The Sony GDM-F520 21 inch, flat face monitor (NIDL paid $1700) has excellent image quality and features that make it an excellent display device for NIMA Imagery Exploitation Capability workstations. The improved electronics of the GDM-F520 allow this monitor to display 1024 x 1024 pixel stereo images at 60.5 Hz per eye (121 Hz vertical refresh rate), which exceeds the IEC specification of 60 Hz per eye. The vertical refresh rate for the 1024 x 1024 or the 1280 x 1024 stereo formats could be increased to as high as 128 Hz. NIDL rates this color monitor "A" in monoscopic mode and "A" in stereoscopic mode and thereby certifies the 21 inch Sony GDM-F520 color monitor as being suitable for IEC workstations for both monoscopic and stereoscopic modes. Briggs Scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 8, 46, 57 and 61, respectively, for the GDM-F520 monitor in 1600 x 1200 monoscopic mode. These scores are comparable to the Sony 24 inch FW900 monitor, and slightly better than the scores for the ViewSonic P815, and for the Cornerstone p1700 and p1750 monitors.

Evaluation of the Sony GDM-F520 21-Inch Diagonal Color CRT Monitor for Monoscopic and Stereoscopic Imagery

National Technology Alliance
National Information Display Laboratory

P. O. Box 8619
Princeton, NJ 08543-8619
Tel: (609) 951-0150
Fax: (609) 734-2313
e-mail: nidl@nidl.org

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NIDL IEC Monitor Certification Report

The Sony GDM F520 Color CRT Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: A

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

Color monitors are more difficult to evaluate and their performance may not compare to monochrome monitors. Color monitors have three electron guns (R, G, and B) to focus and converge. They also have a perforated steel shadow mask that separates the colors on the screen and this adds complexity. Color lines formed on the phosphor screen may not be as narrow as for a monochrome, single electron gun-formed spot. The color monitor's light output may not be as high. The IEC monitor specifications for color monitors reflect this difference, and have lower luminance and stereo extinction ratio requirements than a monochrome monitor. In spite of these limitations, Imagery and Geospatial Analysts at a number of sites may do all their analyses on color monitors.

NIDL was looking for a color monitor that would perform both monoscopic and stereoscopic tasks on an IEC workstation, particularly since the NIDL-certified Cornerstone P1700 is no longer being manufactured. Based on the excellent published manufacturer's specifications, we decided this monitor has the potential for satisfying the IEC Working Group specifications for both stereoscopic and monoscopic IA and GI specific tasks. Since Sony did not provide a monitor for loan, NIDL purchased the monitor and then proceeded with our tests. We found the Sony GDM-F520 21 inch, flat face monitor (NIDL paid $1700) has excellent image quality and features that make it an excellent display device for NIMA Imagery Exploitation Capability workstations. It has a phosphor pitch of 0.22 mm over the entire face and 2048 x 1536 pixel maximum addressability. NIDL has verified that this monitor achieves stereo mode operation at 1024 x 1024 addressability at 120 Hz and also at 1280 x 1024 at 120 Hz. NIDL rates this color monitor "A" in monoscopic mode and "A" in stereoscopic mode and thereby certifies the 21 inch Sony GDM-F520 color monitor as being suitable for IEC workstations for both monoscopic and stereoscopic modes. NIDL tested the monitor at an addressability of 1600 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 43% in Zone A and 41% over the face of the whole CRT, well above the IEC minimum performance values. The reliability of the Sony GDM-F520 monitor is expected to be excellent; it has a limited warranty of 3 years for parts, labor and the CRT.

Briggs Scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 8, 46, 57 and 61, respectively, for the GDM-F520 monitor. These scores were comparable to the FW900 monitor and slightly better than the scores for the ViewSonic P815 monitor.

The color temperature can be preset to 5000, 6500, and 9300K, or can be adjusted by the user from 5000 to 11000K. Adjusting the color temperature somewhat affects the output luminance of the monitor. The luminance of a white full screen, Lmax, is approximately 15% higher at 9300K (34fL) compared to 6500K (30fL). Other color features include: variable RGB gain/bias and the sRGB color display system.

NIMA has stated that color reproducibility over time is an important feature for IEC workstations. Accordingly, NIDL demonstrated for the Sony GDM-FW900 monitor that the CIE x and y coordinates can be reproduced over a period of five 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 for the Sony GDM-F520 monitor as well.

The manufacturer lists the maximum addressability for the Sony F520 as 2048 x 1536 pixels. However, the horizontal phosphor pitch of 0.22 mm limits the number of red, green and blue phosphor stripes that can be addressed to fewer than 2048 pixels in the horizontal direction. As evaluated, NIDL's measurements for a viewable image size of 15.288 x 11.405 inches indicate a maximum of 1765 pixels in the horizontal direction based on the horizontal phosphor pitch.

The manufacturer recommended addressability setting is 1600 x 1200 at 85Hz. The improved electronics of the GDM-F520 allow this monitor to display 1024 x 1024 pixel stereo images at 60.5 Hz per eye (121 Hz vertical refresh rate), which is exceeds the IEC specification of 60 Hz per eye. The monitor exceeds the IEC stereo extinction ratio specification of 15:1 with the StereoGraphics CrystalEyes shutter glasses and achieves 26:1 at 60.5 Hz per eye. The stereo extinction ratio at 60.5 Hz per eye with the StereoGraphics ZScreen is 12:1. With a value of 6.1 fL at the analyst's eye position, the Sony GDM-F520 meets the IEC luminance specification in the stereoscopic mode.

The Sony GDM-F520 monitor is described in the Manufacturer's Specifications in the section below and on the Sony website:
http://www.ita.sel.sony.com/support/displays/legacy/specs/gdmf520.pdf

The Sony GDM-F520 passes all the IEC Working Group specifications for monoscopic and stereoscopic modes. Highlights of NIDL's evaluation results for the Sony GDM-520 monitor are summarized below:

- Full screen white-to-black contrast ratio measured in 1600 x 1200 format is 315:1 (25.0 dB dynamic range) in a dark room. With a measured screen reflectance of 6.2%, the contrast ratio decreases to 142:1 (21.5 dB) in 2-fc diffuse ambient illumination.
- The luminance of a white full screen, Lmax, was 31.8 fL at 6500K measured at screen center in 1600 x 1200 format and exceeded the 30 fL minimum value. Lmax was 33.6 fL at a CCT of 9300K.
- Lmax can vary with luminance mode from 20.9 fL in the professional mode to 25.4 fL in the standard mode, and to 29.5 fL in the dynamic mode at a CCT of 6500K.
- Maximum luminance (Lmax) varied by up to 6.0% across the screen. Chromaticity variations were 0.002 delta u'v' units or less.
- The CCT of the measured white point is 6941 K as tested and lies within the boundaries accepted by IEC.
- Halation was 3.88% +/- 0.33% on a small black patch surrounded by a large full white area.

- 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 at 6500K or at 9300K CCT presets.
- This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200 x 85 Hz, 1024 x 1024 x 121 Hz, and 1280 x 1024 x 121 Hz**.**
- Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 43% in Zone A of diameter 7.6 inches, and 43% for Zone A diameter of 9.42 inches (40% of image area). Cm exceeded 41% in Zone B.
- A 60-minute warm-up was necessary for Lmin to stabilize within 10% of its final value.
- Vertical refresh rate for 1600 x 1200 format was set to 85 Hz. Vertical refresh rate for the 1024 x 1024 stereo format was set to 121 Hz, but could be increased to as high as 129Hz.
- Stereo extinction ratio using the StereoGraphics ZScreen and passive polarized glasses averaged 12:1 (12.6 left, 12.3 right) at screen center.
- Stereo extinction ratio using StereoGraphics LC shutter glasses averaged 21 to 1 (21.3 left, 19.9 right) at screen center.
- The FWHM spot size in the vertical direction averages 9.03 +/-0.98 mils over the entire screen, and in the horizontal direction averages 11.84 +/-1.86 mils over the entire screen.

The Sony F520 has a flat face Trinitron screen with RGB phosphor stripes. The newer Cornerstone p1750 monitor also has phosphor stripes in its Mitsubishi-sourced CRT, but the NIDL-certified p1700 monitor has phosphor dot triads. Analysts may prefer one type of screen to the other for their tasks.

Four separate Evaluation Datasheets compare the Sony GDM-F520 with the Sony GDM-F500, the Sony GDM-FW900, the ViewSonic P815-4, and the Cornerstone p1700. The Sony F520 color monitor performs better than the Cornerstone P1700 in the following areas:

- ♦ Uniformity, 6% deviation for the Sony F520 compared to 11.5% for P1700
- ♦ Contrast modulation, 17% better in the horizontal direction for the Sony F520
- ♦ Straightness, 42% better for the F520
- ♦ Vertical refresh rate in stereo is better for the Sony GDM F520, up to 129 Hz versus120 Hz for the P1700, so the potential for flicker should be less in stereo with the Sony F520.
- ♦ Extinction ratio in stereo, 20% better for Sony F520 compared to the P1700

The Cornerstone P1700 color monitor performs better than the Sony F520 in the following areas:

- ♦ Luminance, 34.8 fL for the P1700 compared to 33.6 fL for the Sony F520
- ♦ Reflectance, 5% for the P1700 compared to 6.2% for the Sony F520
- ♦ Contrast modulation, 51% better in the vertical direction for the P1700
- ♦ Linearity, 18% better for the P1700

The dimensions for the Sony F520 and the Cornerstone P1700 are about the same: 19 inches Wide x 19 inches High x 19 inches Deep x 70 pounds.

NIDL also evaluated the ViewSonic P815 color monitor, and gave it an “A” for monoscopic viewing based on measurements of its performance but did not certify it for stereo tasks. Measured electron beam linewidths for the Sony 520 monitor are compared to the ViewSonic P815 monitor below:

- The Sony F520 achieves, on average, 29% smaller line widths at the 50% intensity level compared to the ViewSonic P815. The RAR for the Sony F520 averages 0.5 H x 1.0 V compared to 1.3 H x 0.9 V for the ViewSonic P815.
- The monitors also differ significantly in that the F520 linewidths are more constant over the entire luminance range while the P815 linewidths increase by up to 87% between 7fL to 29fL.
- The contrast modulations of 1 pixel wide white lines on 7 pixel wide black backgrounds and 1 pixel wide black lines on 7 pixel wide white backgrounds were measured for the Sony F520 monitor with Trinitron CRT, and compared to the ViewSonic P815 monitor with phosphor dot shadowmask CRT. White lines are displayed with about the same contrast on both monitors and averaged greater than 90% over luminance values ranging from 10 to 29 fL. The Sony F520 displayed better white or black line contrast than the ViewSonic P815 at the highest luminance setting of 29 fL did. For lower luminances (7fL to 22 fL) horizontal black lines are displayed with slightly more contrast on the ViewSonic P815 (60-66% versus 42-53%) while vertical black lines are displayed with slightly more contrast on the Sony F520 (71-75% versus 58-64%).

The Sony GDM-F520 is compared in Table I with other color monitors that NIDL has certified for stereoscopic mode. Other color CRT monitors certified by NIDL for monoscopic-mode-only operation are listed 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**	**Sony**	**Cornerstone**	**EIZO**	**Hitachi**	**Siemens**	**ViewSonic**
Model		GDM-F520	P1700	F980	CM814	SCM21130	P817
Certified for stereoscopic *		Y	Y	Y	Y	Y	Y
Monoscopic		A	A	B	B	B	B
Stereoscopic		A	B	B	B	B	B
Cm, Zone A	25%	43%	57%	37%	35%	36%	29%
Cm, Zone B	20%	41%	52%	27%	30%	21%	40%
Refresh per eye	60 Hz	60.5 Hz	60 Hz	60 Hz	60 Hz	60.5 Hz	60 Hz
Extinction ratio, panel	No spec	12.5	10.6	12.6	11.2	11.2	10.1
IR glasses	15 to 1	25.7	21.0	14.3		18.1	
Price		$1700	$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	Cornerstone 22 inch	Mitsubishi 22 inch	SONY 24 inch Tested at 1920 x 1200 addressability	
Model		PF815	p1750	2040U	24W900	GDM-FW900
Certified for monoscopic-only*		Y	Y	Y	Y	Y
Monoscopic		A	B	A	A	A
Stereoscopic		C	C	C		C
Cm, Zone A	25%	55%	60%	54%	51%	48%
Cm, Zone B	20%	47%	54%	42%	35%	38%
Refresh per eye	60 Hz	55 Hz	60 Hz	55 Hz	46 Hz	56 Hz
Extinction ratio, panel	No spec	10.3	11.0	10.4	12.9	11.1
IR glasses	15 to 1	17.6	18.0	17.6		18.7
Price		$926	$780	$1123	$2371	$1999

Evaluation Datasheet for Sony GDM-F500R and Sony GDM-F520

		Sony GDM-F500R		Sony GDM-F520	
Mode	**IEC Requirement**	**Measurement**	**Compliance**	**Measurement**	**Compliance**
MONOSCOPIC					
Addressability	1024 x 1024 min.	1600 x 1200	pass	1600 x 1200	Pass
Contrast Ratio (Dynamic Range)	300:1 (24.8 dB)	25.6 dB	pass	318:1 (25.0 dB)	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.10 fL	pass	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	36.2 fL	pass	31.8 fL	Pass
Uniformity (Lmax)	20% max.	12.3 %	pass	6.0 %	Pass
Halation	3.5% max.	1.92 %	pass	3.88% +/- 0.33%	Pass
Color Temp	6500 to 9300 K ± 0.01 Δu'v' max.	9380K	pass	6941 K	Pass
Reflectance	Not specified	6.30%		6.2%	Good
Bit Depth	8-bit± 5 counts	8-bit	pass	8-bit	Pass
Step Response	No visible ringing	Clean	pass	Clean	Pass
Uniformity (Chromaticity)	0.010 ± 0.005 Δu'v' max.	0.003 Δu'v'	pass	0.002 Δu'v'	Pass
Pixel aspect ratio	Square, H = V± 6%	Set to square 9.4 x 9.57 mils	pass	H = V+ 0.6%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	18.9 inches	pass	19.074 inches	Pass
Raster Modulation Center, Lmax	Not specified	Not measured		Cm = 4%	
Center Screen, 50% Lmax	Not specified	Not measured		Cm = 7%	
Cm, Zone A, 7.6"	25% min.	43%	pass	70% H x 43% V	Pass
Cm, Zone A, 9.4"	25% min.	43%	pass	71% H x 42% V	Pass
Cm, Zone B	20% min.	37%	pass	71% H x 41% V	Pass
Pixel density	72 ppi min.	106 ppi	pass	105 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.92	pass	0.91	Pass
Straightness	0.5% ± 0.05 mm max.	0.12 %	pass	< 0.15%	Pass
Linearity	1.0% ± 0.05 mm max	1.32 %	fail	< 0.81%	Pass
Jitter	2 ± 2 mils max.	2.76 mils	pass	< 3.57 mils	Pass
Swim, Drift	5 ± 2 mils max.	3.17 mils	pass	< 4.27 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. max	47 min.	fail	24 minutes	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. max	75 mins.	fail	60 minutes	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min	Set to 72 Hz	pass	Set to 85 Hz	Pass
Briggs BTP#4	Not specified	Not measured		Δ1 = 8, Δ3 = 46 Δ7 = 57, Δ15 = 61	
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 1024	pass	1024 x 1024	Pass
Lmin	Not specified	0.1 fL		0.1 fL	Pass
Lmax	6 fL min ± 4%	7.49 fL(n)	pass	6.09fL(Z), 7.05fL (IR)	Pass
Dynamic range	17.7 dB min	18.9 dB(n)	pass	17.6dB(Z),18.5dB (IR)	Pass
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.006	pass	0.006 Δu'v'	Pass
Refresh rate	60 Hz per eye, min	56 Hz	fail	60.5 Hz per eye	Pass
Extinction Ratio	15:1 min	13.3 : 1(n)	fail	12.5:1 (Z), 25:7 (IR)	Pass

(Z) Denotes StereoGraphics ZScreen and Eyewear (IR) Denotes StereoGraphics CrystalEyes IR Eyewear
(n) denotes Nuvision LCD shutter panel

Evaluation Datasheet for Sony GDM-FW900 and Sony GDM-F520

		Sony GDM-FW900		Sony GDM-F520	
Mode	**IEC Requirement**	**Measurement**	**Compliance**	**Measurement**	**Compliance**
MONOSCOPIC					
Addressability	1024 x 1024 min.	1920 x 1200	Pass	1600 x 1200	Pass
Contrast Ratio (Dynamic Range)	300:1 (24.8 dB)	24.9 dB	Pass	318:1 (25.0 dB)	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.10 fL	Pass	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	31.1 fL	Pass	31.8 fL	Pass
Uniformity (Lmax)	20% max.	9.3%	Pass	6.0 %	Pass
Halation	3.5% max.	5.19 ± 0.4%	Fail	3.88% +/- 0.33%	Pass
Color Temp	6500 to 9300 K ± 0.01 Δu'v' max.	9200 K	Pass	6941 K	Pass
Reflectance	Not specified	5.2%		6.2%	Good
Bit Depth	8-bit± 5 counts	8-bit	Pass	8-bit	Pass
Step Response	No visible ringing	Clean	Pass	Clean	Pass
Uniformity (Chromaticity)	0.010 ± 0.005 Δu'v' max.	0.002 Δu'v'	Pass	0.002 Δu'v'	Pass
Pixel aspect ratio	Square, H = V± 6%	H = V- 4.0%	Pass	H = V+ 0.6%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	22.265 ins.	Pass	19.074 inches	Pass
Raster Modulation Center, Lmax	Not specified	Not measured		Cm = 4%	
Center Screen, 50% Lmax	Not specified	Not measured		Cm = 7%	
Cm, Zone A, 7.6"	25% min.	48%V x 56%H	Pass	70% H x 43% V	Pass
Cm, Zone A, 40% area	25% min.	41%V x 59%H	Pass	71% H x 42% V	Pass
Cm, Zone B	20% min.	38%V x 60%H	Pass	71% H x 41% V	Pass
Pixel density	72 ppi min.	102 ppi	Pass	105 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.92 center 1.08 edge	Pass	0.91	Pass
Straightness	0.5% ± 0.05 mm max.	0.35%	Pass	< 0.15%	Pass
Linearity	1.0% ± 0.05 mm max	1.56%	Fail	< 0.81%	Pass
Jitter	2 ± 2 mils max.	3.96 mils	Pass	< 3.57 mils	Pass
Swim, Drift	5 ± 2 mils max.	6.43 mils	Pass	< 4.27 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. max	33 mins.	Pass	24 minutes	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. max	49 mins.	Pass	60 minutes	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min	Set to 85 Hz	Pass	Set to 85 Hz	Pass
Briggs BTP#4	Not specified	Delta-1 = 10 Delta-3 = 40 Delta-7 = 57 Delta-15 = 62		Delta-1 = 8 Delta-3 = 46 Delta-7 = 57 Delta-15 = 61	
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 1024	Pass	1024 x 1024	Pass
Lmin	Not specified	0.1 fL	Pass	0.1 fL	Pass
Lmax	6 fL min ± 4%	6.96 fL (IR)	Pass Pass	6.09fL (Z), 7.05fL (IR)	Pass
Dynamic range	17.7 dB min	18.2 dB (IR)	Pass	17.6dB (Z),18.5dB (IR)	Pass
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.006 Δu'v' (IR)	Pass	0.006 Δu'v'	Pass
Refresh rate	60 Hz per eye, min	56 Hz, per eye	Fail	60.5 Hz per eye	Pass
Extinction Ratio	15:1 min	18.7:1 (IR) 11.1 (Z)	Pass	12.5:1 (Z), 25:7 (IR)	Pass

