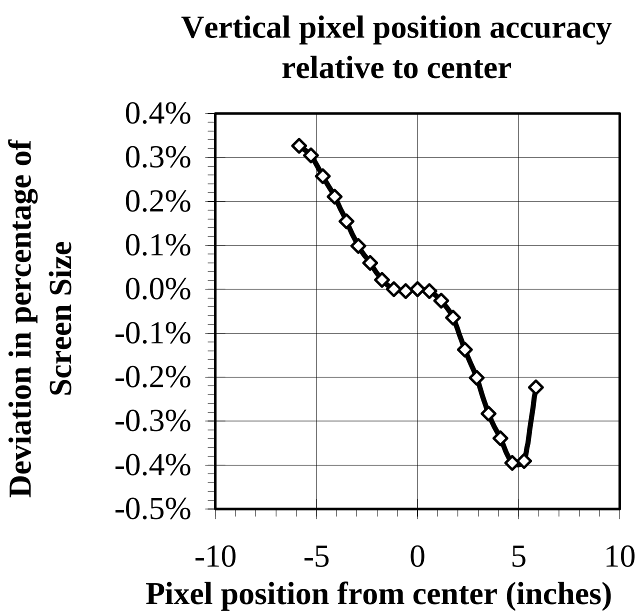


Fig. II.18-4 Vertical linearity characteristic

II.19. Jitter/Swim/Drift

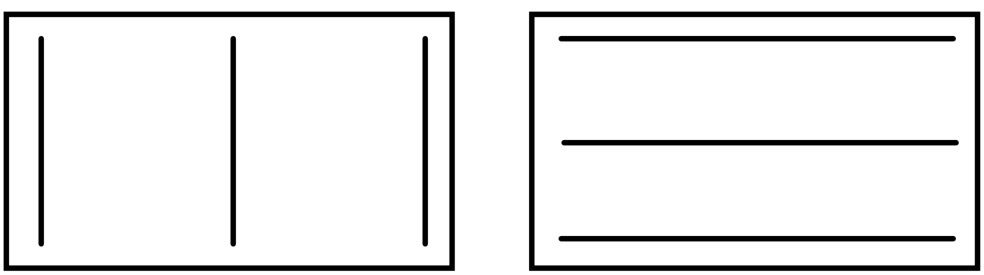
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 3.96 mils and 6.43 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 depends 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.

Moiré Compensation OFF

1920 x 1200 x 85hz

			H-lines	V-lines	
Center	Max Motions				
		Jitter	4.08	4.33	
		Swim	5.22	5.94	
		Drift	6.87	7.02	
Black Tape	Max Motions				
		Jitter	0.326	0.367	
		Swim	0.395	0.459	
		Drift	0.529	0.612	
Less Tape Motion					Maximums
		Jitter	3.75	3.96	3.96
		Swim	4.83	5.48	5.48
		Drift	6.34	6.41	6.41

			H-lines	V-lines	
10D corner	Max Motions				
		Jitter	4.15	4.39	
		Swim	5.46	6.14	
		Drift	6.99	7.11	
Black Tape	Max Motions				
		Jitter	0.467	0.482	
		Swim	0.531	0.572	
		Drift	0.625	0.676	
Less Tape Motion					Maximums
		Jitter	3.68	3.91	3.91
		Swim	4.93	5.57	5.57
		Drift	6.37	6.43	6.43

II.20. Warm-up Period

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

A 49 minute warm-up was necessary for luminance stability of Lmin = 0.101 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 1920 x 1200 format in graphical form. The luminance remains very stable after 49 minutes.

