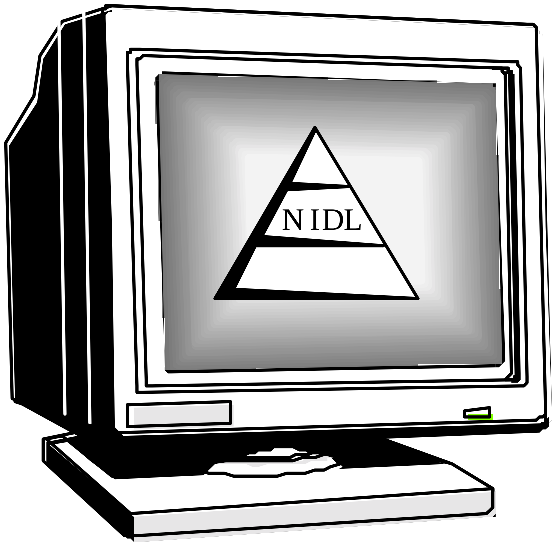

NIDL does not certify the ViewSonic PF815 color monitor as being suitable for IEC workstations requiring stereoscopic performance. NIDL rates this color monitor as “A” in monoscopic, but “C” in stereoscopic mode for the Image Analyst and Cartographer applications. The 1–pixel-on/1-pixel-off contrast modulation over the whole screen in monoscopic mode is excellent for a CRT color monitor. The “C” rating results from the maximum vertical refresh rate of 55 Hz per eye in stereo mode. This is below the IEC Working Group specification of 60 Hz per eye. The monitor passes the stereo extinction requirement of 15:1 with StereoGraphics CrystalEyes shutter glasses at 50 Hz per eye. The CRT is an aperture grill, much like the Sony Trinitron. Originally, NIDL certified the ViewSonic P817 color CRT monitor as acceptable for the IEC workstation. But, the manufacturer withdrew this product from the market. NIDL purchased the new flat face ViewSonic PF815 monitor to determine if this could be an acceptable color monitor in place of the P817. As we see from the discussion above, NIDL does not certify the PF815 monitor. NIDL evaluated two new monitors from Cornerstone and Eizo that can achieve the 60 Hz per eye minimum vertical refresh rate needed for stereo mode acceptability. These are shown in the accompanying table along with the PF815 and other color CRT monitors we have evaluated for the IEC program.

Evaluation of the ViewSonic PF815 4 x 3 Aspect Ratio, 22-Inch Diagonal Color Monitor

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NIDL IEC Monitor Certification Report

The ViewSonic PF815 Color CRT Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: C

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

NIDL does not certify the ViewSonic PF815 color monitor as being suitable for IEC workstations requiring stereoscopic performance. NIDL rates this color monitor as “A” in monoscopic, but “C” in stereoscopic mode for the Image Analyst and Cartographer applications. The 1–pixel-on/1-pixel-off contrast modulation over the whole screen in monoscopic mode is excellent for a CRT color monitor. The “C” rating results from the maximum vertical refresh rate of 55 Hz per eye in stereo mode. This is below the IEC Working Group specification of 60 Hz per eye. The monitor passes the stereo extinction requirement of 15:1 with StereoGraphics CrystalEyes shutter glasses at 50 Hz per eye. The flat face CRT in the PF815 is an aperture grill technology, much like the aperture grill Trinitron CRT used in Sony monitors.

Originally, NIDL certified as acceptable for the IEC workstation the ViewSonic P817 color CRT monitor. But, the manufacturer withdrew this product from the market. NIDL purchased the new flat face ViewSonic PF815 monitor to determine if this could be an acceptable color monitor in place of the P817. As we see from the discussion above, NIDL does not certify the PF815 monitor. NIDL evaluated two new monitors from Cornerstone and Eizo that can achieve the 60 Hz per eye minimum vertical refresh rate needed for stereo mode acceptability. These are shown in the following table along with the PF815 and other color CRT monitors.