(Z) Denotes StereoGraphics ZScreen and Eyewear (IR) Denotes StereoGraphics CrystalEyes IR Eyewear

Evaluation Datasheet for ViewSonic P815-4 and Sony GDM-F520

		ViewSonic P815-4		Sony GDM-F520	
Mode	**IEC Requirement**	**Measurement**	**Compliance**	**Measurement**	**Compliance**
MONOSCOPIC					
Addressability	1024 x 1024 min.	1600 x 1200	Pass	1600 x 1200	Pass
Contrast Ratio (Dynamic Range)	300:1 (24.8 dB)	311:1 (24.9 dB)	Pass	318:1 (25.0 dB)	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.107 fL	Pass	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	33.27 fL	Pass	31.8 fL	Pass
Uniformity (Lmax)	20% max.	10.8 %	Pass	6.0 %	Pass
Halation	3.5% max.	Not measured		3.88% +/- 0.33%	Pass
Color Temp	6500 to 9300 K ± 0.01 Δu'v' max.	8326 K, 9629 K	Pass	6941 K	Pass
Reflectance	Not specified	Not measured		6.2%	Good
Bit Depth	8-bit± 5 counts	Not measured		8-bit	Pass
Step Response	No visible ringing	Clean	Pass	Clean	Pass
Uniformity (Chromaticity)	0.010 ± 0.005 Δu'v' max.	Not measured		0.002 Δu'v'	Pass
Pixel aspect ratio	Square, H = V± 6%	Not measured		H = V+ 0.6%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	Not measured		19.074 inches	Pass
Raster Modulation Center, Lmax	Not specified	Cm = 36%		Cm = 4%	
Center Screen, 50% Lmax	Not specified	Cm = 65%		Cm = 7%	
Cm, Zone A, 7.6"	25% min.	Not measured		70% H x 43% V	Pass
Cm, Zone A, 9.4”	25% min.	Not measured		71% H x 42% V	Pass
Cm, Zone B	20% min.	Not measured		71% H x 41% V	Pass
Pixel density	72 ppi min.	Not measured		105 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	Not measured		0.91	Pass
Straightness	0.5% ± 0.05 mm max.	Not measured		< 0.15%	Pass
Linearity	1.0% ± 0.05 mm max	0.82%	Pass	< 0.81%	Pass
Jitter	2 ± 2 mils max.	Not measured		< 3.57 mils	Pass
Swim, Drift	5 ± 2 mils max.	Not measured		< 4.27 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. max	Not measured		24 minutes	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. max	Not measured		60 minutes	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min	Set to 85 Hz	Pass	Set to 85 Hz	Pass
Briggs BTP#4	Not specified	Δ1 = 9, Δ3 = 39, Δ7 = 52, Δ15 = 57		Δ1 = 8, Δ3 = 46 Δ7 = 57, Δ15 = 61	
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 1024	Pass	1024 x 1024	Pass
Lmin	Not specified	0.1 fL		0.1 fL	Pass
Lmax	6 fL min ± 4%	5.05 fL [Z], 5.86 [IR]	Pass	6.09fL[Z], 7.05fL [IR]	Pass
Dynamic range	17.7 dB min	17.0 dB [Z], 17.7 dB [IR]	Pass	17.6dB[Z],18.5dB[IR]	Pass
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.008 Δu'v'	Pass	0.006 Δu'v'	Pass
Refresh rate	60 Hz per eye, min	55 Hz per eye	Fail	60.5 Hz per eye	Pass
Extinction Ratio	15:1 min	10.2:1 [Z], 15:1 [IR]	Pass	12.5:1 [Z], 25:7 [IR]	Pass
Addressability	1024 x 1024 min.			1280 x 1024	
Lmin	Not specified	Not measured		0.1 fL	
Lmax	6 fL min ± 4%	Not measured		4.89 fL [IR]	
Dynamic range	17.7 dB min	Not measured		16.9 dB [IR]	
Refresh rate	60 Hz per eye, min	Not measured		60.5 Hz per eye	
Extinction Ratio	15:1 min	Not measured		16 .1 [IR]	

Max. Refresh	ViewSonic P815-4		Sony F520		
Addressability	1152 x 864	1024 x 1024	1152 x 864	1024 x 1024	1280 x 1024
Vertical Scan	128.9 Hz	110 Hz	153.3 Hz	128.2 Hz	129.4 Hz
Horizontal Scan	116 kHz	117.310 kHz	137.968 kHz	137.969 kHz	137.968 kHz

[Z] Denotes StereoGraphics ZScreen and Eyewear [IR] Denotes StereoGraphics CrystalEyes IR Eyewear

Evaluation Datasheet for Cornerstone P1700 and Sony GDM-F520

		Cornerstone P1700		Sony GDM-F520	
Mode	**IEC Requirement**	**Measurement**	**Compliance**	**Measurement**	**Compliance**
MONOSCOPIC					
Addressability	1024 x 1024 min.	1600 x 1200	Pass	1600 x 1200	Pass
Contrast Ratio (Dynamic Range)	300:1 (24.8 dB)	25.4 dB	Pass	318:1 (25.0 dB)	Pass
Luminance (Lmin)	0.1 fL ± 4% min.	0.1 fL	Pass	0.10 fL	Pass
Luminance (Lmax)	30 fL ± 4%	34.8 fL	Pass	31.8 fL	Pass
Uniformity (Lmax)	20% max.	11.5 %	Pass	6.0 %	Pass
Halation	3.5% max.	4.17 ± 0.4%	Fail	3.88% +/- 0.33%	Pass
Color Temp	6500 to 9300 K ± 0.01 Δu'v' max.	9075 K	Pass	6941 K	Pass
Reflectance	Not specified	5.0 %	Good	6.2%	Good
Bit Depth	8-bit± 5 counts	8-bit	Pass	8-bit	Pass
Step Response	No visible ringing	Clean	Pass	Clean	Pass
Uniformity (Chromaticity)	0.010 ± 0.005 Δu'v' max.	0.0022 Δu'v'	Pass	0.002 Δu'v'	Pass
Pixel aspect ratio	Square, H = V± 6%	H = V – 0.4%	Pass	H = V+ 0.6%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.7 ins.	Pass	19.074 inches	Pass
Raster Modulation Center, Lmax	Not specified			Cm = 4%	
Center Screen, 50% Lmax	Not specified			Cm = 7%	
Cm, Zone A, 7.6"	25% min.	57% H x 82% V	Pass	70% H x 43% V	Pass
Cm, Zone A, 9.4"	25% min.	56% H x 83% V	Pass	71% H x 42% V	Pass
Cm, Zone B	20% min.	52% H x 86% V	Pass	71% H x 41% V	Pass
Pixel density	72 ppi min.	101 ppi	Pass	105 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.88	Pass	0.91	Pass
Straightness	0.5% ± 0.05 mm max.	0.26 %	Pass	< 0.15%	Pass
Linearity	1.0% ± 0.05 mm max	0.66 %	Pass	< 0.81%	Pass
Jitter	2 ± 2 mils max.	2.63 mils	Pass	< 3.57 mils	Pass
Swim, Drift	5 ± 2 mils max.	3.04 mils	Pass	< 4.27 mils	Pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 mins. max	25 mins.	Pass	24 minutes	Pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 mins. max	60.mins.	Pass	60 minutes	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute min	Set to 85 Hz	Pass	Set to 85 Hz	Pass
Briggs BTP#4	Not specified	Δ1 = 9, Δ3 = 40 Δ7 = 53, Δ15 = 57		Δ1 = 8, Δ3 = 46 Δ7 = 57, Δ15 = 61	
STEREOSCOPIC					
Addressability	1024 x 1024 min.	1024 x 1024 (Z) (IR)	Pass	1024 x 1024	Pass
Lmin	Not specified	0.1 fL	Pass	0.1 fL	Pass
Lmax	6 fL min ± 4%	6.78fL (Z)	Pass	6.09fL (Z), 7.05fL (IR)	Pass
Dynamic range	17.7 dB min	17.9dB (Z)	Pass	17.6dB (Z),18.5dB (IR)	Pass
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.010 Δu'v' (Z)	Pass	0.006 Δu'v'	Pass
Refresh rate	60 Hz per eye, min	60 Hz per eye (Z) (IR)	Pass	60.5 Hz per eye	Pass
Extinction Ratio	15:1 min	10.6:1 (Z) 21.0:1 at 60 Hz (IR)	Pass	12.5:1 (Z), 25:7 (IR)	Pass
Addressability	1024 x 1024 min.	1280 x 1024 (IR)	Pass	1280 x 1024	
Lmin	Not specified	0.1 fL	Pass	0.1 fL	
Lmax	6 fL min ± 4%	6.40fL (IR)	Pass	4.89 fL (IR)	
Dynamic range	17.7 dB min	18.0dB (IR)	Pass	16.9 dB (IR)	
Uniformity (Chromaticity)	0.02 ± 0.005 Δu'v' max	0.018 Δu'v' (IR)	Pass	Not measured	
Refresh rate	60 Hz per eye, min	50 Hz per eye (IR)	Fail	60.5 Hz per eye	
Extinction Ratio	15:1 min	22.7:1 at 50 Hz (IR)	Pass	16 .1 (IR)	

(Z) Denotes StereoGraphics ZScreen and Eyewear (IR) Denotes StereoGraphics CrystalEyes IR Eyewear

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-F520 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 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-F520 Monitor

For details of the manufacture's specifications, please go to Sony web page
http://www.ita.sel.sony.com/support/displays/legacy/specs/gdmf520.pdf .

Features of the Sony GDM-F520 color CRT monitor

- **21 inch (19.8 inch actual visible size) virtually flat Trinitron CRT**
- **Supports PC resolutions up to 2048 x 1536 pixels**
- **0.22 mm aperture grille pitch across the entire screen**
- **Picture effect to boost image luminance to optimize performance for graphics and video applications**
- **HD15 and BNC connectors support the use of two computers**
- **A new level of performance with superb image clarity and brighter colors make it perfect for detailed graphic design work**

Specifications of Sony GDM-F520 CRT monitor

- **Screen treatment** **High contrast anti-reflection coating**
- **Horizontal scan** **30 to 137 kHz**
- **Vertical refresh** **48 to 170 Hz**
- **Maximum resolution** **2048 x 1536 pixels**
- **Recommended resolutions** **1920 x 1440 at 85 Hz, 1600 x 1200 at 85 Hz**
- **Factory preset timings** **27 modes**
- **User adjustable timings** **15 settings**
- **Color temperature presets** **5000K, 6500K, 9300K; 5000K to 10,000K adjustable**
- **\Display weight** **67.4 pounds**
- **Power requirements** **90 to 264 V AC at 50/60 Hz**
- **Power management** **145 W maximum; 3 W active off**
- **Operating conditions** **50 to 104 F, 10 to 80% relative humidity**
- **Front panel user controls**
- **On screen display controls**
- **Warranty** **Parts, CRT and labor for 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

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 1600 x 1200 format is 315:1 (25.0 dB dynamic range) in a dark room and exceeds the IEC specification. We measured a screen reflectance of 6.2% which is fairly low. In spite of this average-to-low reflectivity, the contrast ratio decreases to 196:1 (22.9 dB) in 1 fc diffuse ambient illumination. The absolute threshold for IEC is 158:1 (22 dB). Thus, the strong influence of ambient light on the achievable contrast ratio is shown. For the highest contrast ratio, the amount of light falling on the screen should be minimized by turning off overhead florescent lights and substituting indirect reflected light from a wall wash.

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)

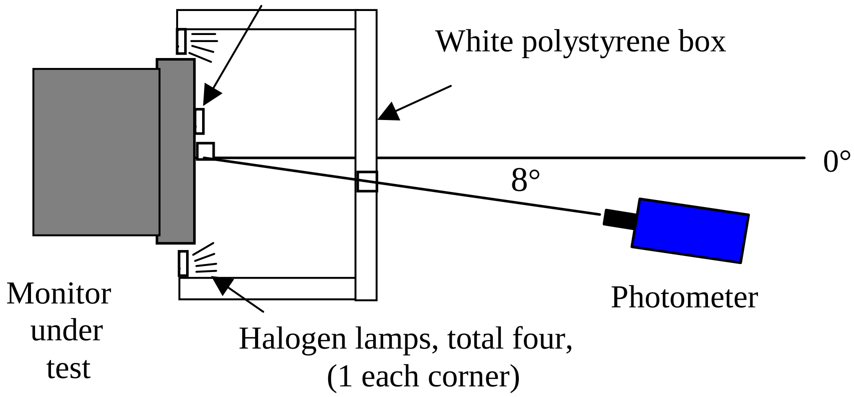


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

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

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20.4 fc
Reflected Luminance	1.26 fL
Faceplate Reflectance	6.2 %

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 315:1 (25.0 dynamic range) in a dark room to 142:1 (21.5 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)	315 :1	25.0 dB
1 fc	196 :1	22.9 dB
2 fc	142 :1	21.5 dB
3 fc	112 :1	20.5 dB
4 fc	92 :1	19.6 dB
5 fc	78 :1	18.9 dB
6 fc	68 :1	18.3 dB
7 fc	60 :1	17.8 dB
8 fc	54 :1	17.3 dB
9 fc	49 :1	16.9 dB
10 fc	45 :1	16.5 dB
11 fc	42 :1	16.2 dB
12 fc	39 :1	15.9 dB
13 fc	36 :1	15.6 dB
14 fc	34 :1	15.3 dB
15 fc	32 :1	15.0 dB

II.2. Maximum Luminance (Lmax) in Monoscopic and Stereo Modes

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

Lmax can be as high as 33.6 fL depending on the choice of preset modes and CCT. Through the ZScreen and passive glasses, it exceeds 6 fL for stereo viewing in the standard and dynamic modes when the gain is at its maximum setting. The professional setting yields less than 6 fL in stereo. With stereo active glasses, Lmax is greater than 7 fL in 1024 x 1024 and about 4.9 fL in a 1280 x 1024 pixel addressability.

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
1600 x 1200	6941K	0.307	0.318	31.8 fL

Table II.2-2. Measured Luminance Through ZScreen and Stereo Passive Glasses

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

Mode	Professional		Standard		Dynamic	
	Default	Gain at Max	Default	Gain at Max	Default	Gain at Max
CCT	8920 K	8370 K	8900 K	8350 K	8870 K	8340 K
x	0.274	0.278	0.274	0.279	0.276	0.278
y	0.327	0.343	0.327	0.343	0.328	0.344
fL	4.81	5.35	5.65	6.12	5.81	6.11

II.3. Luminance at Lmax and Color Uniformity

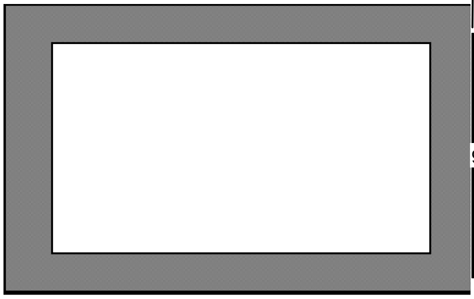
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by 6% across the screen, well below the IEC maximum value of 20%. Chromaticity variations were 0.002 delta u'v' units or less, or about a factor of 5 lower than allowed by the IEC specification.

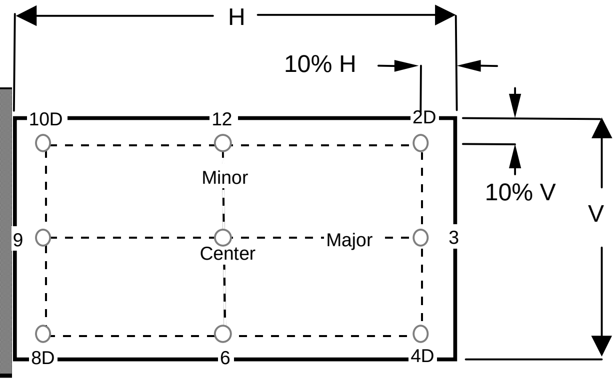
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

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 $\Delta u'v'$.

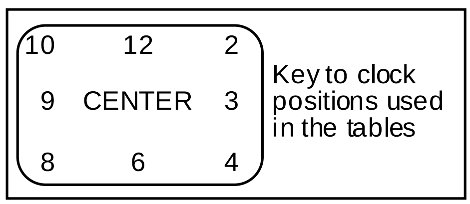
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

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	CIE x	CIE y	L, fL
center	6941	0.307	0.318	31.8
2	6817	0.309	0.318	30.2
3	6890	0.308	0.317	29.9
4	6929	0.307	0.319	30.1
6	6806	0.309	0.319	31.7
8	6745	0.310	0.319	31.6
9	6745	0.310	0.319	30.5
10	6726	0.310	0.321	30.6
12	6817	0.309	0.318	31.2



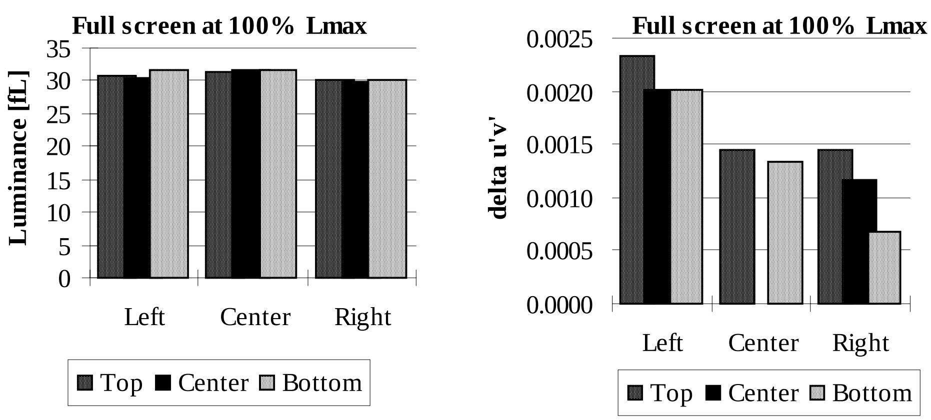


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity at Lmax. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

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

Halation was 3.88% +/- 0.33% on a small black patch surrounded by a large full white area and within the tolerance range of the IEC specification of 3.5% for a color temperature of 6500K.

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:

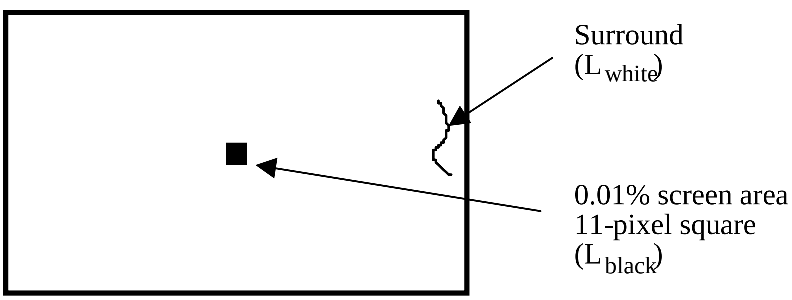


Figure II.4-1 *Test pattern for measuring halation.*

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 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lmin	0.077 fL ± 4%	0.0739 fL to 0.0801 fL
Lblack	1.247 fL ± 4%	1.197 fL to 1.297 fL
Lwhite	30.27 fL ± 4%	29.06 fL to 31.48 fL
Halation	3.88% ± 0.33%	3.56% to 4.22%

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 6941 K as tested 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.