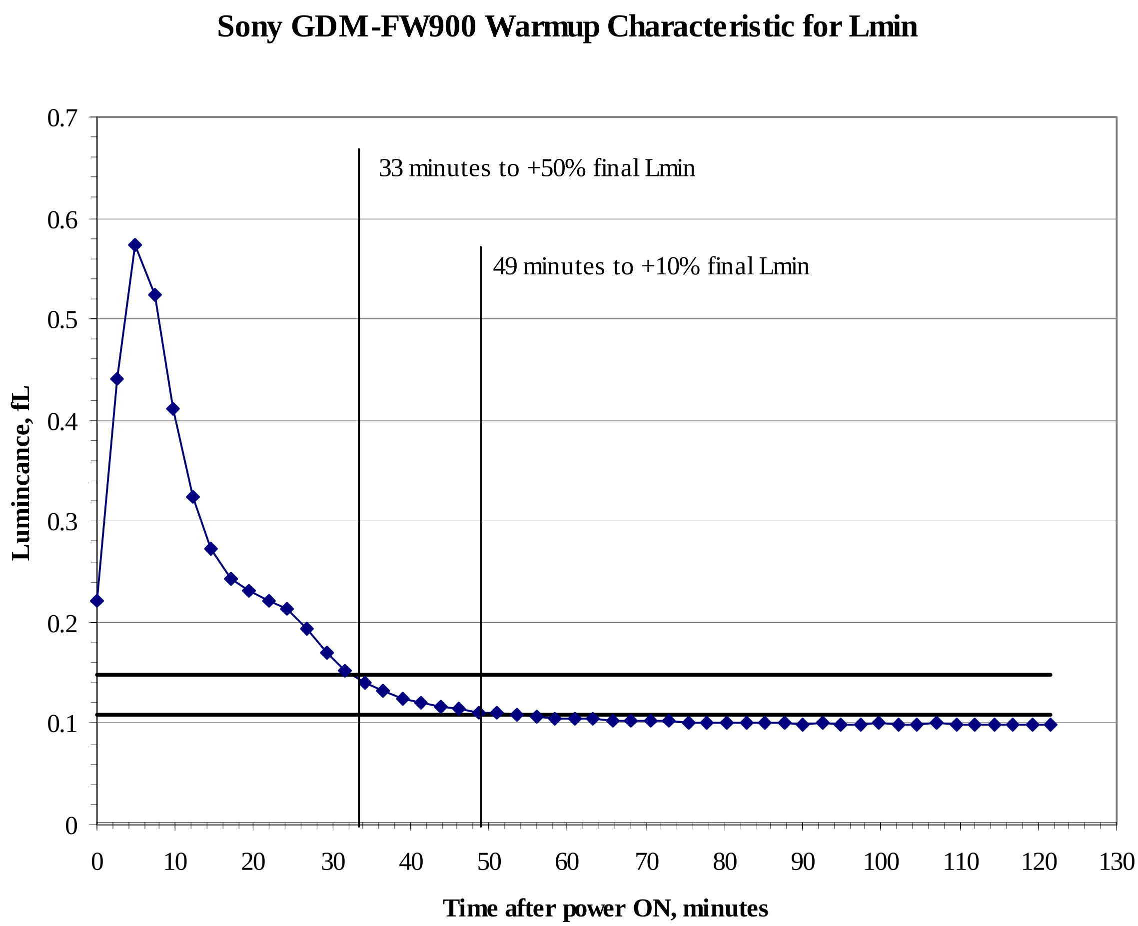


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).

II. 21 Briggs Scores

Reference: SofTrak User's Guidelines and Reference Manual version 3.0, NIDL, Sept. 1994, page 3.

Briggs Scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 10, 40, 57 and 62, respectively.

The Briggs series of test targets illustrated in Figures II.21-1 were developed to visually evaluate the image quality of grayscale monitors. Three observers selected the maximum scores for each target set shown in Figure II.21-2 displayed on the Sony FW900 color CRT monitor driven using a Sun Microsystems Ultra 60 workstation with dual 360 MHz processors and a Creator3D graphics card. Magnifying devices were used when deemed by the observer to be advantageous in achieving higher scores.

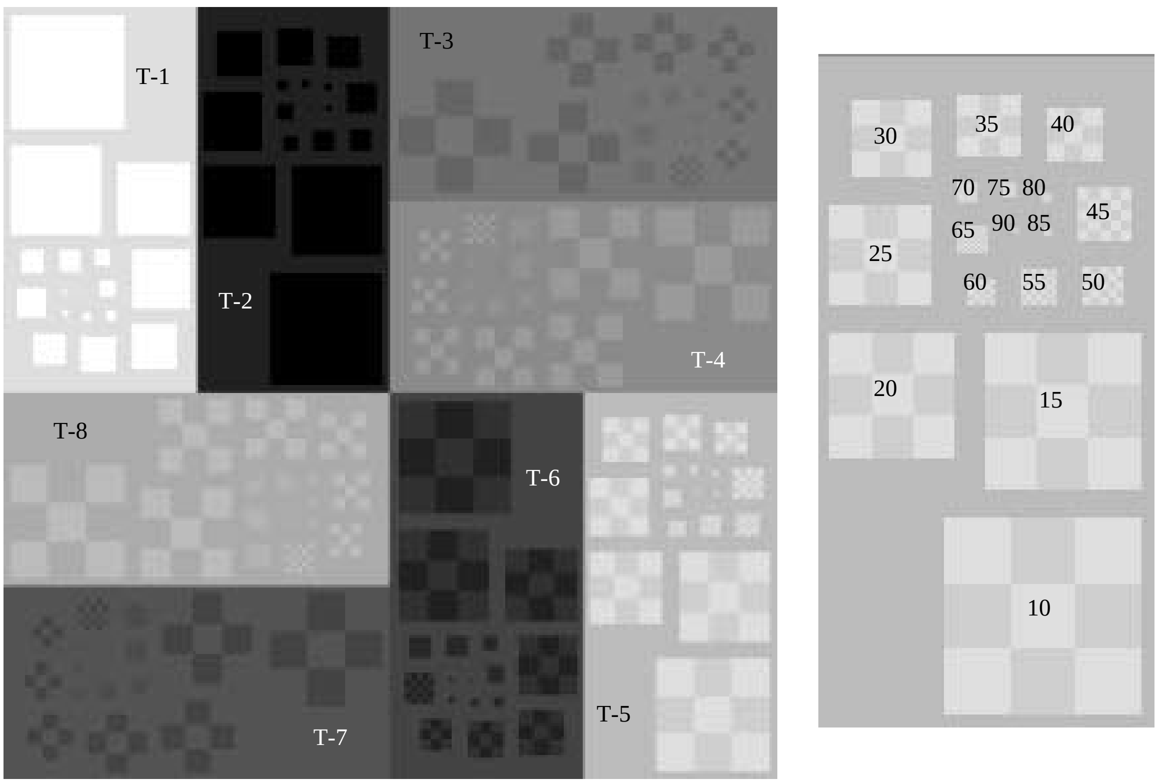


Figure II.21.1. Briggs BPT#4 Test Patterns comprised of 8 targets labeled T-1 through T-8. A series of 17 checkerboards are contained within each of the 8 targets. Each checkerboard is assigned a score value ranging from 10 to 90. Higher scores are assigned to smaller checkerboards.