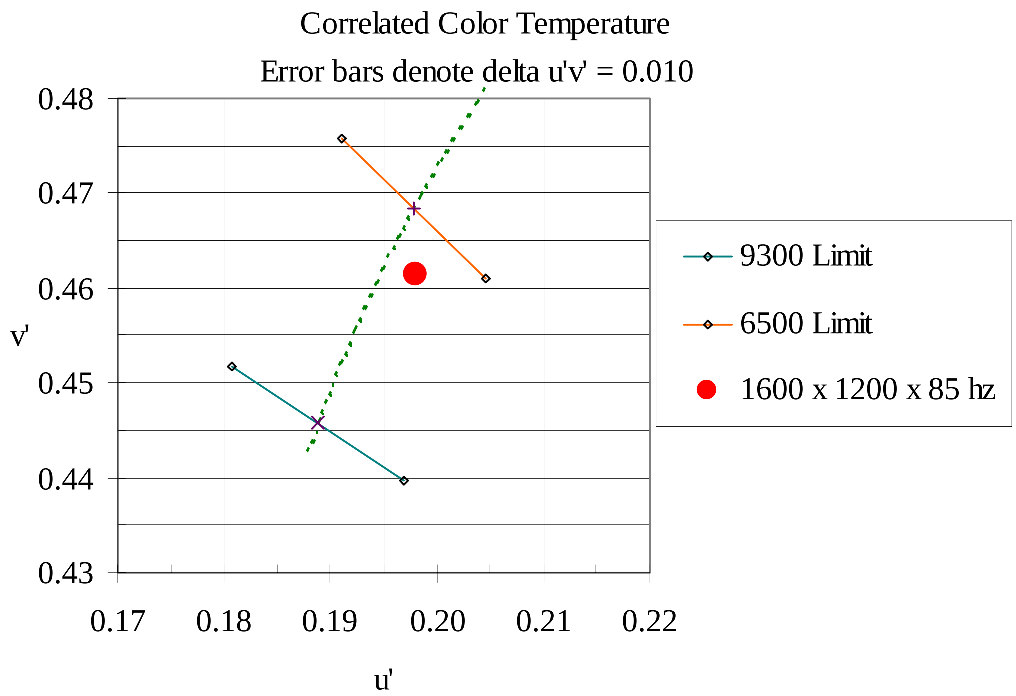


Figure II.5-1 *CCTs of measured white points are within the boundaries required by IEC.*

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

	1600 x 1200
CIE x	0.307
CIE y	0.318
CIE u'	0.198
CIE v'	0.461
CCT	6941 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. Between one and two JNDs separated each level. Neither black level clipping nor white level saturation was observed at 6500K or 9300K CCT presets. The shapes of the tonal transfer curves for both 6500K and 9300K are similar; 9300K achieves a 20% higher Lmax compared to 6500K.

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 and the perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) as a function of input counts measured at screen center. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

6500 K

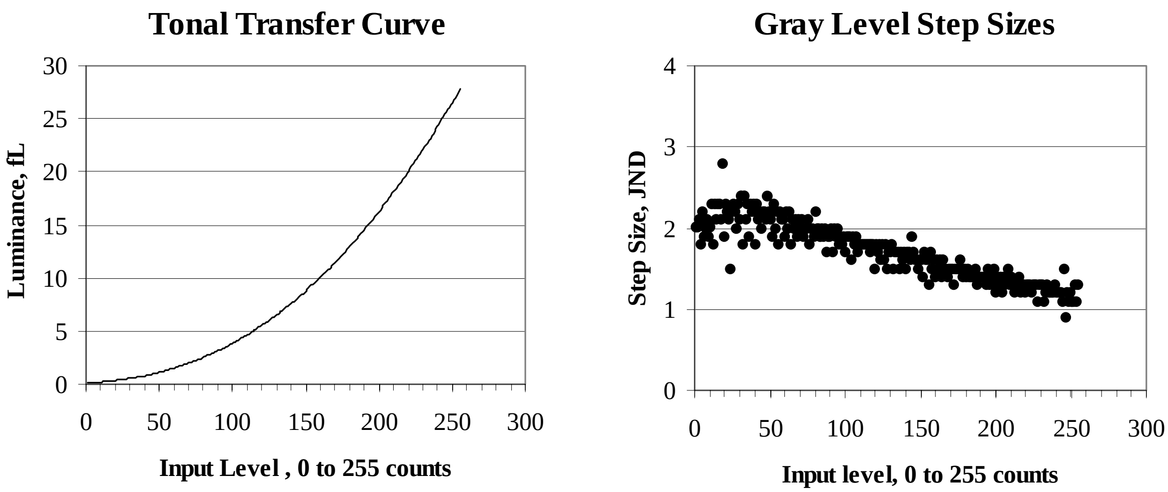


Figure II.6-1. System Tonal Transfer and perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) as a function of input counts for whitepoint CCT preset selected to 6500 K.

9300 K

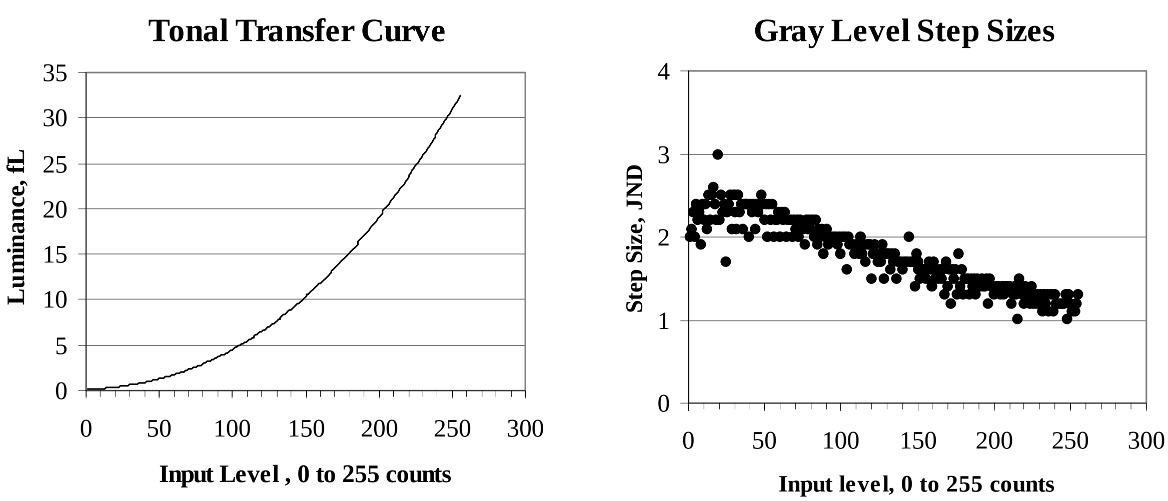


Figure II.6-2. System Tonal Transfer and perceptibility of gray level step sizes in Just Noticeable Differences (JNDs) as a function of input counts for whitepoint CCT preset selected to 9300 K.

Table II.6-1. System Tonal Transfer for CCT of 6500K 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	0.104	0	0.0	61	64	1.692	0.040	1.8
39	1	0.112	0.008	2.0	61	65	1.74	0.048	2.1
39	2	0.12	0.008	2.0	62	66	1.787	0.047	2.0
39	3	0.129	0.009	2.1	62	67	1.836	0.049	2.1
40	4	0.137	0.008	1.8	62	68	1.882	0.046	1.9
40	5	0.147	0.010	2.2	63	69	1.932	0.050	2.1
41	6	0.156	0.009	1.9	63	70	1.982	0.050	2.0
41	7	0.166	0.010	2.0	63	71	2.035	0.053	2.1
41	8	0.177	0.011	2.1	64	72	2.083	0.048	1.9
42	9	0.187	0.010	1.9	64	73	2.137	0.054	2.0
42	10	0.198	0.011	2.0	64	74	2.190	0.053	2.0
42	11	0.211	0.013	2.3	65	75	2.246	0.056	2.1
43	12	0.222	0.011	1.8	65	76	2.296	0.050	1.8
43	13	0.236	0.014	2.3	65	77	2.353	0.057	2.0
43	14	0.249	0.013	2.1	66	78	2.409	0.056	2.0
44	15	0.264	0.015	2.3	66	79	2.464	0.055	1.9
44	16	0.28	0.016	2.3	66	80	2.528	0.064	2.2
44	17	0.296	0.016	2.3	67	81	2.589	0.061	2.0
45	18	0.311	0.015	2.1	67	82	2.650	0.061	2.0
45	19	0.332	0.021	2.8	67	83	2.710	0.060	1.9
45	20	0.347	0.015	1.9	68	84	2.768	0.058	1.9
46	21	0.366	0.019	2.3	68	85	2.832	0.064	2.0
46	22	0.384	0.018	2.2	69	86	2.895	0.063	1.9
46	23	0.402	0.018	2.1	69	87	2.962	0.067	2.0
47	24	0.415	0.013	1.5	69	88	3.018	0.056	1.7
47	25	0.435	0.020	2.2	70	89	3.085	0.067	1.9
48	26	0.456	0.021	2.3	70	90	3.152	0.067	1.9
48	27	0.477	0.021	2.2	70	91	3.222	0.070	2.0
48	28	0.496	0.019	2.0	71	92	3.283	0.061	1.7
49	29	0.519	0.023	2.3	71	93	3.354	0.071	2.0
49	30	0.541	0.022	2.1	71	94	3.424	0.070	1.9
49	31	0.566	0.025	2.4	72	95	3.499	0.075	2.0
50	32	0.586	0.020	1.8	72	96	3.567	0.068	1.8
50	33	0.613	0.027	2.4	72	97	3.642	0.075	1.9
50	34	0.637	0.024	2.1	73	98	3.715	0.073	1.8
51	35	0.664	0.027	2.3	73	99	3.791	0.076	1.9
51	36	0.687	0.023	1.9	73	100	3.858	0.067	1.7
51	37	0.715	0.028	2.3	74	101	3.937	0.079	1.9
52	38	0.743	0.028	2.2	74	102	4.016	0.079	1.9
52	39	0.773	0.030	2.3	74	103	4.095	0.079	1.9
52	40	0.797	0.024	1.8	75	104	4.165	0.070	1.6
53	41	0.828	0.031	2.3	75	105	4.247	0.082	1.9
53	42	0.857	0.029	2.1	76	106	4.328	0.081	1.8
53	43	0.889	0.032	2.2	76	107	4.413	0.085	1.9
54	44	0.918	0.029	2.0	76	108	4.489	0.076	1.7
54	45	0.951	0.033	2.2	77	109	4.574	0.085	1.8
55	46	0.984	0.033	2.2	77	110	4.655	0.081	1.8
55	47	1.018	0.034	2.1	77	111	4.743	0.088	1.8
55	48	1.055	0.037	2.4	78	112	4.830	0.087	1.8
56	49	1.092	0.037	2.2	78	113	4.918	0.088	1.8
56	50	1.127	0.035	2.1	78	114	5.005	0.087	1.8
56	51	1.165	0.038	2.2	79	115	5.096	0.091	1.8
57	52	1.198	0.033	1.9	79	116	5.181	0.085	1.7
57	53	1.238	0.040	2.3	79	117	5.274	0.093	1.8
57	54	1.275	0.037	2.0	80	118	5.367	0.093	1.8
58	55	1.316	0.041	2.2	80	119	5.464	0.097	1.8
58	56	1.351	0.035	1.8	80	120	5.545	0.081	1.5
58	57	1.393	0.042	2.2	81	121	5.642	0.097	1.8
59	58	1.434	0.041	2.1	81	122	5.735	0.093	1.7
59	59	1.477	0.043	2.1	81	123	5.837	0.102	1.8
59	60	1.516	0.039	1.9	82	124	5.925	0.088	1.6
60	61	1.561	0.045	2.2	82	125	6.027	0.102	1.8
60	62	1.604	0.043	2.0	83	126	6.123	0.096	1.6
60	63	1.652	0.048	2.2	83	127	6.228	0.105	1.8

Table II.6-2. System Tonal Transfer for CCT of 6500K 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	6.313	0.085	1.5	106	192	14.89	0.16	1.4
84	129	6.418	0.105	1.7	106	193	15.07	0.18	1.4
84	130	6.523	0.105	1.7	106	194	15.23	0.16	1.3
84	131	6.631	0.108	1.8	107	195	15.41	0.18	1.5
85	132	6.727	0.096	1.5	107	196	15.57	0.16	1.3
85	133	6.836	0.109	1.7	107	197	15.75	0.18	1.4
85	134	6.943	0.107	1.7	108	198	15.92	0.17	1.3
86	135	7.054	0.111	1.7	108	199	16.11	0.19	1.5
86	136	7.151	0.097	1.5	108	200	16.27	0.16	1.2
86	137	7.262	0.111	1.7	109	201	16.45	0.18	1.4
87	138	7.372	0.11	1.6	109	202	16.62	0.17	1.3
87	139	7.489	0.117	1.7	109	203	16.81	0.19	1.4
87	140	7.591	0.102	1.5	110	204	16.97	0.16	1.2
88	141	7.711	0.12	1.7	110	205	17.16	0.19	1.4
88	142	7.825	0.114	1.7	111	206	17.34	0.18	1.3
88	143	7.945	0.12	1.6	111	207	17.53	0.19	1.4
89	144	8.082	0.137	1.9	111	208	17.74	0.21	1.5
89	145	8.202	0.12	1.7	112	209	17.93	0.19	1.3
90	146	8.321	0.119	1.6	112	210	18.12	0.19	1.4
90	147	8.444	0.123	1.6	112	211	18.31	0.19	1.3
90	148	8.555	0.111	1.5	113	212	18.48	0.17	1.2
91	149	8.680	0.125	1.6	113	213	18.68	0.2	1.3
91	150	8.803	0.123	1.6	113	214	18.87	0.19	1.3
91	151	8.931	0.128	1.6	114	215	19.08	0.21	1.4
92	152	9.042	0.111	1.4	114	216	19.25	0.17	1.2
92	153	9.173	0.131	1.7	114	217	19.45	0.2	1.3
92	154	9.302	0.129	1.6	115	218	19.65	0.2	1.3
93	155	9.433	0.131	1.6	115	219	19.85	0.2	1.3
93	156	9.547	0.114	1.3	115	220	20.04	0.19	1.2
93	157	9.684	0.137	1.7	116	221	20.25	0.21	1.3
94	158	9.815	0.131	1.5	116	222	20.45	0.2	1.3
94	159	9.95	0.135	1.6	116	223	20.65	0.2	1.3
94	160	10.07	0.12	1.4	117	224	20.85	0.2	1.2
95	161	10.21	0.14	1.6	117	225	21.06	0.21	1.3
95	162	10.35	0.14	1.5	118	226	21.27	0.21	1.3
95	163	10.49	0.14	1.6	118	227	21.49	0.22	1.3
96	164	10.62	0.13	1.4	118	228	21.68	0.19	1.1
96	165	10.76	0.14	1.6	119	229	21.90	0.22	1.3
97	166	10.90	0.14	1.5	119	230	22.11	0.21	1.3
97	167	11.04	0.14	1.5	119	231	22.33	0.22	1.3
97	168	11.17	0.13	1.4	120	232	22.52	0.19	1.1
98	169	11.32	0.15	1.5	120	233	22.74	0.22	1.2
98	170	11.46	0.14	1.5	120	234	22.96	0.22	1.3
98	171	11.61	0.15	1.5	121	235	23.18	0.22	1.2
99	172	11.74	0.13	1.3	121	236	23.38	0.2	1.2
99	173	11.89	0.15	1.5	121	237	23.61	0.23	1.2
99	174	12.04	0.15	1.5	122	238	23.82	0.21	1.2
100	175	12.19	0.15	1.5	122	239	24.05	0.23	1.3
100	176	12.35	0.16	1.6	122	240	24.27	0.22	1.2
100	177	12.51	0.16	1.5	123	241	24.50	0.23	1.2
101	178	12.66	0.15	1.4	123	242	24.72	0.22	1.2
101	179	12.82	0.16	1.5	123	243	24.96	0.24	1.2
101	180	12.96	0.14	1.4	124	244	25.17	0.21	1.1
102	181	13.13	0.17	1.5	124	245	25.45	0.281	1.5
102	182	13.28	0.15	1.4	125	246	25.63	0.179	0.9
102	183	13.44	0.16	1.4	125	247	25.86	0.23	1.2
103	184	13.59	0.15	1.4	125	248	26.07	0.21	1.1
103	185	13.75	0.16	1.4	126	249	26.31	0.24	1.2
104	186	13.91	0.16	1.4	126	250	26.53	0.22	1.1
104	187	14.08	0.17	1.5	126	251	26.76	0.23	1.1
104	188	14.23	0.15	1.3	127	252	26.98	0.22	1.1
105	189	14.39	0.16	1.4	127	253	27.24	0.26	1.3
105	190	14.56	0.17	1.4	127	254	27.47	0.23	1.1
105	191	14.73	0.17	1.4	128	255	27.74	0.27	1.3