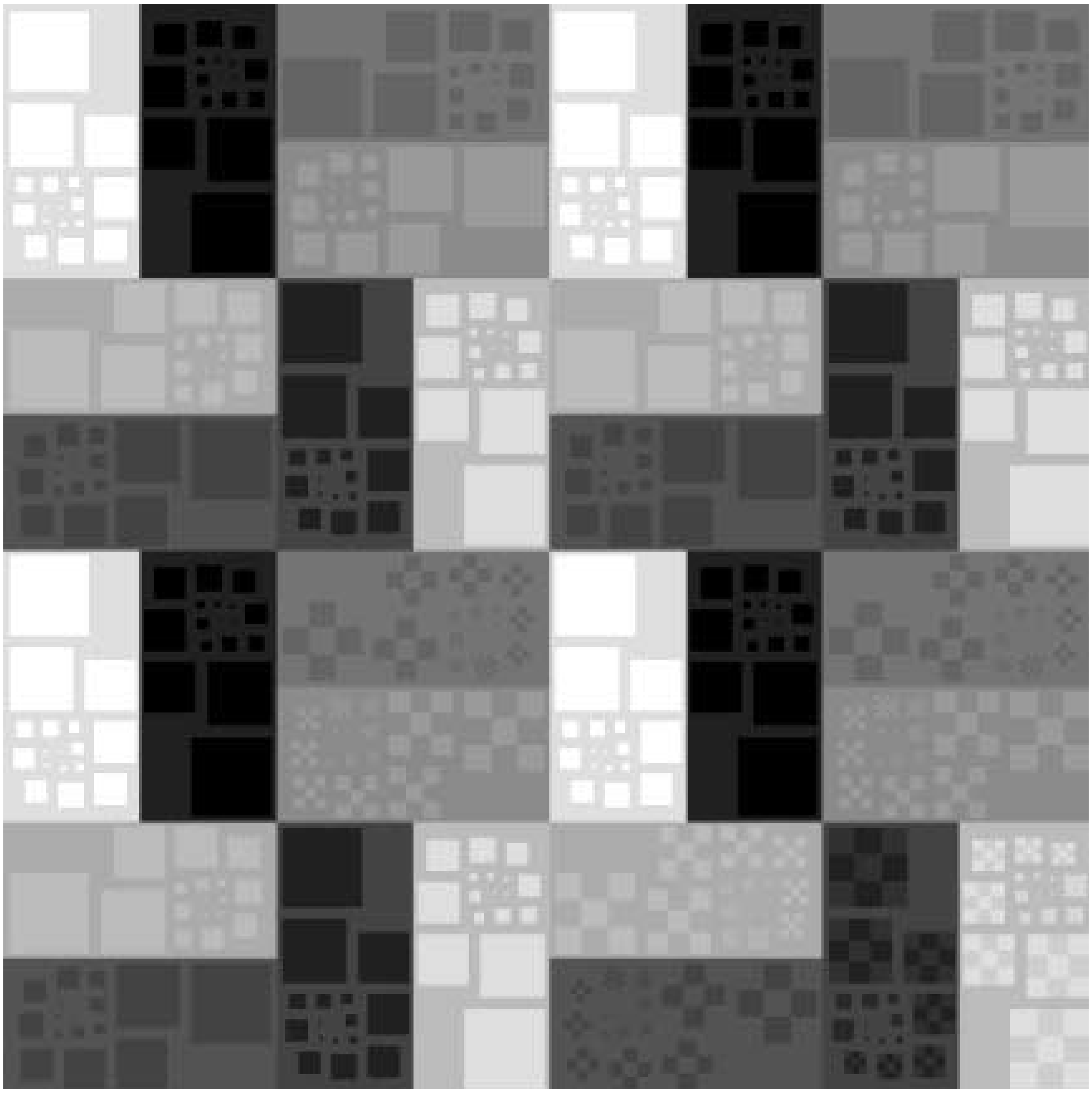


Figure II.21.2. 1024 x 1024 mosaic comprised of four 512 x 512 Briggs BPT#4 Test Patterns. The upper left quadrant contains the set of 8 Briggs targets with command contrast of delta 1. The upper right quadrant contains command contrast of delta 3. Delta 7 targets are in the lower left quadrant and delta 15 targets are in the lower right.

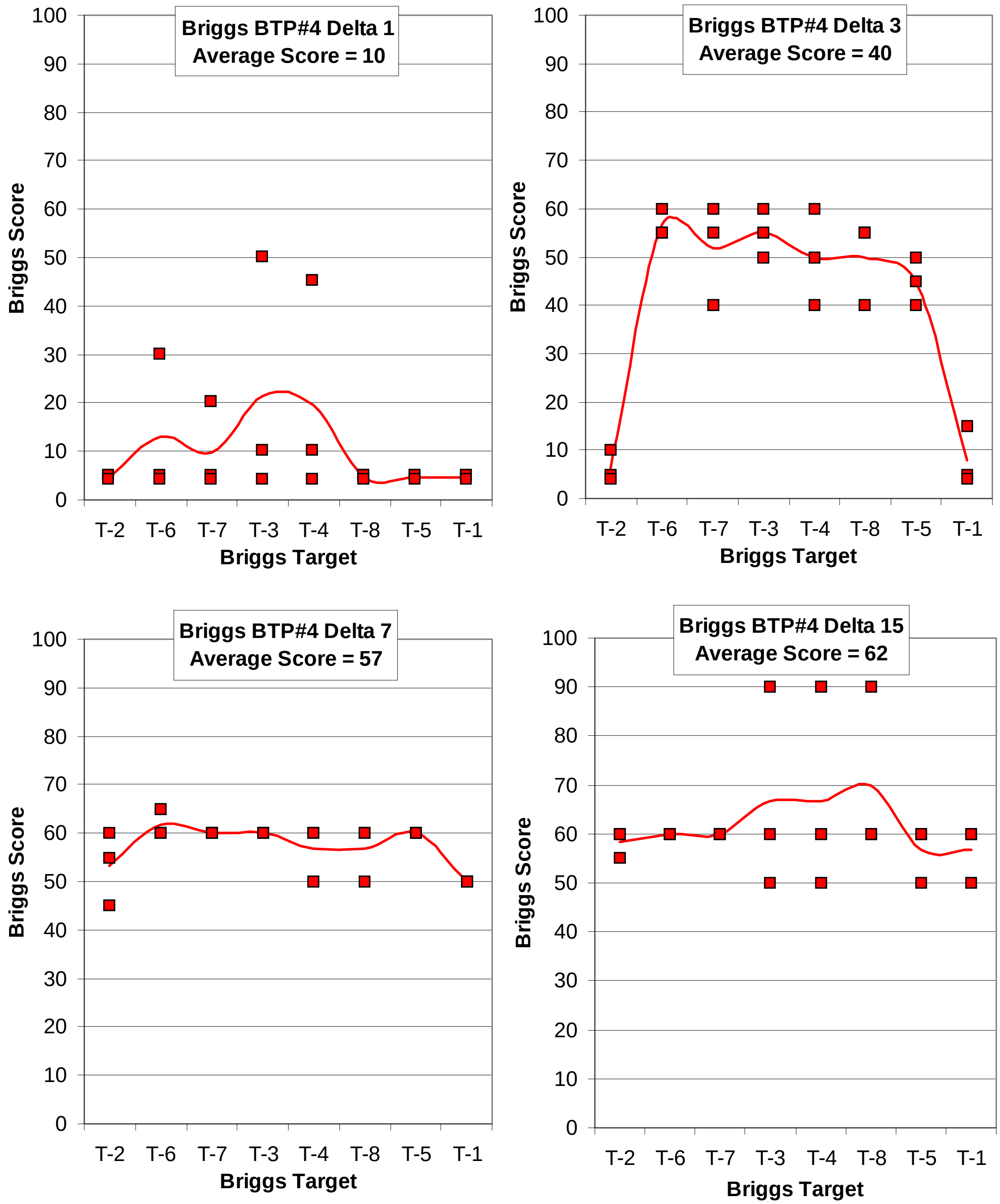


Figure II.21.3. Briggs Scores by three observers for Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratios on BPT#4 Test Pattern for the Sony GDM-FW900 flat face CRT monitor.

II. 22 Color Gamut

Reference: VESA FPDM Version 2.0, Section 302-4A, p. 47.

The area bounded by CIE 1976 u'v' color coordinates of R, G, and B primaries of the Sony GDM-FW900 CRT color monitor is 27% of the total area bounded by the spectrum locus from 380 nm to 700.

The area bounded by CIE 1976 u'v' color coordinates of R, G, and B primaries is measured and compared to the total area accessible to the display. The total area accessible to the display is defined to be equal to a value of 0.1952 and is equal to the area inside the spectrum locus from 380 nm to 700 nm evaluated at 1 nm intervals. After multiplying by 100%, the gamut area of the display is computed as:

$$\text{Gamut Area} = 256.1\,[(u'_r - u'_b)(v'_g - v'_b)-(u'_g - u'_b)(v'_r - v'_b)]$$