Table II.6-3. System Tonal Transfer for CCT of 9300K 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	0.107	0	0.0	61	64	1.963	0.049	2.0
39	1	0.115	0.008	2.0	61	65	2.019	0.056	2.2
39	2	0.124	0.009	2.1	62	66	2.075	0.056	2.2
39	3	0.134	0.01	2.3	62	67	2.132	0.057	2.2
40	4	0.143	0.009	2.0	62	68	2.185	0.053	2.0
40	5	0.154	0.011	2.4	63	69	2.245	0.06	2.2
41	6	0.165	0.011	2.2	63	70	2.305	0.06	2.1
41	7	0.177	0.012	2.3	63	71	2.367	0.062	2.2
41	8	0.187	0.01	1.9	64	72	2.422	0.055	2.0
42	9	0.2	0.013	2.4	64	73	2.488	0.066	2.2
42	10	0.213	0.013	2.2	64	74	2.549	0.061	2.1
42	11	0.227	0.014	2.4	65	75	2.614	0.065	2.1
43	12	0.24	0.013	2.1	65	76	2.673	0.059	1.9
43	13	0.256	0.016	2.5	65	77	2.741	0.068	2.2
43	14	0.271	0.015	2.2	66	78	2.809	0.068	2.1
44	15	0.288	0.017	2.5	66	79	2.879	0.07	2.2
44	16	0.307	0.019	2.6	66	80	2.948	0.069	2.1
44	17	0.325	0.018	2.4	67	81	3.021	0.073	2.2
45	18	0.342	0.017	2.2	67	82	3.091	0.07	2.0
45	19	0.366	0.024	3.0	67	83	3.167	0.076	2.2
45	20	0.384	0.018	2.2	68	84	3.234	0.067	1.9
46	21	0.405	0.021	2.5	68	85	3.31	0.076	2.1
46	22	0.426	0.021	2.3	69	86	3.383	0.073	2.0
46	23	0.447	0.021	2.4	69	87	3.462	0.079	2.1
47	24	0.463	0.016	1.7	69	88	3.529	0.067	1.8
47	25	0.485	0.022	2.3	70	89	3.607	0.078	2.0
48	26	0.509	0.024	2.4	70	90	3.689	0.082	2.1
48	27	0.535	0.026	2.5	70	91	3.771	0.082	2.0
48	28	0.557	0.022	2.1	71	92	3.844	0.073	1.9
49	29	0.584	0.027	2.5	71	93	3.926	0.082	2.0
49	30	0.61	0.026	2.3	71	94	4.01	0.084	2.0
49	31	0.638	0.028	2.5	72	95	4.094	0.084	2.0
50	32	0.663	0.025	2.1	72	96	4.182	0.088	2.0
50	33	0.693	0.03	2.5	72	97	4.267	0.085	2.0
50	34	0.721	0.028	2.3	73	98	4.352	0.085	1.9
51	35	0.752	0.031	2.4	73	99	4.445	0.093	2.0
51	36	0.78	0.028	2.1	73	100	4.524	0.079	1.8
51	37	0.812	0.032	2.4	74	101	4.617	0.093	2.0
52	38	0.845	0.033	2.4	74	102	4.711	0.094	2.0
52	39	0.879	0.034	2.4	74	103	4.807	0.096	2.0
52	40	0.908	0.029	2.0	75	104	4.886	0.079	1.6
53	41	0.943	0.035	2.4	75	105	4.985	0.099	2.0
53	42	0.978	0.035	2.3	76	106	5.081	0.096	1.9
53	43	1.016	0.038	2.4	76	107	5.178	0.097	1.9
54	44	1.05	0.034	2.1	76	108	5.274	0.096	1.9
54	45	1.088	0.038	2.4	77	109	5.37	0.096	1.8
55	46	1.127	0.039	2.3	77	110	5.467	0.097	1.9
55	47	1.168	0.041	2.4	77	111	5.572	0.105	1.9
55	48	1.212	0.044	2.5	78	112	5.671	0.099	1.8
56	49	1.255	0.043	2.4	78	113	5.779	0.108	2.0
56	50	1.296	0.041	2.2	78	114	5.881	0.102	1.8
56	51	1.341	0.045	2.4	79	115	5.989	0.108	1.9
57	52	1.38	0.039	2.0	79	116	6.085	0.096	1.7
57	53	1.426	0.046	2.4	79	117	6.196	0.111	1.9
57	54	1.47	0.044	2.2	80	118	6.307	0.111	1.9
58	55	1.519	0.049	2.4	80	119	6.421	0.114	1.9
58	56	1.561	0.042	2.0	80	120	6.517	0.096	1.5
58	57	1.609	0.048	2.2	81	121	6.628	0.111	1.8
59	58	1.657	0.048	2.2	81	122	6.742	0.114	1.9
59	59	1.708	0.051	2.3	81	123	6.859	0.117	1.8
59	60	1.754	0.046	2.0	82	124	6.967	0.108	1.7
60	61	1.807	0.053	2.3	82	125	7.084	0.117	1.8
60	62	1.859	0.052	2.2	83	126	7.198	0.114	1.7
60	63	1.914	0.055	2.3	83	127	7.323	0.125	1.9

Table II.6-4. System Tonal Transfer for CCT of 9300K 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	7.425	0.102	1.5	106	192	17.47	0.2	1.5
84	129	7.551	0.126	1.8	106	193	17.67	0.2	1.4
84	130	7.67	0.119	1.8	106	194	17.87	0.2	1.4
84	131	7.799	0.129	1.8	107	195	18.08	0.21	1.5
85	132	7.91	0.111	1.6	107	196	18.26	0.18	1.2
85	133	8.041	0.131	1.8	107	197	18.47	0.21	1.5
85	134	8.164	0.123	1.7	108	198	18.68	0.21	1.4
86	135	8.298	0.134	1.8	108	199	18.89	0.21	1.4
86	136	8.409	0.111	1.5	108	200	19.08	0.19	1.3
86	137	8.543	0.134	1.7	109	201	19.29	0.21	1.4
87	138	8.669	0.126	1.7	109	202	19.5	0.21	1.4
87	139	8.806	0.137	1.7	109	203	19.72	0.22	1.4
87	140	8.925	0.119	1.6	110	204	19.91	0.19	1.3
88	141	9.065	0.14	1.7	110	205	20.13	0.22	1.4
88	142	9.201	0.136	1.7	111	206	20.34	0.21	1.3
88	143	9.34	0.139	1.7	111	207	20.56	0.22	1.4
89	144	9.5	0.16	2.0	111	208	20.79	0.23	1.4
89	145	9.646	0.146	1.7	112	209	21.02	0.23	1.4
90	146	9.786	0.14	1.7	112	210	21.24	0.22	1.4
90	147	9.932	0.146	1.7	112	211	21.47	0.23	1.4
90	148	10.06	0.128	1.4	113	212	21.67	0.2	1.2
91	149	10.21	0.15	1.8	113	213	21.9	0.23	1.3
91	150	10.36	0.15	1.7	113	214	22.13	0.23	1.4
91	151	10.51	0.15	1.6	114	215	22.36	0.23	1.3
92	152	10.64	0.13	1.5	114	216	22.526	0.166	1.0
92	153	10.79	0.15	1.6	114	217	22.79	0.264	1.5
92	154	10.94	0.15	1.6	115	218	23.03	0.24	1.4
93	155	11.09	0.15	1.6	115	219	23.26	0.23	1.3
93	156	11.23	0.14	1.5	115	220	23.48	0.22	1.2
93	157	11.39	0.16	1.6	116	221	23.73	0.25	1.4
94	158	11.55	0.16	1.7	116	222	23.96	0.23	1.3
94	159	11.71	0.16	1.6	116	223	24.2	0.24	1.3
94	160	11.85	0.14	1.4	117	224	24.43	0.23	1.2
95	161	12.02	0.17	1.7	117	225	24.68	0.25	1.4
95	162	12.17	0.15	1.5	118	226	24.92	0.24	1.2
95	163	12.33	0.16	1.6	118	227	25.17	0.25	1.3
96	164	12.49	0.16	1.5	118	228	25.39	0.22	1.2
96	165	12.66	0.17	1.6	119	229	25.64	0.25	1.3
97	166	12.82	0.16	1.5	119	230	25.87	0.23	1.2
97	167	12.99	0.17	1.6	119	231	26.13	0.26	1.3
97	168	13.13	0.14	1.3	120	232	26.35	0.22	1.1
98	169	13.31	0.18	1.7	120	233	26.61	0.26	1.3
98	170	13.47	0.16	1.4	120	234	26.85	0.24	1.2
98	171	13.65	0.18	1.6	121	235	27.11	0.26	1.3
99	172	13.78	0.13	1.2	121	236	27.34	0.23	1.1
99	173	13.97	0.19	1.6	121	237	27.6	0.26	1.3
99	174	14.14	0.17	1.5	122	238	27.87	0.27	1.3
100	175	14.32	0.18	1.6	122	239	28.12	0.25	1.1
100	176	14.48	0.16	1.3	122	240	28.38	0.26	1.3
100	177	14.69	0.21	1.8	123	241	28.65	0.27	1.2
101	178	14.86	0.17	1.4	123	242	28.89	0.24	1.2
101	179	15.05	0.19	1.6	123	243	29.17	0.28	1.2
101	180	15.21	0.16	1.3	124	244	29.42	0.25	1.2
102	181	15.4	0.19	1.5	124	245	29.68	0.26	1.2
102	182	15.58	0.18	1.5	125	246	29.95	0.27	1.2
102	183	15.78	0.2	1.5	125	247	30.24	0.29	1.3
103	184	15.94	0.16	1.3	125	248	30.47	0.23	1.0
103	185	16.13	0.19	1.5	126	249	30.76	0.29	1.3
104	186	16.32	0.19	1.4	126	250	31.03	0.27	1.2
104	187	16.52	0.2	1.5	126	251	31.29	0.26	1.1
104	188	16.69	0.17	1.3	127	252	31.55	0.26	1.1
105	189	16.89	0.2	1.5	127	253	31.81	0.26	1.1
105	190	17.08	0.19	1.4	127	254	32.1	0.29	1.2
105	191	17.27	0.19	1.4	128	255	32.4	0.3	1.3

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.

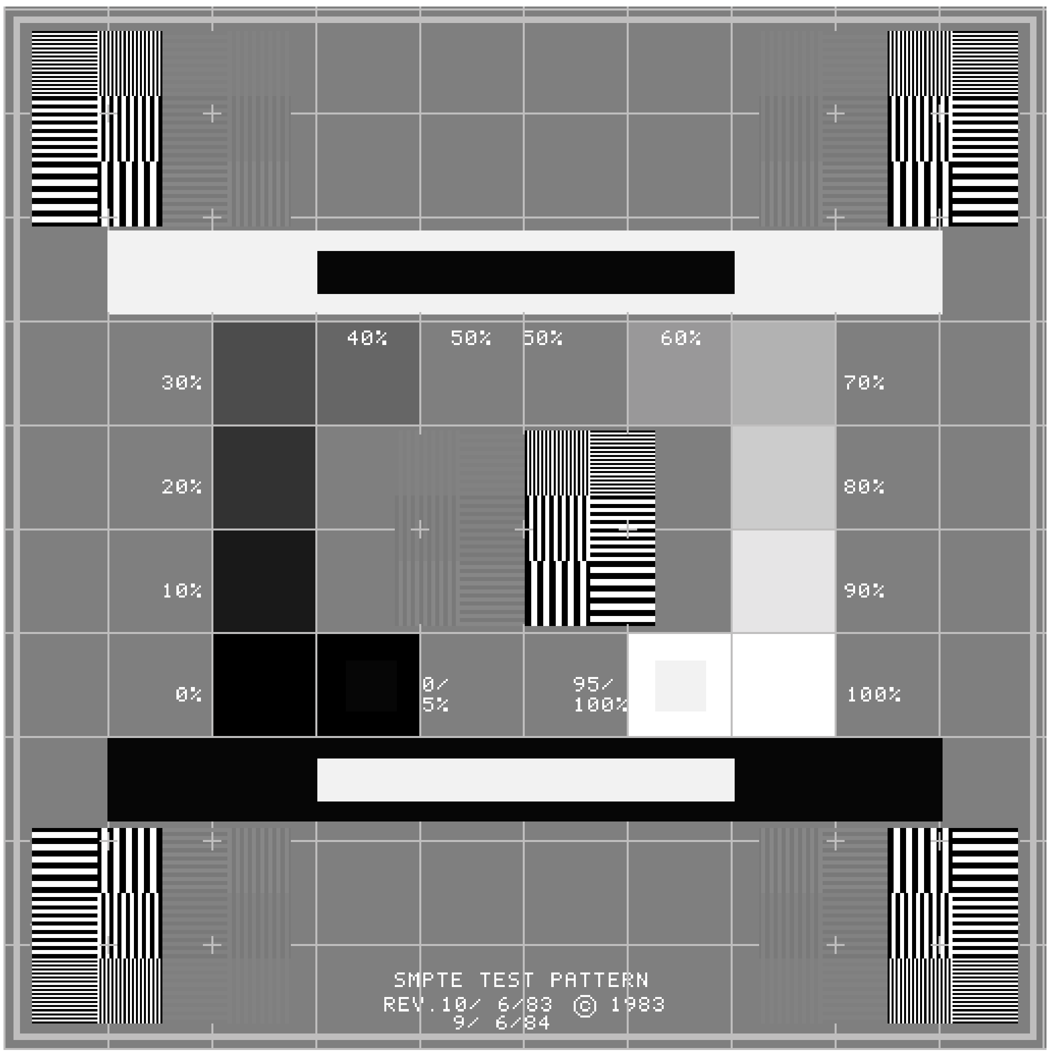


Figure II.8-1. SMPTE Test Pattern.

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-F520 monitor, signifying good electrical performance of the video circuits.

II.9. Monoscopic and Stereoscopic 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 1200 x 85 Hz, monoscopic mode; 1024 x 1024 x 121 up to 128 Hz, 1280 x 1024 x 121 Hz, stereoscopic mode.

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	Stereoscopic Modes
1600 x 1200 x 85 Hz	1024 x 1024 x 121 Hz 1280 x 1024 x 121 Hz 1024 x 1024 x 128 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 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.

Table II.10-1. Pixel Aspect Ratio

Addressability (H x V)	**1600 x 1200 full image**
H x V Image Size (inches)	15.288 x 11.405
H x V Average Pixel Spacing (mils)	9.56 x 9.50 mils
H x V Pixel Aspect Ratio	H = V + 0.6%

II.11. Screen Size (Viewable Active Image)

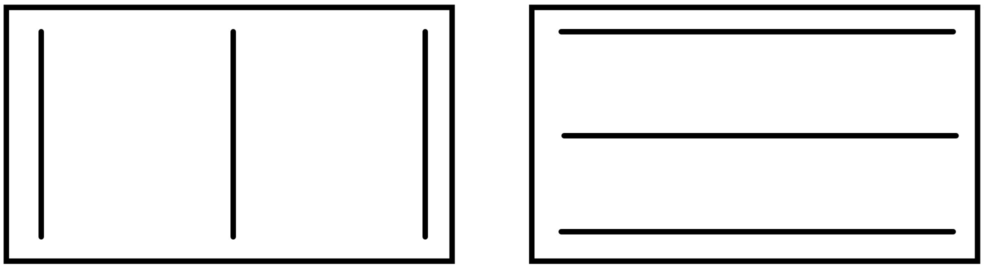
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size for 1600 x 1200 format was 19.074 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)	15.288 x 11.405 19.074

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 = 43% in Zone A of diameter 7.6 inches, and Zone A diameter of 9.42 inches (40% of image area). Cm exceeded 41% in Zone B. Moiré cancellation circuitry was turned OFF for this measurement. These values substantially exceed the IEC specifications. Contrast modulation for a vertical grille pattern (measurement in the horizontal direction) is somewhat lower for a 9300K setting than for 6500K. The horizontal grille values (measurement in the vertical direction) are virtually identical for both 9300K and 6500K.

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

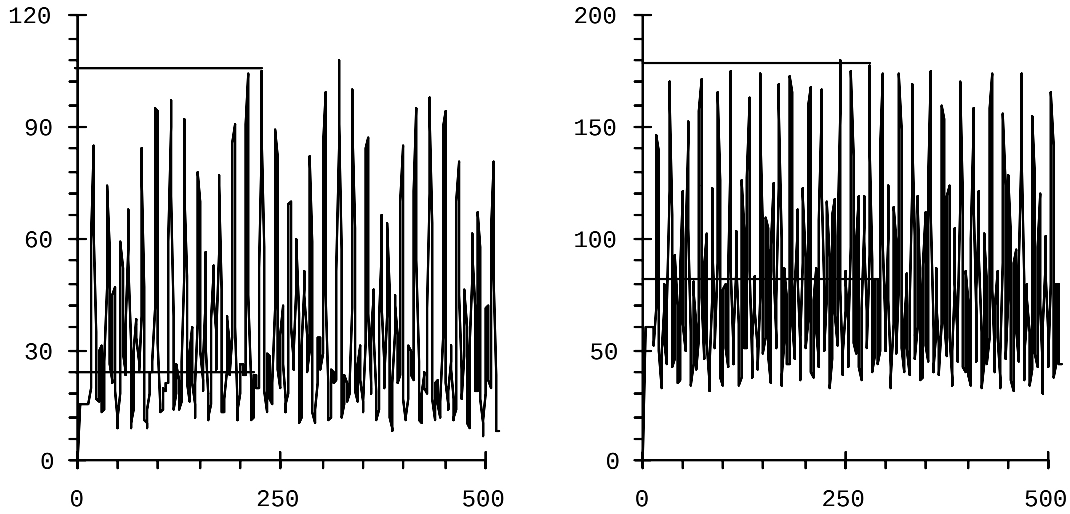
Procedure: The maximum video modulation frequency for each format (1024 x 1024, 1920 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen 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.

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

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

CCT Set to 6941K

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	53%	62%			44%	66%			49%	63%
			49%	66%	45%	67%	47%	66%		
Major	62%	61%	54%	65%	46%	68%	53%	66%	60%	63%
			47%	67%	43%	70%	52%	67%		
Bottom	50%	66%			41%	71%			61%	66%

Zone A = 9.42-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	53%	62%			44%	66%			49%	63%
			49%	65%	44%	66%	47%	66%		
Major	62%	61%	56%	64%	46%	68%	54%	65%	60%	63%
			48%	67%	42%	71%	53%	67%		
Bottom	50%	66%			41%	71%			61%	66%

CCT Set to 9300K

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	63%	56%			44%	59%			63%	42%
			50%	56%	43%	58%	51%	50%		
Major	60%	47%	51%	52%	42%	56%	55%	58%	68%	59%
			48%	51%	43%	56%	52%	56%		
Bottom	56%	42%			43%	55%			66%	55%

Zone A = 9.42-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%	56%			44%	59%			63%	42%
			52%	56%	44%	59%	53%	49%		
Major	60%	47%	53%	51%	42%	56%	58%	58%	68%	59%
			49%	49%	43%	55%	54%	56%		
Bottom	56%	42%			43%	55%			66%	55%

II.13. Pixel Density

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

Pixel density was 105 ppi as tested 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
H x V Addressability, Pixels	1600 x 1200
H x V Image Size, Inches	15.288 x 11.405
H x V Pixel Density, ppi	105 x 105 ppi

II.14. Moiré

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

Phosphor-to-pixel spacing ratio is 0.91 at screen center for the 1600 x 1200 format and passes the IEC specification. 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	1600 x 1200
Phosphor Pitch, horizontal	0.22 mm
Pixel Spacing, horizontal	9.56 mils (0.243 mm)
Phosphor-to-Pixel-Spacing	0.91

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.

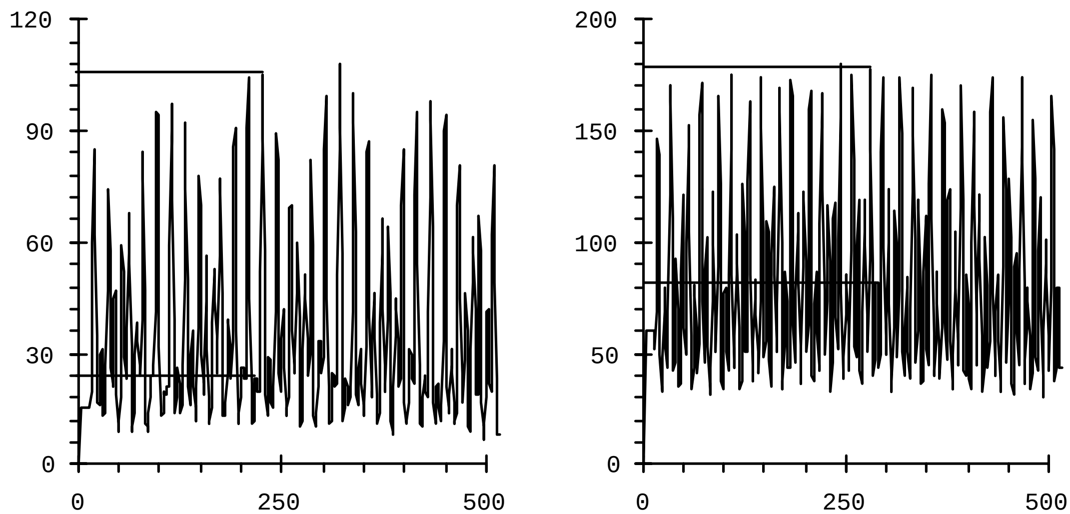


Figure II.14-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

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

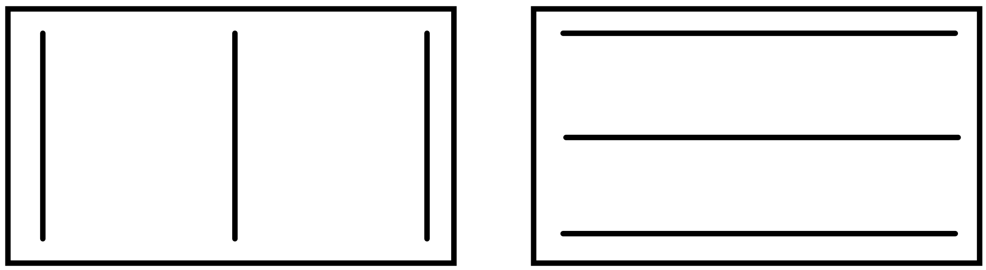
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.15% of the image width or height and passes the IEC specification.