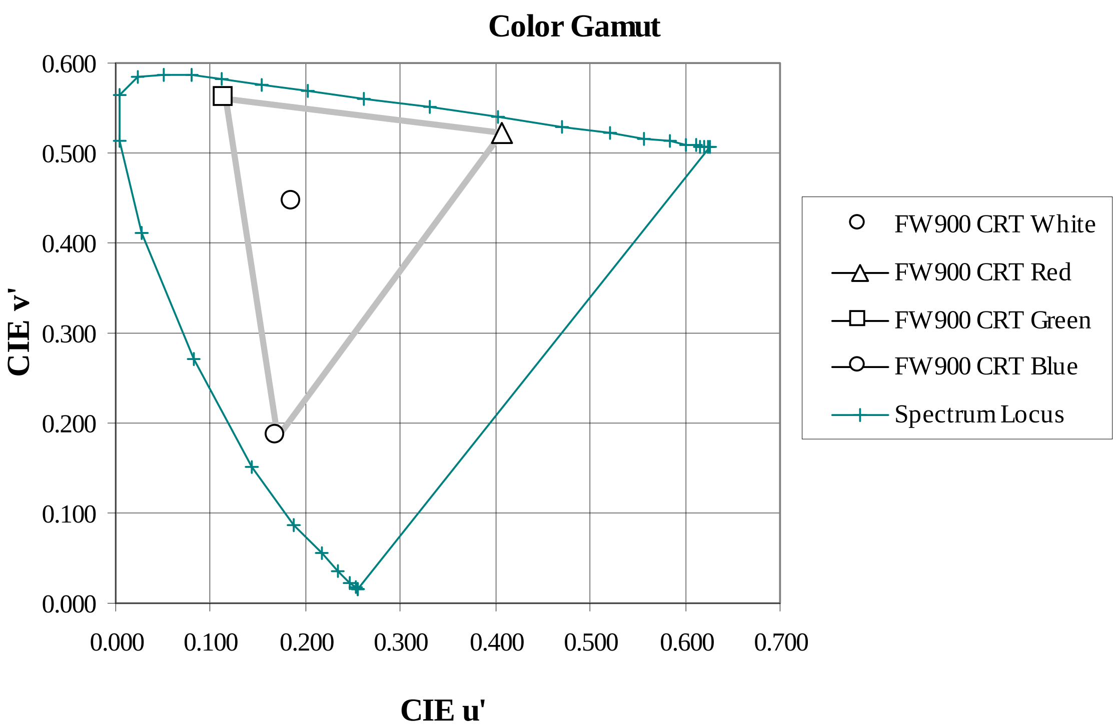


Figure II.22.1. CIE chromaticity coordinates and color gamut of the Sony GDM-FW900 color CRT monitor.

Table II.22.1. CIE chromaticity coordinates and color gamut area of the Sony GDM-FW900 CRT color monitor.

	x	y	u'	v'	fL	CCT
White	0.31	0.348	0.189	0.478	31.4	9652
Red	0.602	0.344	0.406	0.523	7.77	
Green	0.28	0.599	0.116	0.560	22.3	
Blue	0.152	0.073	0.170	0.184	3.87	
Gamut Area	**27% of total area from 380 nm to 700.**					

II. 23 Color Tracking

Reference:

The whitepoint varied among gray levels less than 0.013 delta u'v' units between Lmin (0.12 fL, input level 0) and Lmax (32.0 fL, level 255). This is a measure of color tracking.

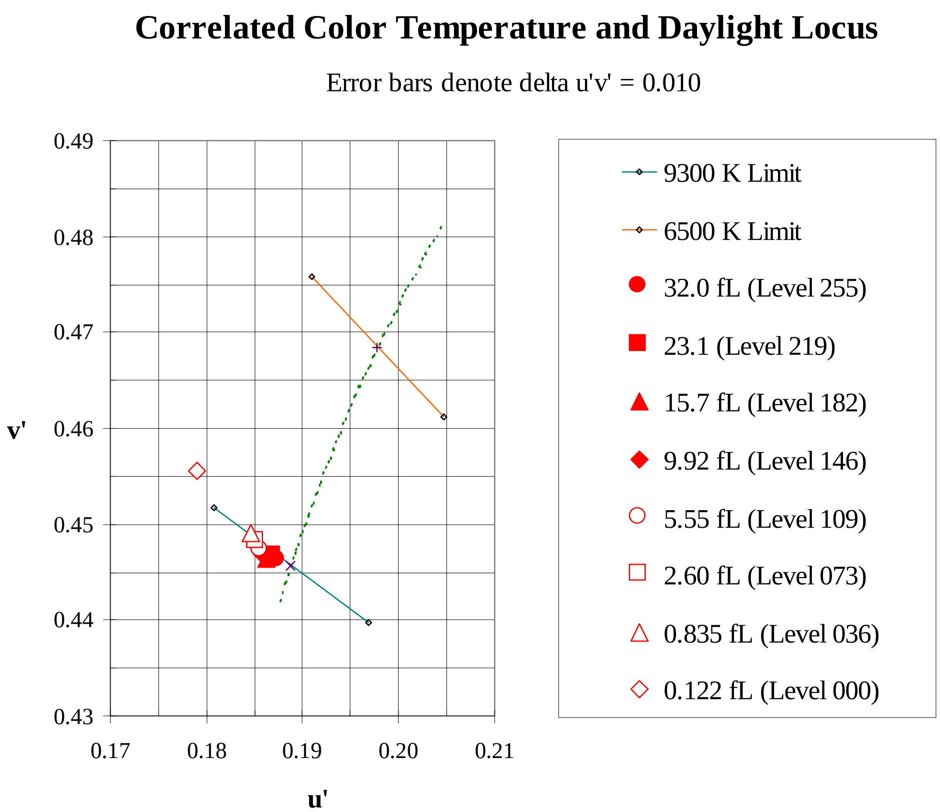


Figure II.23-1 *CCT of measured white points for luminance values 0.12 fL to 32.0 fL shown relative to the Daylight Locus.*

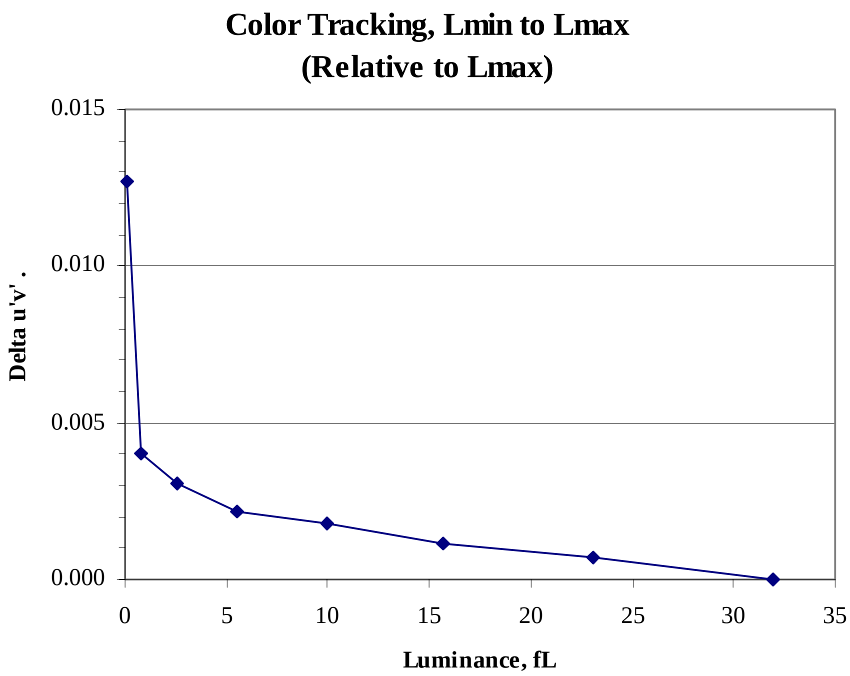


Figure II.23-2 Chromaticity shift of measured white points for 8 input levels spanning Lmin to Lmax shown relative to Lmax (Level 255) for Sony GDM-FW900 CRT monitor.

II. 24 Color Temporal Control

The IEC Program Office had requested a method to control color in a monitor over time. In response to this request, NIDL investigated use of the built-in Sony factory reset button on the front panel of the monitor. The procedure is to reset the color monitor to the factory default color temperature (9300K) and red, green, and blue gun drive conditions to compensate for any drift. Lmin is then adjusted to 0.1 fL. The Sony FW900 monitor was run 24/7 for two months. During this time the luminance and CIE color coordinates were periodically measured after first resetting the monitor. Table II.24-1 shows that the CIE x,y color coordinates for white, red, green, and blue are reproducible over a two month period. Thus, use of the front panel reset button is a practical way to assure a consistency of color over time.

Table II.24-1. Tests that show color CIE coordinates x, y of white can be controlled over time by using the reset button each day and adjusting Lmin to 0.1 fL