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.

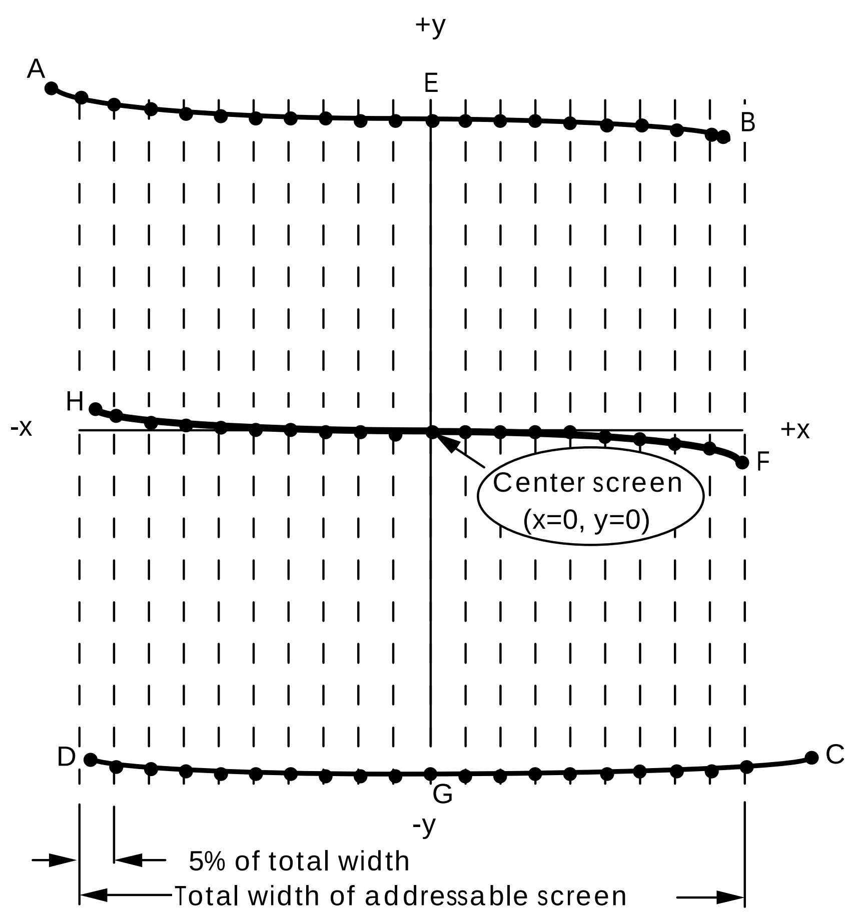


Figure II.15-2. Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

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
-7605	5719	-7637	-5675	-7613	-5	-14	5704	-7605	5719	7691	5689
-7200	5719	-7200	-5676	-7200	-5	-17	5400	-7602	5400	7686	5400
-6400	5716	-6400	-5681	-6400	-3	-18	4800	-7602	4800	7685	4800
-5600	5712	-5600	-5683	-5600	-1	-16	4200	-7602	4200	7686	4200
-4800	5709	-4800	-5685	-4800	-1	-12	3600	-7604	3600	7686	3600
-4000	5707	-4000	-5688	-4000	0	-8	3000	-7605	3000	7686	3000
-3200	5706	-3200	-5691	-3200	0	-5	2400	-7605	2400	7683	2400
-2400	5706	-2400	-5694	-2400	1	-2	1800	-7605	1800	7678	1800
-1600	5706	-1600	-5697	-1600	1	0	1200	-7605	1200	7670	1200
-800	5706	-800	-5700	-800	1	0	600	-7607	600	7668	600
0	5706	0	-5702	0	0	0	0	-7610	0	7667	0
800	5704	800	-5704	800	-1	0	-600	-7613	-600	7665	-600
1600	5702	1600	-5706	1600	-4	-1	-1200	-7620	-1200	7664	-1200
2400	5700	2400	-5707	2400	-6	-4	-1800	-7627	-1800	7663	-1800
3200	5698	3200	-5707	3200	-8	-5	-2400	-7628	-2400	7661	-2400
4000	5694	4000	-5707	4000	-13	-9	-3000	-7628	-3000	7652	-3000
4800	5693	4800	-5709	4800	-16	-13	-3600	-7628	-3600	7646	-3600
5600	5693	5600	-5712	5600	-19	-16	-4200	-7629	-4200	7643	-4200
6400	5692	6400	-5716	6400	-22	-18	-4800	-7629	-4800	7643	-4800
7200	5689	7200	-5722	7200	-25	-19	-5400	-7631	-5400	7642	-5400
7691	5689	7647	-5727	7671	-28	-22	-5702	-7635	-5675	7646	-5727

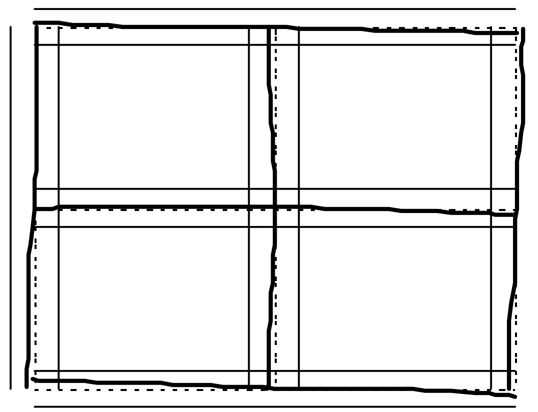


Figure II.15-3. Waviness of Sony GDM-F520 color monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

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

Vertical refresh rate for 1600 x 1200 format was set to 85 Hz. Vertical refresh rate for the 1024 x 1024 or 1280 x 1024 stereo format was set to 121 Hz. The maximum vertical refresh rate achieved at 1024 x 1024 is 128.2 Hz, and at 1280 x 1024 is 129.4 Hz.

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	85.0 Hz 106.250 kHz	121-128.2 Hz 130.243 – 137.969 kHz

II.17. Extinction Ratio

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

Stereo extinction ratio using the StereoGraphics ZScreen and passive polarized glasses averaged 12:1 (12.6 left, 12.3 right) at screen center. Luminance of white varied by up to 9.6 % across the screen. Chromaticity variations of white were less than 0.006 delta u'v' units.

Stereo extinction ratio using StereoGraphics LC shutter glasses averaged 21 to 1 (21.3 left, 19.9 right) at screen center, and 11 to 1 along the bottom of the screen when tested in 1024 x 1024 x 121 Hz (60.5 Hz per eye) mode. Luminance of white varied by up to 17.3% across the screen.

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.

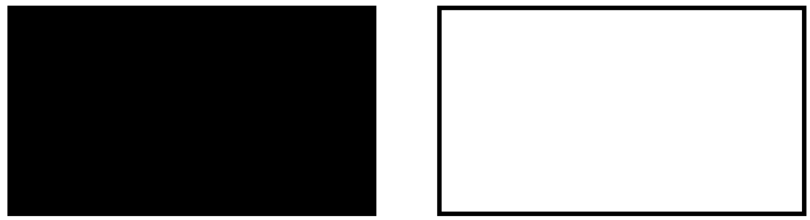
Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

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

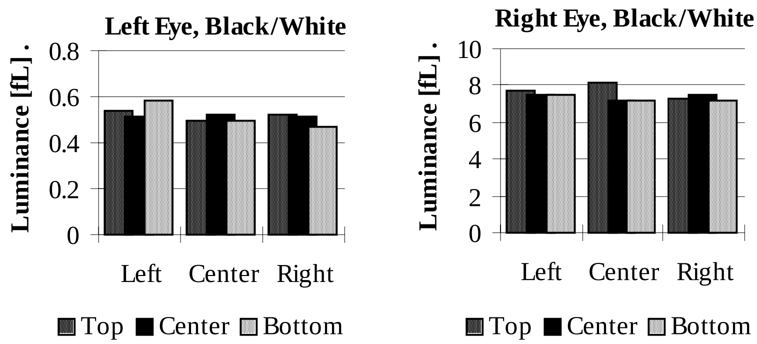
Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

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 ZScreen LC Shutter with Passive Glasses



StereoGraphics CrystalEyes Active Glasses

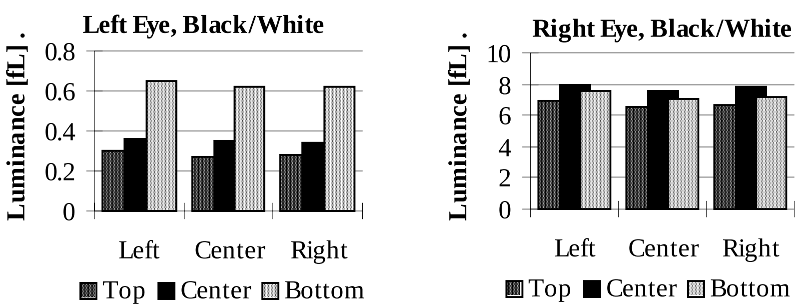
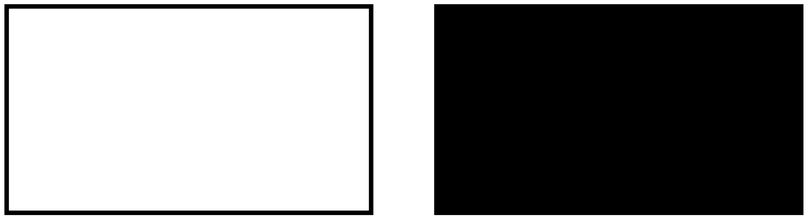
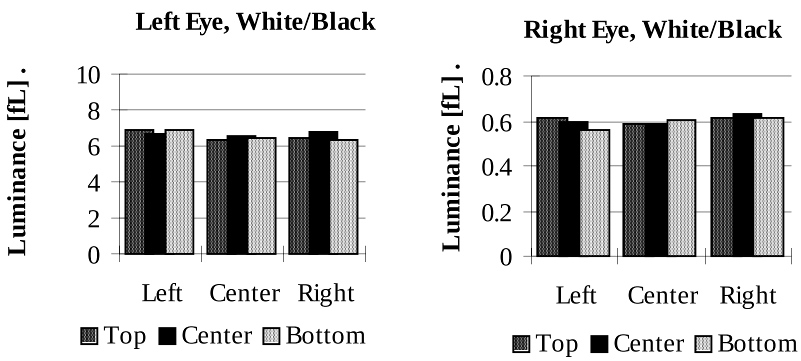


Figure II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.



Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses



StereoGraphics CrystalEyes Active Glasses

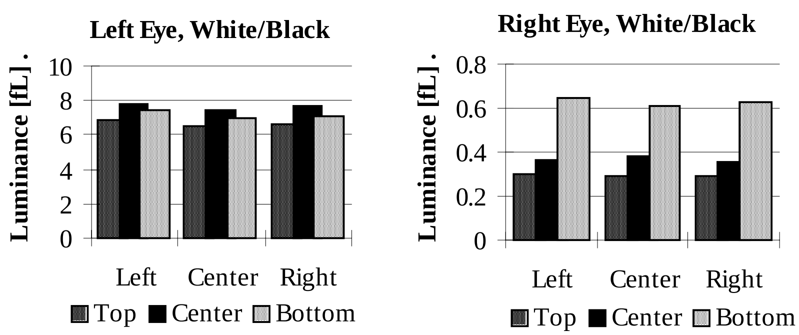


Figure II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

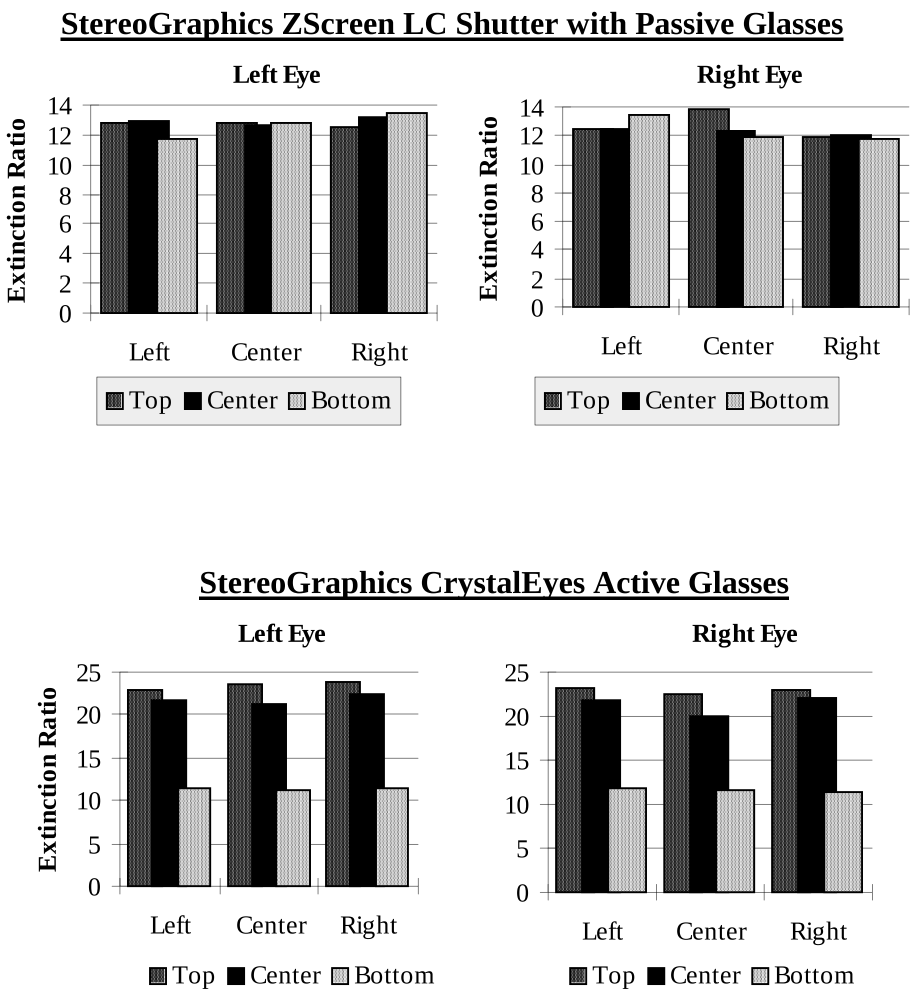
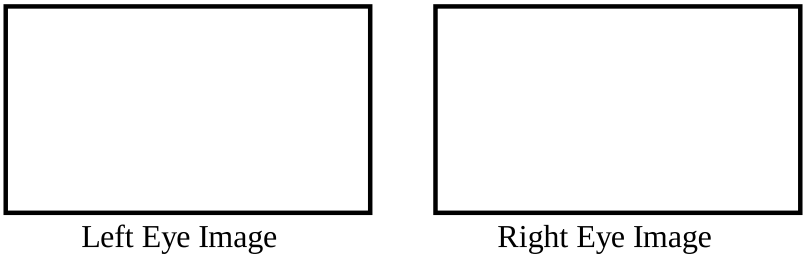
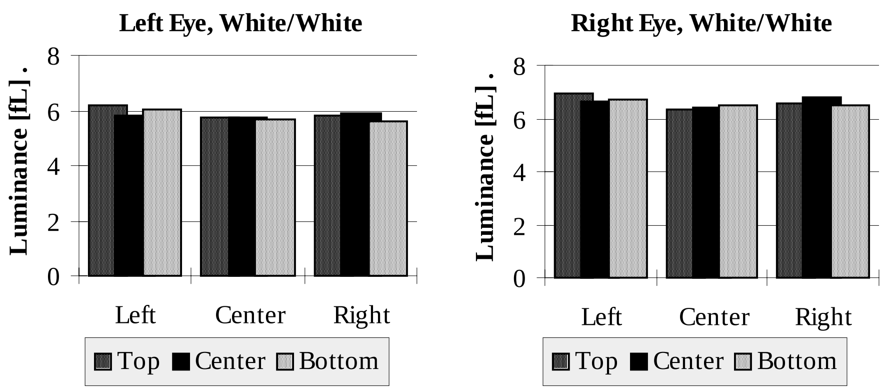


Figure II.17-3. Spatial Uniformity of extinction ratio in stereo mode.



StereoGraphics ZScreen LC Shutter with Passive Glasses



StereoGraphics CrystalEyes Active Glasses

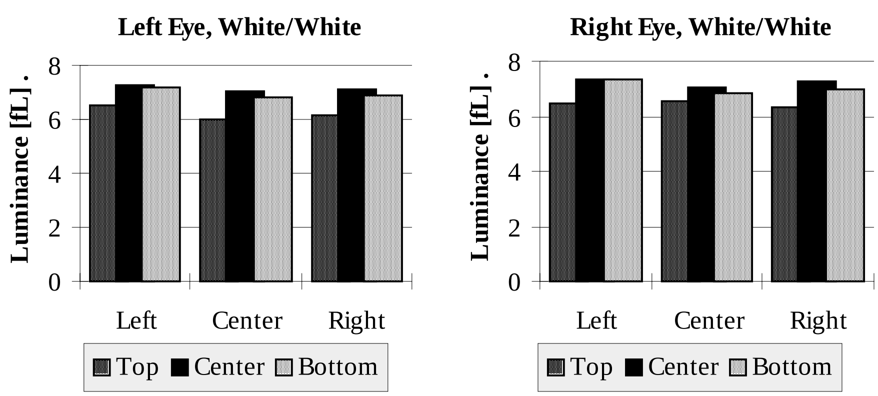
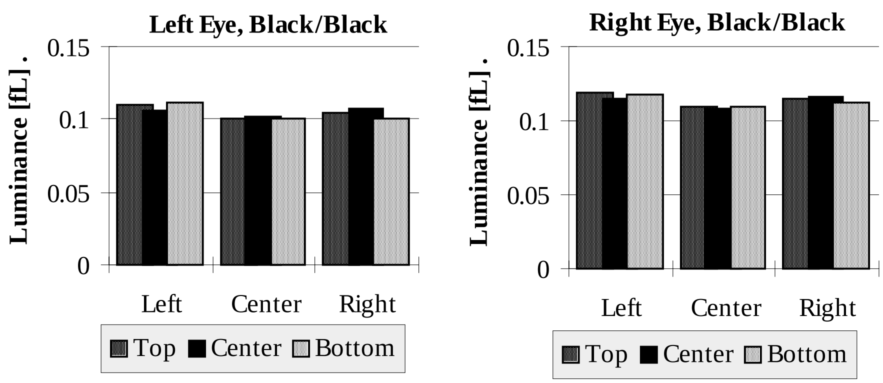


Figure II.17-4. Spatial uniformity of luminance of white in stereo mode.