	White				Red			Green			Blue		
DATE	***Lum (fL)***	***x***	***y***	***CCT(K)***	***Lum(fL)***	***x***	***y***	***Lum(fL)***	***x***	***y***	***Lum(fL)***	***x***	***y***
7/2/01	34.00	0.2826	0.2974	9323	7.366	0.6109	0.3481	21.43	0.3067	0.5932	5.636	0.1465	0.0960
7/3/01	34.02	0.2828	0.2979	9287	7.472	0.6083	0.3472	21.51	0.3067	0.5936	5.603	0.1465	0.0958
7/4/01													
7/5/01	33.78	0.2823	0.2978	9332	7.358	0.6091	0.3487	21.14	0.3066	0.5933	5.561	0.1464	0.0958
7/6/01	33.43	0.2822	0.2976	9352	7.227	0.6100	0.3478	21.11	0.3067	0.5937	5.527	0.1465	0.0958
7/7/01													
7/8/01													
7/9/01	34.02	0.2819	0.2971	9401	7.402	0.6106	0.3484	21.46	0.3064	0.5939	5.597	0.1463	0.9550
7/10/01	34.18	0.2818	0.2973	9405	7.454	0.6093	0.3478	21.70	0.3068	0.5939	5.634	0.1464	0.9570
7/11/01	34.10	0.2815	0.2892	9388	7.442	0.6095	0.3479	21.95	0.3067	0.5950	5.613	0.1460	0.0952
7/12/01	34.19	0.2817	0.2980	9383	7.379	0.6082	0.3478	21.67	0.3064	0.5940	5.612	0.1464	0.0955
7/13/01	33.93	0.2815	0.2966	9492	7.409	0.6096	0.3478	21.35	0.3068	0.5940	5.614	0.1462	0.0956
7/14/01													
7/15/01													
7/16/01													
7/17/01	33.99	0.2816	0.2969	9439	7.377	0.6091	0.3480	21.45	0.3069	0.5937	5.617	0.1463	0.0957
7/18/01	34.01	0.2815	0.2974	9433	7.340	0.6085	0.3480	21.49	0.3068	0.5939	5.633	0.1461	0.0955
7/19/01	33.91	0.2820	0.2994	9296	7.290	0.6082	0.3474	21.59	0.3070	0.5940	5.536	0.1463	0.0958
7/20/01	35.47	0.2824	0.3012	9190	7.553	0.6088	0.3481	22.54	0.3067	0.5950	5.627	0.1492	0.0955
7/21/01													
7/22/01													
7/23/01													
7/24/01													
7/25/01													
7/26/01													
7/27/01													
7/28/01													
7/29/01													
7/30/01													
7/31/01													
8/1/01													
8/2/01													
8/3/01													
8/4/01													
8/5/01													
8/6/01													
8/7/01	32.26	0.2824	0.3001	9227	6.975	0.6110	0.3492	20.47	0.3071	0.5935	5.275	0.1463	0.0963
8/8/01													
8/9/01													
8/10/01													
8/11/01													
8/12/01													
8/13/01													
8/14/01													
8/15/01													
8/16/01													
8/17/01													
8/18/01													
8/19/01													
8/20/01													

8/21/01													
8/22/01													
8/23/01	32.90	0.2836	0.3024	9033	7.057	0.6099	0.3488	21.12	0.3086	0.5919	5.316	0.1460	0.0974
8/28/01	32.98	0.2831	0.3018	9105	7.078	0.6084	0.3482	21.40	0.3082	0.5908	5.372	0.1492	0.0974

II. 25 Output Luminance with Color Temperature Setting

The Sony FW900 color monitor has three preset color temperatures: 5000, 6500, 9300K and a setting for sRGB. The factory preset color temperature is 9300K. NIDL made measurements of the output luminance and CIE coordinates for each color temperature. These results are shown in Table II.25-1. Further, the output luminance is virtually the same at 6500 and 9300K, while it decreases by about 5 fL (14%) for a 5000K color temperature. Some within the IEC community have advocated 6500K as being closer to natural light, and therefore appropriate for viewing color imagery taken in daylight. This table shows that no output luminance is sacrificed by adopting a 6500K color temperature set point if that is preferred.

Table II.25-1 Photo Research PR704 spectroradiometer measurements for luminance, CIE coordinates, and CCT at three preset color temperature settings. The International Electrotechnical Commission document 61966-2-1 and the ITU-R BT.709-2 document give sRGB phosphors with chromaticities standardized for high-definition color television as: white x=0.3127 y=0.3290; R x=0.6400, y=0.3300; G x=0.3000, y=0.6000; B x=0.1500 y=0.0600.

	White				**Red**			**Green**			**Blue**		
Color Temp (K)	***Lum(fL)***	***x***	***y***	***CCT (K)***	***Lum(fL)***	***x***	***y***	***Lum(fL)***	***x***	***y***	***Lum (fL)***	***x***	***y***
5000	32.47	0.3477	0.3623	4939	9.747	0.5963	0.3498	20.79	0.3088	0.5816	3.431	0.1599	0.1148
6500	37.67	0.3112	0.3312	6563	9.933	0.5835	0.3482	24.52	0.3070	0.5793	5.397	0.1558	0.1094
9300	38.02	0.2824	0.2964	9392	8.917	0.5792	0.3426	24.04	0.3042	0.5774	6.858	0.1509	0.1018
sRGB	35.03	0.3095	0.3334	6639	8.061	0.6125	0.3498	21.71	0.3065	0.5965	3.950	0.1458	0.0954