Left Eye Image

Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses



StereoGraphics CrystalEyes Active Glasses

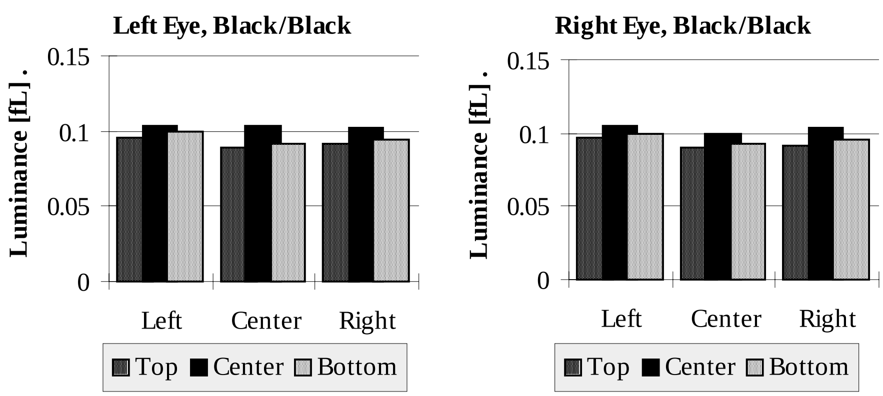
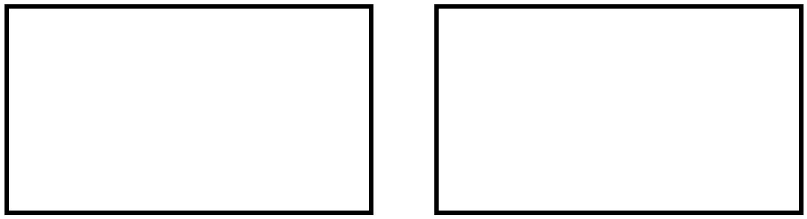


Figure II.17-5. Spatial uniformity of luminance of black in stereo mode.



Left Eye Image Right Eye Image

StereoGraphics ZScreen LC Shutter with Passive Glasses

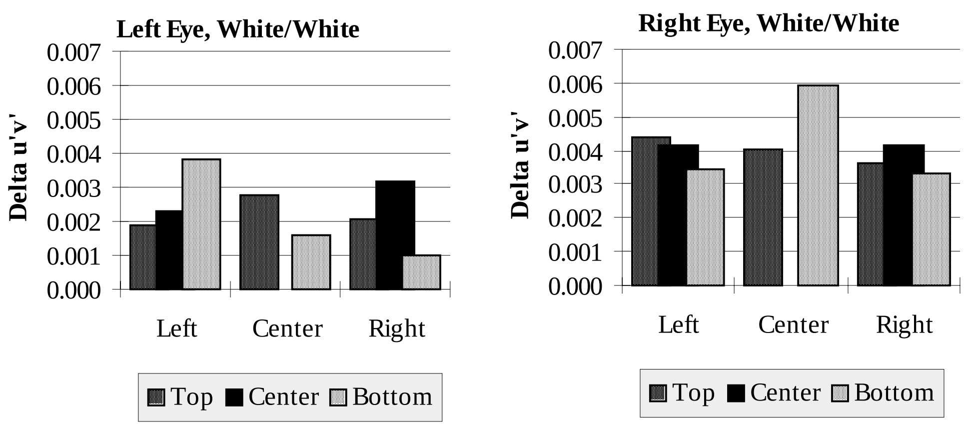


Figure II.17-6. Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

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

The maximum nonlinearity of the scan was 0.81% of full screen and passes the IEC specification.

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.

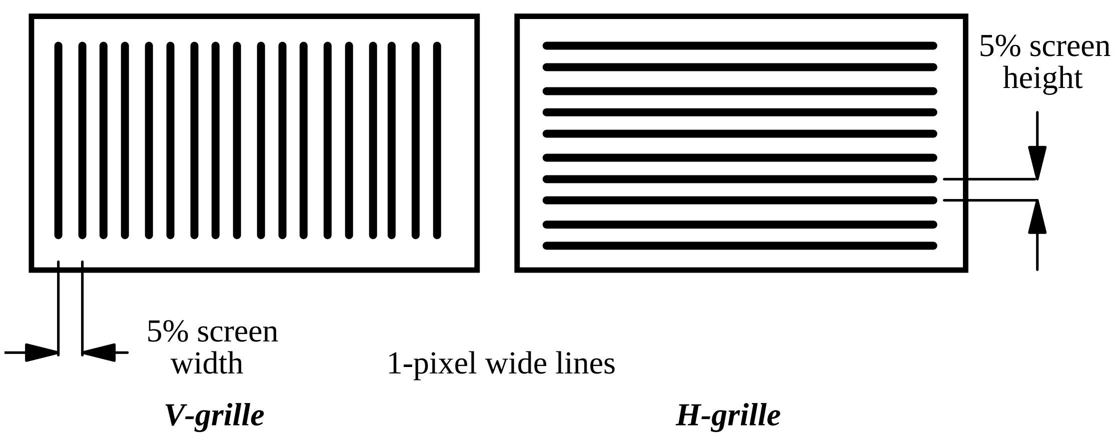


Figure II.18-1. *Grille patterns for measuring linearity*

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.

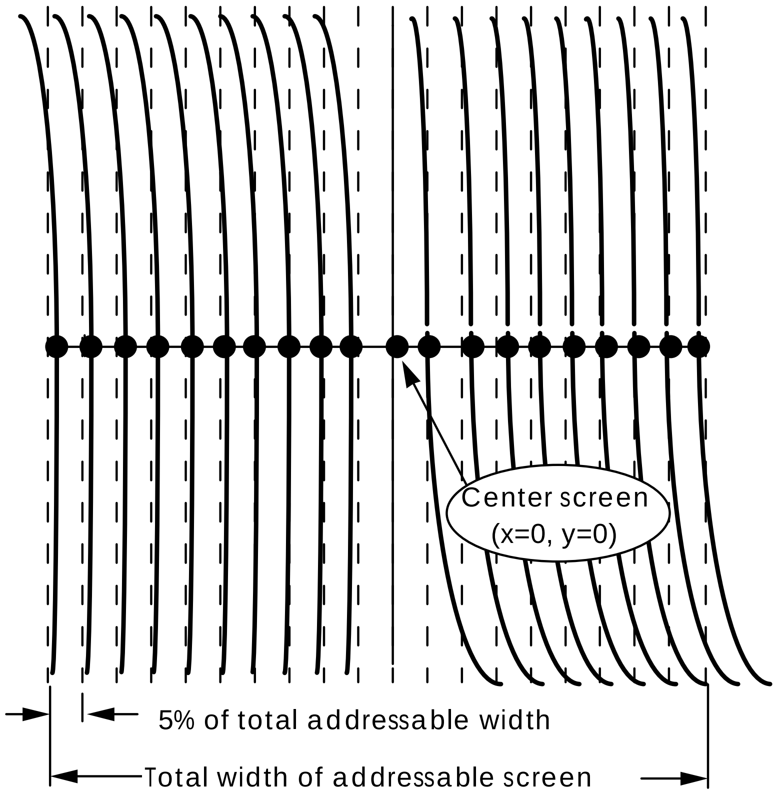


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

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
1600 x 1200	-0.54%	0.81%	0.12%	-0.04%

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
-7531	7573	5623	-5612
-6776	6818	5061	-5053
-6014	6049	4497	-4493
-5246	5275	3933	-3931
-4483	4506	3369	-3369
-3725	3739	2805	-2808
-2975	2980	2244	-2247
-2230	2231	1684	-1686
-1488	1487	1122	-1124
-746	744	560	-562
0	0	0	0

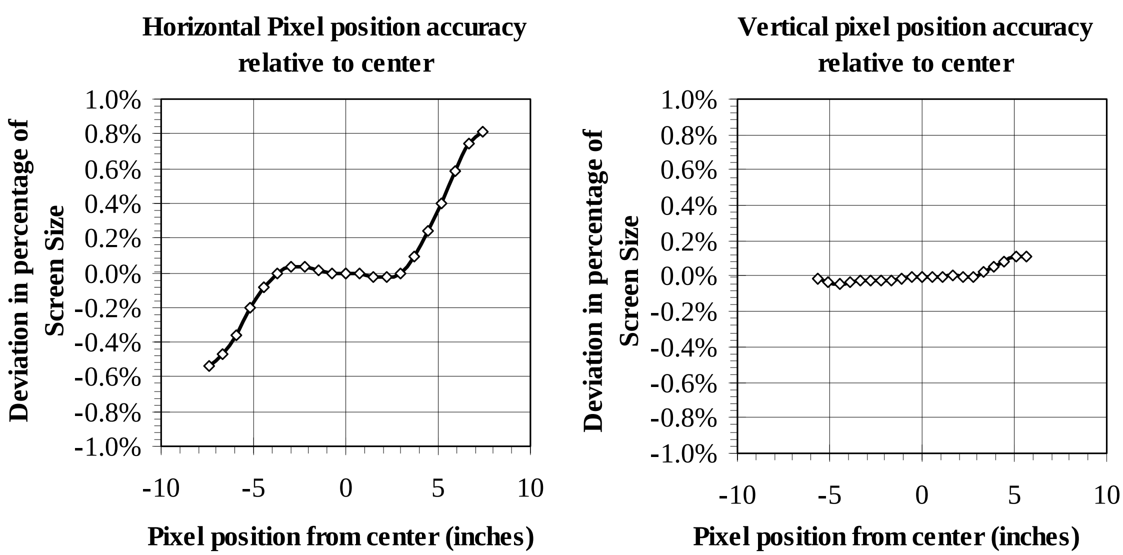


Figure II.18-3. Horizontal and Vertical Linearity Characteristics.

II.19. Jitter/Swim/Drift

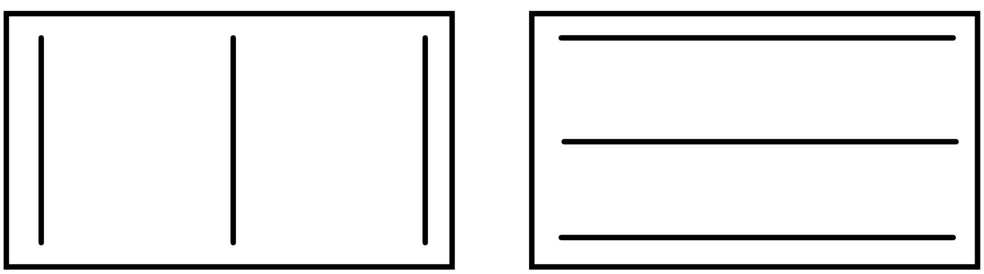
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift were 3.57 mils and 4.27 mils, respectively, and pass the IEC specification.

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

1600 x 1200 x 85 Hz

	Max Motions	H-lines	V-lines	
Center				
	Jitter	1.01	3.79	
	Swim	1.11	4.28	
	Drift	1.16	4.53	
Black Tape				
	Jitter	0.218	0.222	
	Swim	0.211	0.236	
	Drift	0.252	0.259	
Less Tape Motion				maximums
	Jitter	0.79	3.57	3.57
	Swim	0.90	4.04	4.04
	Drift	0.91	4.27	4.27
10D corner				
	Jitter	1.03	3.39	
	Swim	1.10	3.76	
	Drift	1.18	3.86	
Black Tape				
	Jitter	0.206	0.264	
	Swim	0.224	0.301	
	Drift	0.232	0.312	
Less Tape Motion				maximums
	Jitter	0.82	3.13	3.13
	Swim	0.88	3.46	3.46
	Drift	0.95	3.55	3.55

II.20. Warm-up Period

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

A 60-minute warm-up was necessary for Lmin to stabilize within 10% of its final value.

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 1600 x 1200 format in graphical form. The luminance remains very stable after 60 minutes.

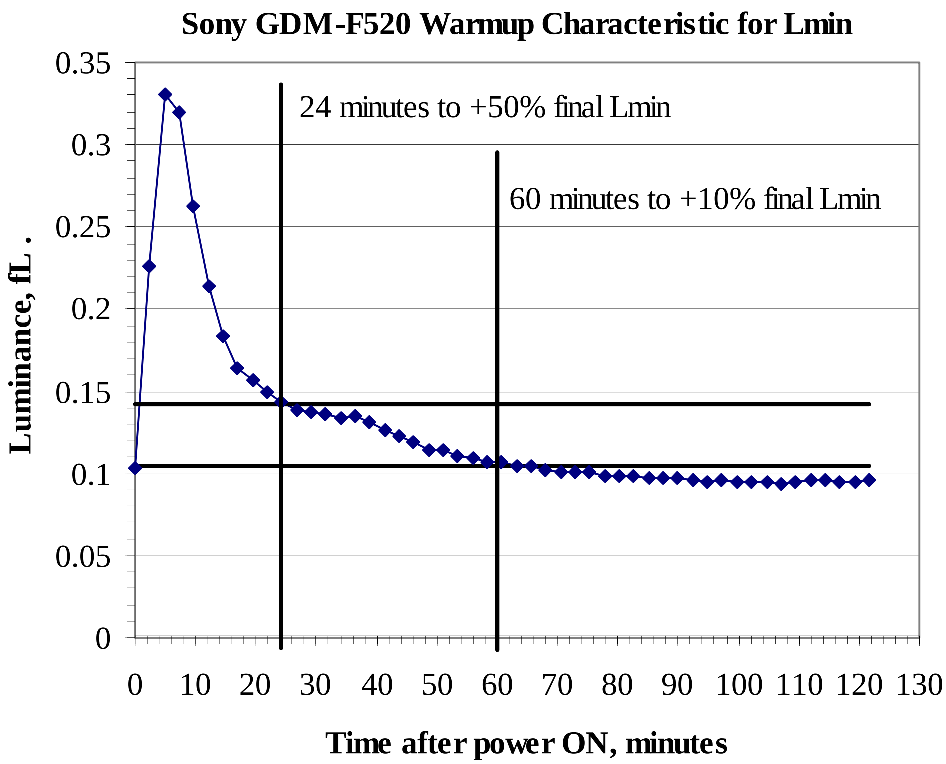


Figure II.20-1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0.

II. 21. Briggs Scores

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

Briggs scores for the BTP #4 Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets averaged 8, 46, 57 and 61, respectively, for the GDM-F520 monitor. These scores were comparable to the FW900 monitor and are slightly better than the scores for the ViewSonic P815, the Cornerstone p1700 and the Cornerstone p1750 monitors. The reported values are base scores.

The Briggs series of test targets illustrated in Figures II.21-1 were developed to visually evaluate the image quality of grayscale monitors. Three NIDL observers selected the maximum scores for each target set shown in Figure II.21-2 displayed on the Sony F520 color CRT monitor driven using a Quantum Data 8701 400 MHz programmable test pattern generator. For comparison, Briggs scores are also shown for the Sony FW900 24-inch CRT color monitor and the ViewSonic P815 21-inch color CRT monitor. Magnifying devices were used when deemed by the observer to be advantageous in achieving higher scores.

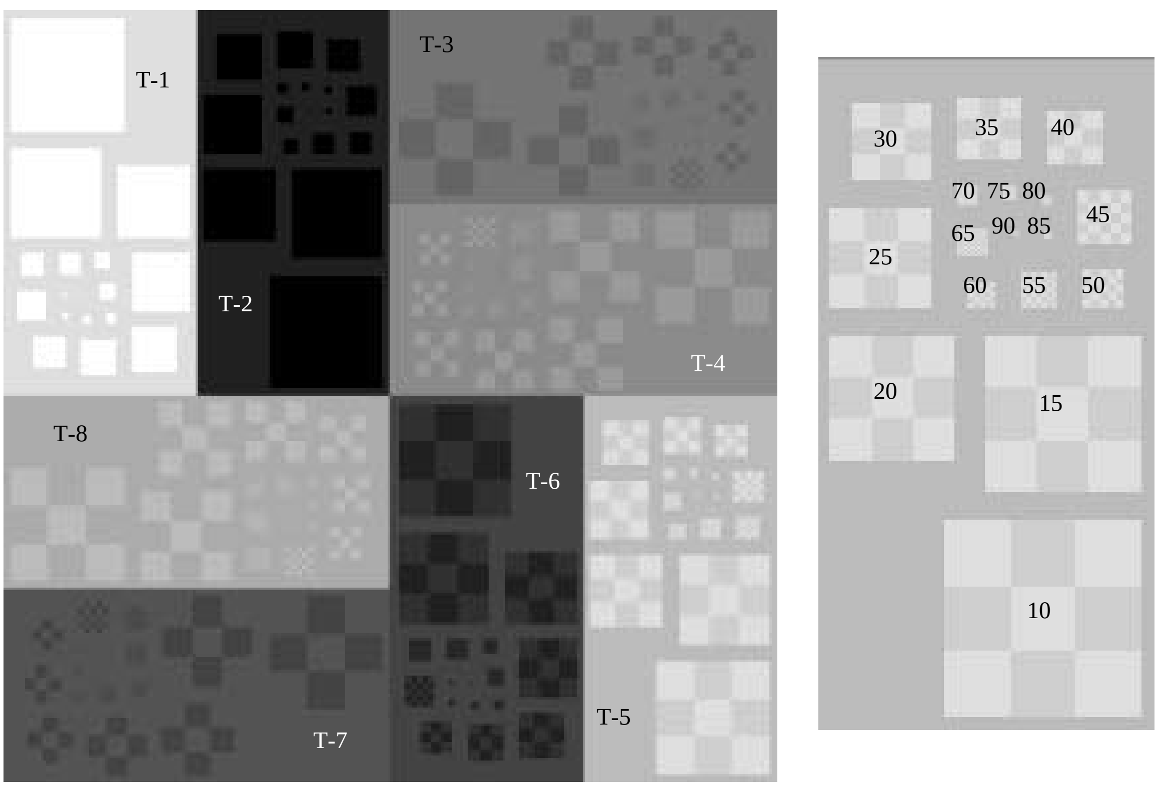


Figure II.21-1. Briggs BPT#4 Test Patterns comprised of 8 targets labeled T-1 through T-8. A series of 17 checkerboards are contained within each of the 8 targets. Each checkerboard is assigned a score value ranging from 10 to 90. Higher scores are assigned to smaller checkerboards.

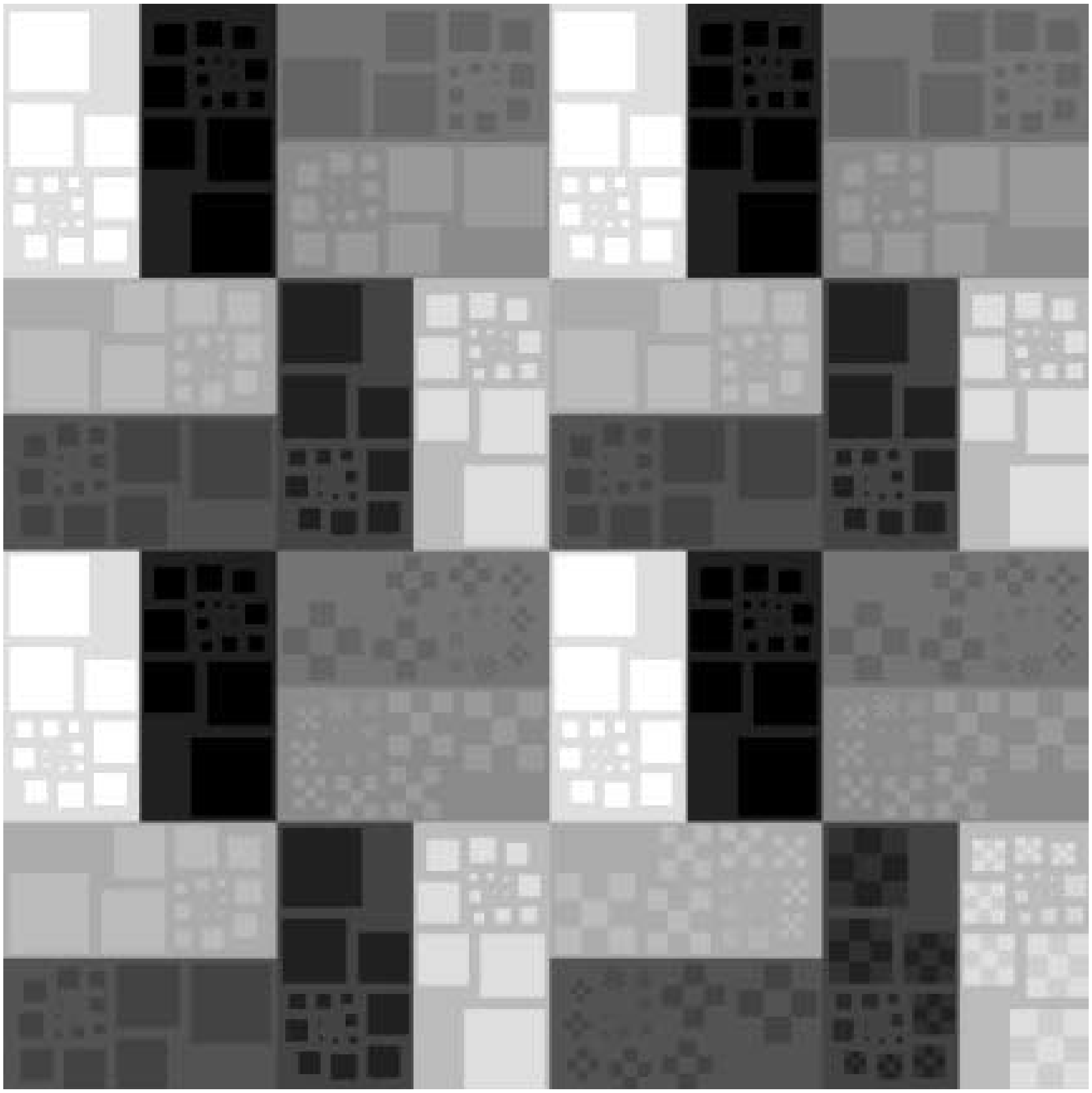


Figure II.21-2. 1024 x 1024 mosaic comprised of four 512 x 512 Briggs BPT#4 Test Patterns. The upper left quadrant contains the set of 8 Briggs targets with command contrast of delta 1. The upper right quadrant contains command contrast of delta 3. Delta 7 targets are in the lower left quadrant and delta 15 targets are in the lower right.

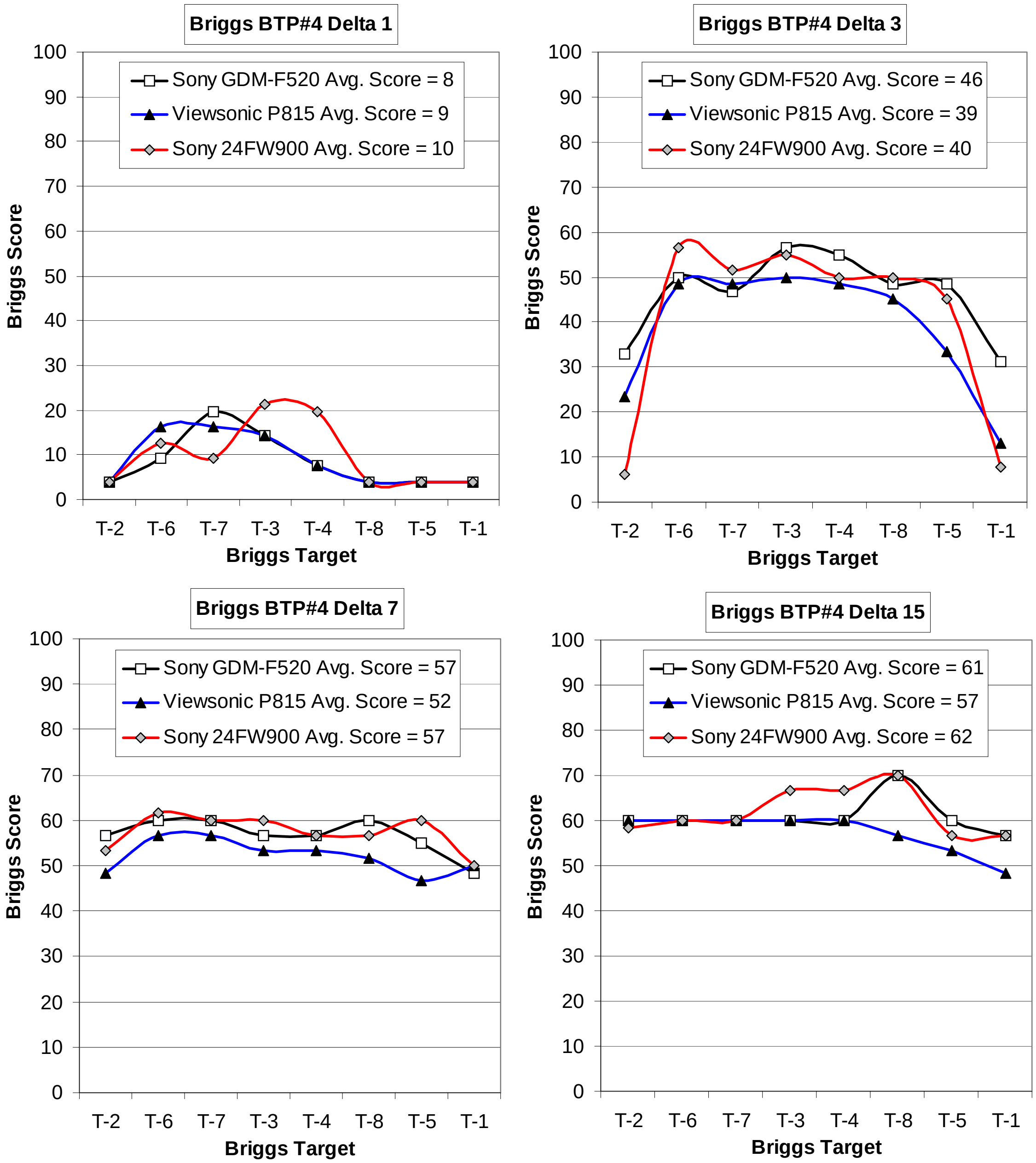


Figure II.21-3. Briggs Scores averaged for three NIDL observers for Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratios on BPT#4 Test Patterns for the Sony GDM-F520 21-inch flat face CRT monitor compared to the Sony FW900 24-inch flat face CRT monitor and the ViewSonic P815 21-inch color CRT monitor.

II. 22. Output Luminance with Color Temperature Setting

The luminance of a white full screen, Lmax, is approximately 15% higher at 9300K compared to 6500K. Selection of the dynamic mode at 9300K results in the highest Lmax, 33.59 fL. This compares to the Lmax value of 20.92 fL if the professional mode at 6500K is selected. It should be noted that adjusting RGB Gain could further increase Lmax.

The Sony F520 color monitor has three preset luminance modes: professional, standard, and dynamic. It also has 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 for 6500 K and 9300 K preset color temperatures. These results are shown in Table II.22-1. The output luminance is approximately 15% higher at 9300K compared to 6500K. Some within the IEC community have advocated 6500K as being closer to natural light, and therefore appropriate for viewing color imagery taken in daylight. However, a CCT of 9300K is a factory default setting for a number of color monitors and more closely matches that of monochrome monitors used for exploitation. This data also shows that the maximum output luminance increases by approximately 21% by selecting from the professional mode to the standard mode, and by approximately 16% by selecting from the standard mode to the dynamic mode.

Table II.22-1 Measured Luminance for 6500K and 9300K Preset Modes

Mode	Professional		Standard		Dynamic	
CCT Preset	6500 K	9300 K	6500 K	9300 K	6500 K	9300 K
Lmin, fL	0.101	0.098	0.100	0.099	0.100	0.098
Lmax, fL	20.92	24.11	25.36	29.06	29.48	33.59

NOTE: Luminance can be further increased by adjusting RGB Gain.

II. 23. Electron Beam Line Width and RAR

The Sony F520 achieves, on average, 29% smaller line widths at the 50% intensity level compared to the ViewSonic P815. The RAR for the Sony F520 averages 0.5 H x 1.0 V compared to 1.3 H x 0.9 V for the ViewSonic P815.

The monitors also differ significantly in that the F520 linewidths are more constant over the entire luminance range while the ViewSonic P815 linewidths increase by up to 87% between 7fL to 29fL.

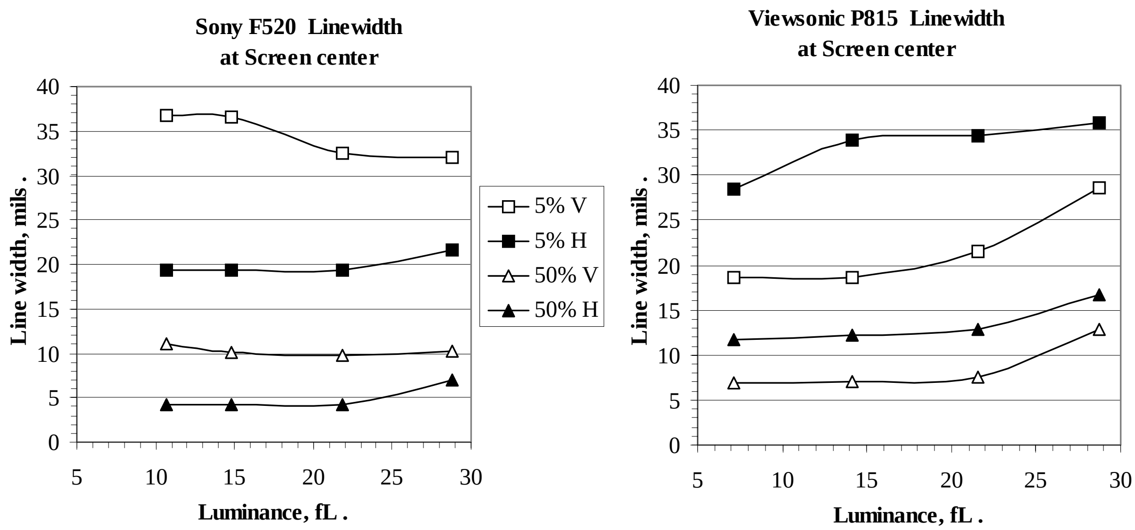


Figure II.23-1. Electron beam line widths measured at screen center as a function of luminance for the Sony F520 and ViewSonic P815 color CRT monitors.

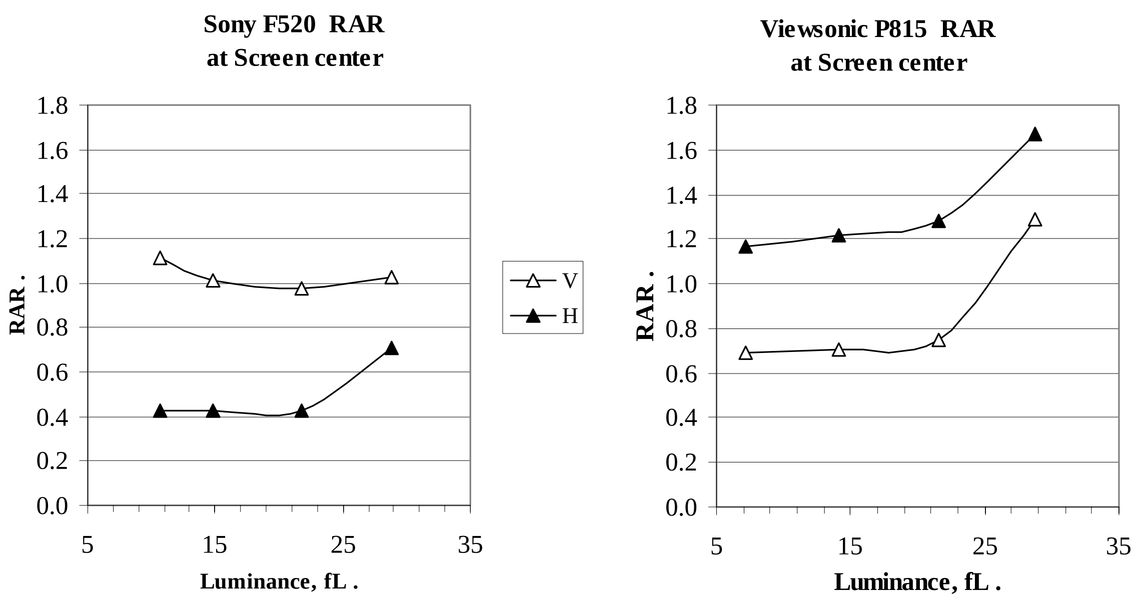


Figure II.23-2. Resolution-Addressability-Ratios computed for 100 ppi using line widths measured at screen center as a function of luminance for the Sony F520 and ViewSonic P815 color CRT monitors.

Table II.23-1 Sony GDM-520 and ViewSonic P815 Linewidths at Center Screen

Luminance set using front panel contrast control.

Luminance	Vertical Percent Peak of H-Lines		Horizontal Percent Peak of V-Lines		Average H,V Percent Peak of V-Lines	
Sony F520 Linewidths at Center Screen						
fL	50% V	5% V	50% H	5% H	50% H,V	5% H,V
28.8	10.3	32.0	7.1	21.6	8.7	26.8
21.8	9.8	32.6	4.2	19.4	7.0	26.0
14.8	10.1	36.6	4.3	19.4	7.2	28.0
10.6	11.1	36.8	4.2	19.4	7.7	28.1
Average	10.3	34.5	5.0	20.0	7.6	27.2
ViewSonic P815 Linewidths at Center Screen						
fL	50% V	5% V	50% H	5% H	50% H,V	5% H,V
28.7	12.9	28.6	16.7	35.8	14.8	32.2
21.5	7.5	21.6	12.8	34.4	10.1	28.0
14.2	7.1	18.6	12.2	33.9	9.6	26.3
7.1	6.9	18.7	11.7	28.4	9.3	23.6
Average	8.6	21.9	13.4	33.1	11.0	27.5
Difference, F520 - P815						
fL	50% V	5% V	50% H	5% H	50% H,V	5% H,V
28.7	-20%	12%	-58%	-40%	-41%	-17%
21.5	30%	51%	-67%	-44%	-31%	-7%
14.2	43%	97%	-65%	-43%	-25%	7%
7.1	61%	97%	-64%	-32%	-18%	19%
Average	28%	64%	-63%	-39%	-29%	1%

Sony GDM-520

Contrast Control	Horizontal Profile of Vertical Line	Vertical Profile of Horizontal Line
100% 28.8 fL		
75% 21.8 fL		
50% 14.8 fL		
25% 10.6 fL		

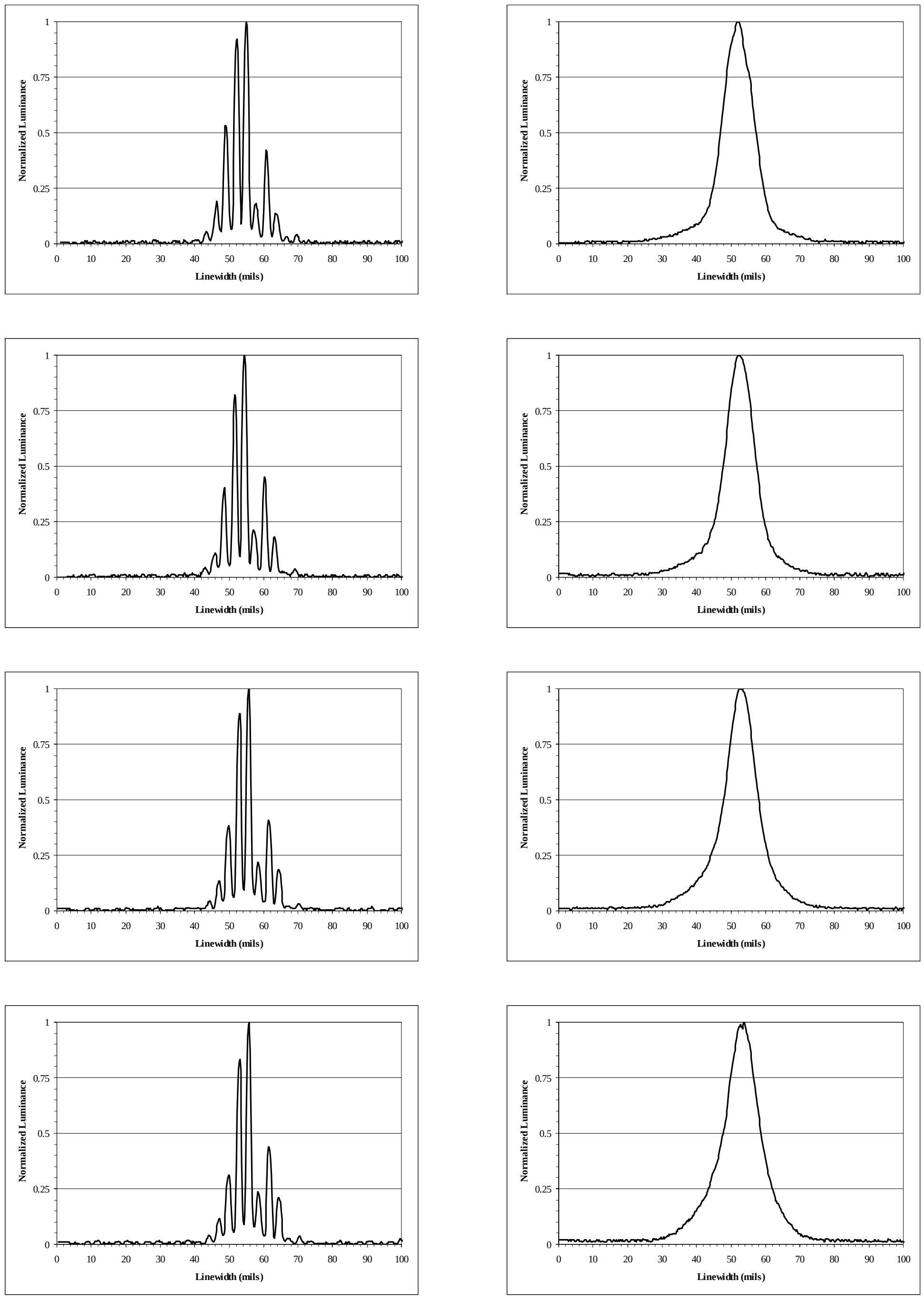


Figure II.23-3. Electron beam line widths measured at screen center for the Sony F520 color monitor with Trinitron CRT. The individual R, G, and B phosphor stripes are evident only along the horizontal line profiles.

ViewSonic P815

Contrast Control	Horizontal Profile of Vertical Line	Vertical Profile of Horizontal Line
100% 29.4 fL		
75% 22.3 fL		
50% 14.8 fL		
25% 7.38 fL		

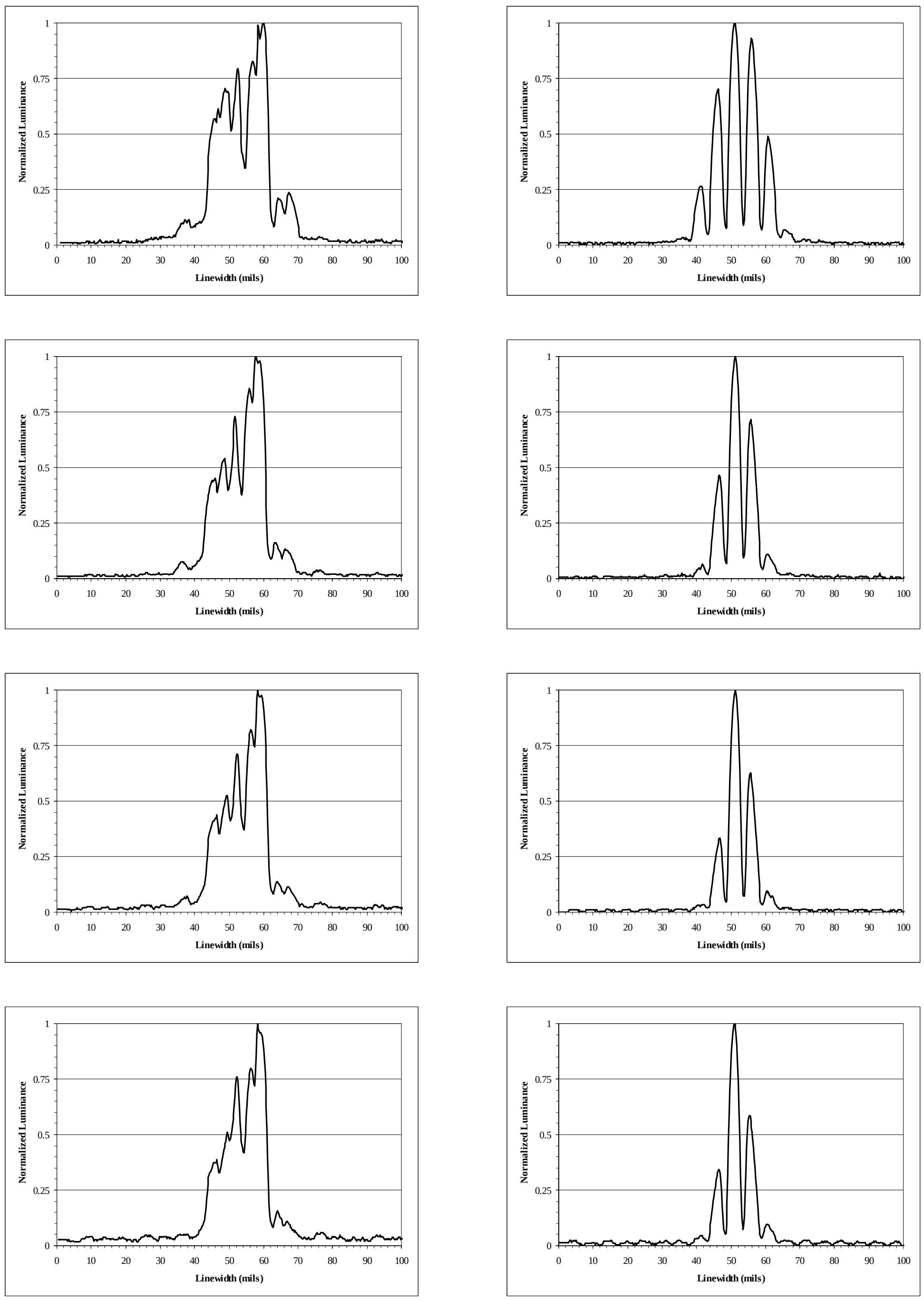


Figure II.23-4. Electron beam line widths measured at screen center for the ViewSonic P815 color monitor with phosphor dot shadowmask CRT. The individual R, G, and B phosphor dot triads are evident along both the horizontal and vertical line profiles.

II. 24. Electron Beam Line Contrast

The contrast modulations of 1 pixel wide white lines on 7 pixel wide black backgrounds and 1 pixel wide black lines on 7 pixel wide white backgrounds were measured for the Sony F520 monitor with Trinitron CRT, and compared to the ViewSonic P815 monitor with phosphor dot shadowmask CRT. White lines are displayed with about the same contrast on both monitors and averaged greater than 90% over luminance values ranging from 10 to 29 fL. The Sony F520 displayed better white or black line contrast than the ViewSonic P815 at the highest luminance setting of 29 fL did. For lower luminances (7fL to 22 fL) horizontal black lines are displayed with slightly more contrast on the ViewSonic P815 (60-66% versus 42-53%) while vertical black lines are displayed with slightly more contrast on the Sony F520 (71-75% versus 58-64%).

Table II.24-1 Measured Line Contrast Modulation

	Sony GDM-F520			**ViewSonic P815**		
	Luminance	H-line	V-line	Luminance	H-line	V-line
White Line (1-line-on/7-lines-off)						
	28.8 fL	94%	93%	29.4 fL	91%	90%
	21.8 fL	92%	93%	22.3 fL	93%	92%
	14.8 fL	96%	95%	14.8 fL	92%	91%
	10.6 fL	91%	94%	7.38 fL	91%	90%
Black Line (7-lines-on/1-line-off)						
	28.8 fL	51%	61%	29.4 fL	44%	50%
	21.8 fL	53%	71%	22.3 fL	60%	58%
	14.8 fL	48%	71%	14.8 fL	66%	64%
	10.6 fL	42%	75%	7.38 fL	64%	61%

II. 25. Electron Beam Spot Size

The FWHM spot size in the vertical direction averages 9.03 +/-0.98 mils across the entire screen, and in the horizontal direction averages 11.84 +/-1.86 mils across the entire screen.

Table II.25-1 Measured Spot Size in Mils
Full Width Half Maximum
Shown according to position on the screen.

Horizontal direction	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction	Vertical direction
15.5	9.0	10.7	10.5	10.9	8.2
10.5	8.6	10.5	9.5	14.5	7.8
11.1	9.0	12.0	10.5	10.9	8.2

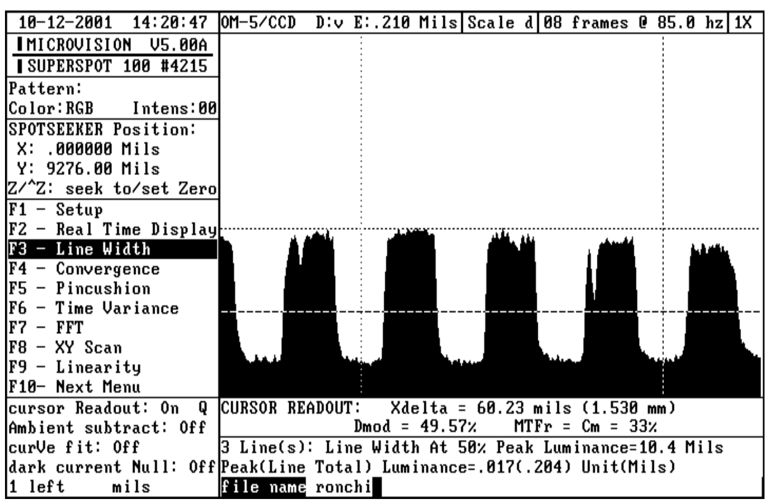


Figure II.25-1. Spatial calibration for the CCD optic module used for the electron beam spot size measurements is shown above. The Ronchi ruling consists of 10-mil wide stripes spaced apart on 20-mil centers. Measurement accuracy is shown to be within 4%.

White Spot Contours at 6500K CCT

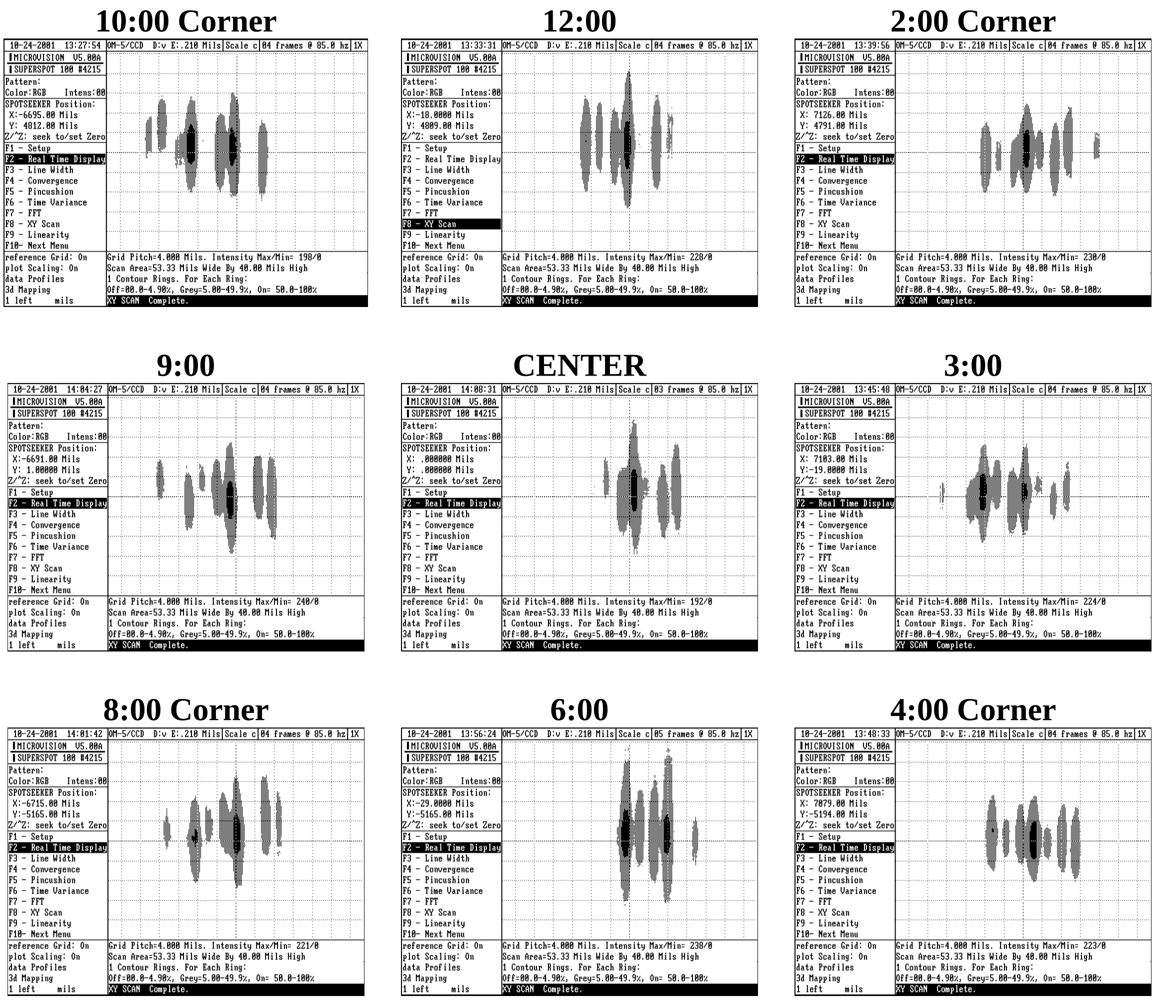


Figure II.25-2. Measured spot contours are plotted for nine positions on the screen. The red, green and blue phosphor stripes of the Trinitron CRT are evident in the spot contours. Horizontal and vertical luminance profiles of the spots shown in the following figures are used to determine the H and V spot sizes.

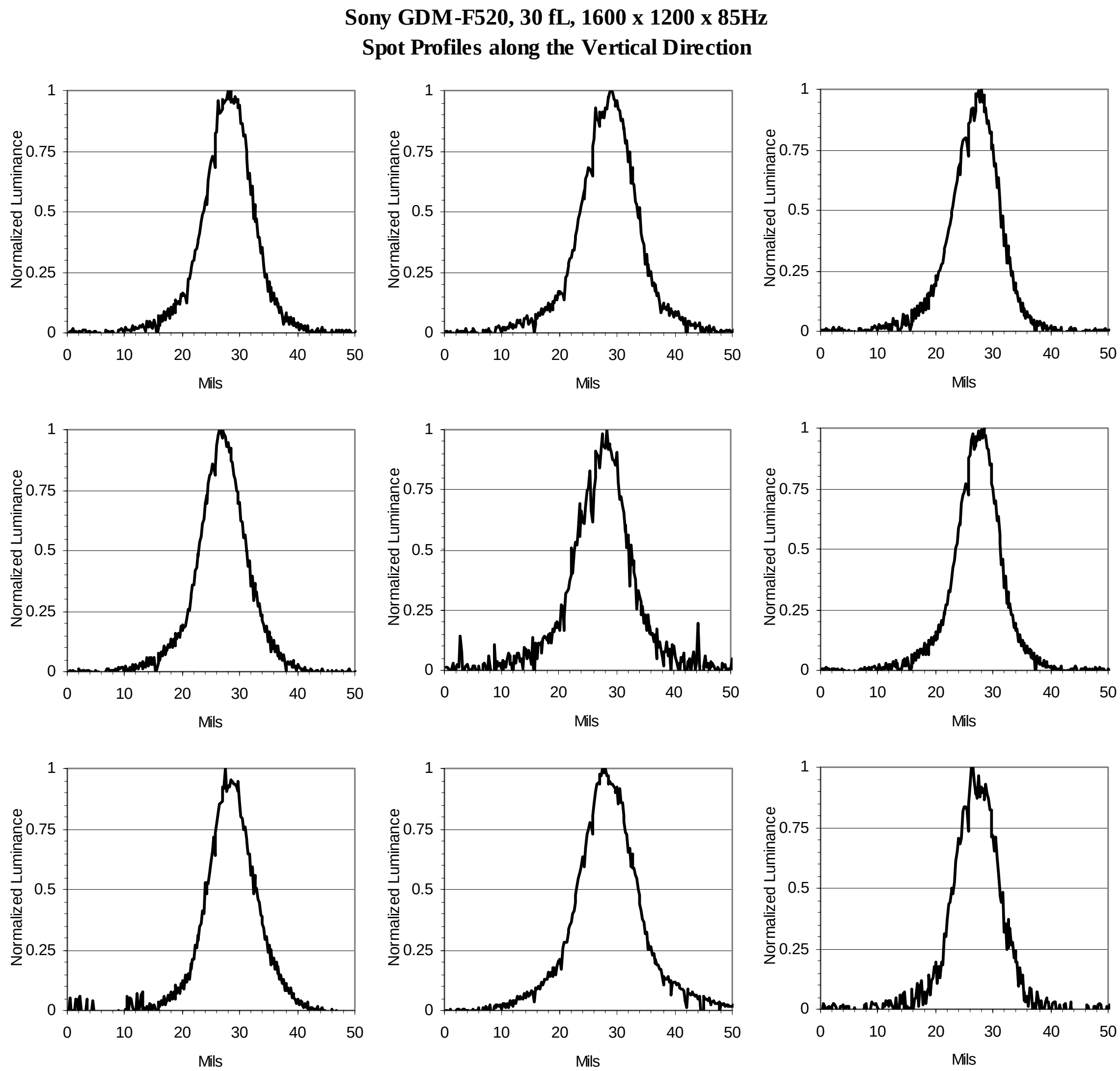


Figure II.25-3. Vertical luminance profiles of single-pixel white electron beam spots are plotted for nine positions on the screen.

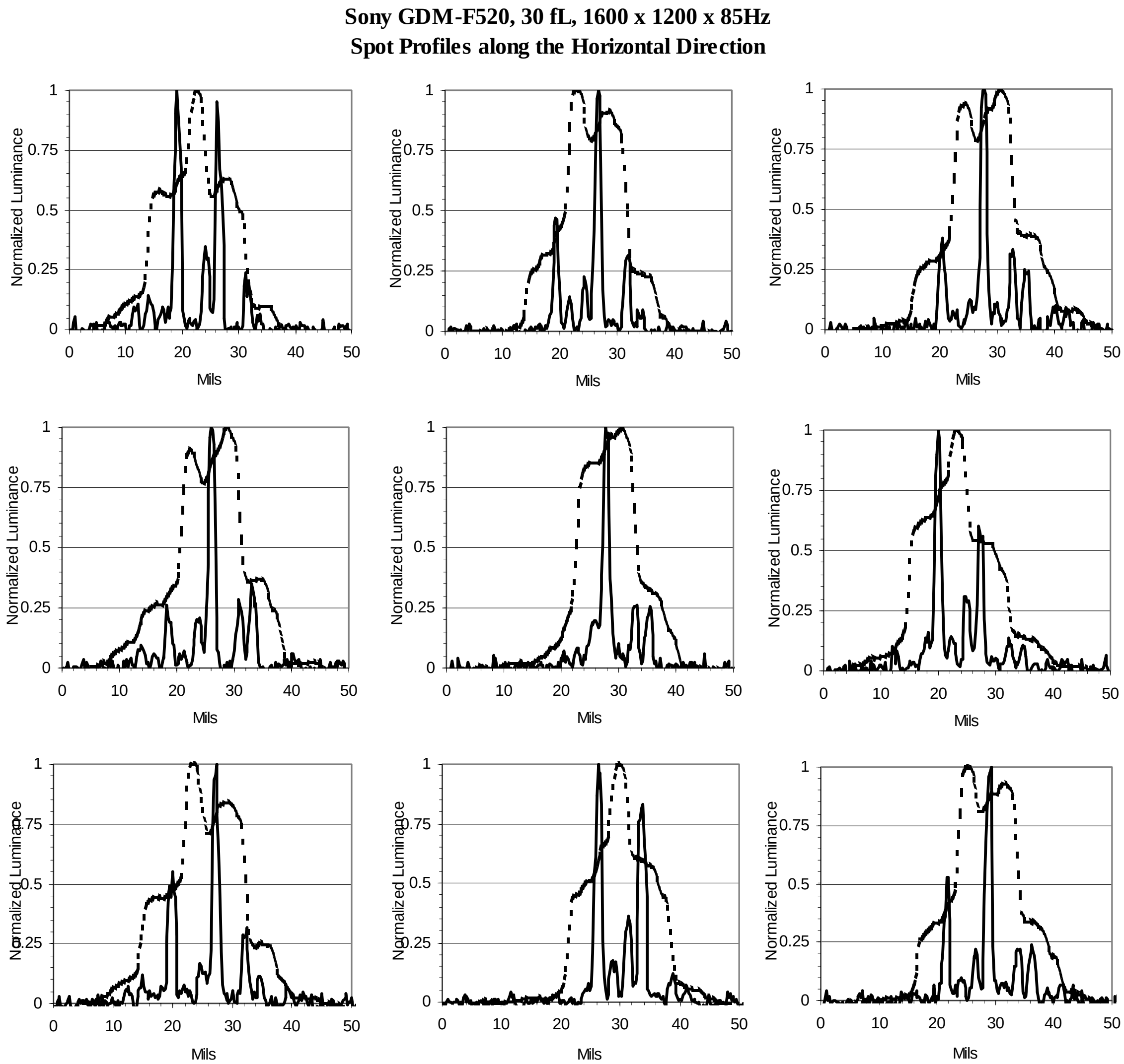


Figure II.25-4. Horizontal luminance profiles of single-pixel white electron beam spots are plotted for nine positions on the screen. The red, green and blue phosphor stripes of the Trinitron CRT are evident in the raw luminance profiles (solid curves) and increase the difficulty in determining the width of the spot profile. The normalized filtered luminance profile (dotted curves) provides a smoother continuous curve for a more repeatable determination of the spot width. The filtered profile is obtained by mathematically applying a 10-mil wide moving-window-average filter to the normalized raw luminance profile. In this case, a 10-mil window is chosen because it corresponds to the actual width of a single pixel on the screen. This filtering procedure is explained in detail in VESA's Flat Panel Display Measurement Standard Version 2.0, Section 303-1.