NIDL paid $926 for its monitor for these tests. The ViewSonic website is http://www.viewsonic.com/

NIDL Color Monitor Certification for IEC

Monitor Manufacturer	IEC Spec	Cornerstone	EIZO	ViewSonic		Mitsubishi		Hitachi	SONY		Siemens
Model		P1700	F980	PF815	P817	2040U	2020U	CM814	24W900	F500	SCM21 130
Certified*		Y	Y	N	Y	N	N	Y	Y	N	Y
Monoscopic		A	B	A	B	A	C	B	A	B-	B
Stereoscopic		B	B	C	B	C	C	B		C	B
Cm, Zone A	25%	57%	37%	55%	29%	54%	30%	35%	64%	43%	36%
Cm, Zone B	20%	52%	27%	47%	40%	42%	16%	30%	53%	37%	21%
Refresh per eye	60 Hz	60 Hz	60 Hz	55 Hz	60 Hz	55 Hz	55 Hz	60 Hz	46 Hz	56 Hz	60.5 Hz
Extinction ratio, panel	No spec	10.6	12.6	10.3	10.1	10.4	11.1	11.2	12.9	13.3	11.2
IR glasses	15.1	21.0	14.3	17.6		17.6					18.1
Price		$1363	$1790	$926	$1600	$1123		$1200	$2371	$1758	< $2800

* 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. The ratings for the Cornerstone, EIZO, and the ViewSonic PF815 are new.

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1600 x 1200	Pass
Dynamic Range	24.7dB	24.8 dB	Pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.1 fL	Pass
Luminance (Lmax)	30 fL ± 4%	30.4 fL	Pass
Uniformity (Lmax)	20% max.	7.2%	Pass
Halation	3.5% max.	5.55 ± 0.5%	Fail
Color Temp	6500 to 9300 K	9246 K	Pass
Reflectance	Not specified	5.7%	N/A
Bit Depth	8-bit± 5 counts	8-bit	Pass
Step Response	No visible ringing	Clean	Pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 Δu'v'	0.003 delta u'v'	Pass
Pixel aspect ratio	Square H = V± 6%	9.92 H x 9.85 V (mils) H = V+ 0.7%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.8 ins.	Pass
Cm, Zone A, 7.6"	25% min.	55%	Pass
Cm, Zone A, 9.8"	25% min.	51%	Pass
Cm, Zone B	20% min.	47%	Pass
Pixel density	72 ppi min.	101 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.99	Pass
Straightness	0.5% max ± 0.05 mm	0.16%	Pass
Linearity	1.0% max ± 0.05 mm	0.38%	Pass
Jitter	2 ± 2 mils max.	2.32 mils	Pass
Swim, Drift	5 ± 2 mils max.	2.82 mils	Pass
Warm-up time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	11 mins.	Pass
Warm-up time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	17 mins.	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 75 Hz	Pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 1024 (I)	Pass
Lmin	Not specified	0.1 fL	Pass
Lmax	6 fL min ± 4%	5.86 fL	Pass
Dynamic range	17.7 dB min	17.7 dB	Pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δu'v'	0.009 delta u'v'	Pass
Refresh rate	60 Hz per eye, min	55 Hz, per eye (z)	Fail
Extinction Ratio- ZScreen	Not Specified	10.3:1 (z)	N/A
Extinction Ratio-CrytalEyes	15:1 min	17.6:1 (IR)	Pass
AMBIENT LIGHTING			
Dynamic range = 22 dB (158:1)	N/A	1.6 fc	N/A
Dynamic range = 17 dB (50:1)	N/A	9 fc	N/A

(I) Denotes interlaced scanning
(z) Denotes Z-Screen 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 ViewSonic PF815 color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

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

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

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

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

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

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

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*

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

I.1 The ViewSonic PF815 Color CRT Monitor

Manufacturer's Specifications

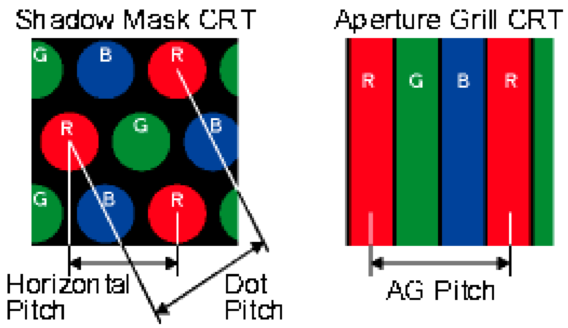
According to ViewSonic Corporation, the specifications for the ViewSonic monitor are:

Specifications	**Features**
CRT Type	22" (20.0" diagonal viewable area) 90 degree deflection
CRT Pitch	0.25mm (center) / 0.27mm (corner), aperture grille
CRT Phosphor	RGB medium-short persistence B22
CRT Faceplate Glass	ARAG (anti-reflection, anti-glare) Tint (TM=39.8%)
Display Area Size* (W x H)	15.6 x 11.7" (396 mm x 297 mm) factory setting, 15.7" x 11.8" (400 mm x 300 mm) maximum dependent on signal timing
Maximum Addressable Format (H x V pixels)	1920 x 1440/75Hz non-interlaced maximum 1600 x 1200/92 Hz non-interlaced recommended
Compatibility	PC, VGA up to 1920 x 1440 non-interlaced Power Macintosh, 640 x 480 up to 1600 x 1200
Auto-Scan Range	H: 30 - 117 kHz V: 50 - 180 Hz
Fully Adjustable Color Balance	5000° - 9300° variable
Video Input Bandwidth	300 MHz
Input Signal	RGB Analog(0.7 / 1.0 Vp-p, 75 ohms) HV Separated (TTL),Composite (TTL), Sync-on-green
Connectors	Video: 15-pin mini D-sub, BNC x 5 [RGBHV] Power: 3-pin plug (IEC320)
Signal Cable	VGA/VGA 15HD-D-Sub connectors)
Cable Accessories	Macintosh adapter not included.
Power Requirements	AC 90-132V/198-264 VAC; 50/60 Hz(+/-3)Hz
Power Consumption	150 W (typ)
Power Cord	U.S. version cord with 3P plug
Compact Tilt/ Swivel Base	Integrated with monitor
Operating Conditions Temperature Humidity	 +41 to +95 degrees F. (+5 to +35 degrees C.) 5% to 90% (no condensation)
Dimensions (W x H x D)	19.8 x 19.7 x 18.8" (504 x 501 x 477 mm)
Weight	70.4 lbs. (32 kg)
Packing Carton (W x H x D)	26.10 x 25.63 x 24.69" (663 x 651 x 627 mm)
Shipping Weight	78.3 lbs. (35.5 kg)
Regulatory Approvals	UL, DHHS, FCC-B, CE, CSA, MPR-II, Energy Star, TCO 99, Energy 2000, IC-B, TUV ERGO (ISO9241-3), TUV/GS, PCBC, PTB Security, BSMI, SEMKO, NEMKO, DEMKO, FIMKO, VCCI-II, C-TICK, S-MARK, NOM, SASO
Power Management	Meets Energy Star, VESA DPMS, TCO 99, Energy 2000 standards
Warranty	Three-year limited warranty on CRT, parts and labor 48 hour Express Exchange service option available

Additional information supplied by the manufacturer

ViewSonic is now offering its first 22" (20.0" viewable) high performance CRT with the incredible PerfectFlat technology providing full, brilliant edge-to-edge precise images! In addition to a maximum resolution of 1920 x 1440, the ViewSonic PF815 also boasts of a super fine 0.25-0.27mm variable aperture grille pitch and a wide video bandwidth of 300MHz. Combining all these features along with its low light transmission and on screen corner purity adjustments, the PF815 users can be assured of the ultimate in image clarity and color saturation – an ideal choice for CAD/CAM, animation, desktop publishing and graphics design applications.

Note: The CRT in the PF815 is an aperture grill, having a configuration shown in the figure below.



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 III infrared wireless 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 dynamic range measured in 1600 x 1200 format is 24.8 dB in a dark room. It decreases to less than 22 dB (the absolute threshold for IEC) in 2 fc diffuse ambient illumination.

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

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

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

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

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are 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: Define dynamic range by: $DR=10\log(Lmax/Lmin)$

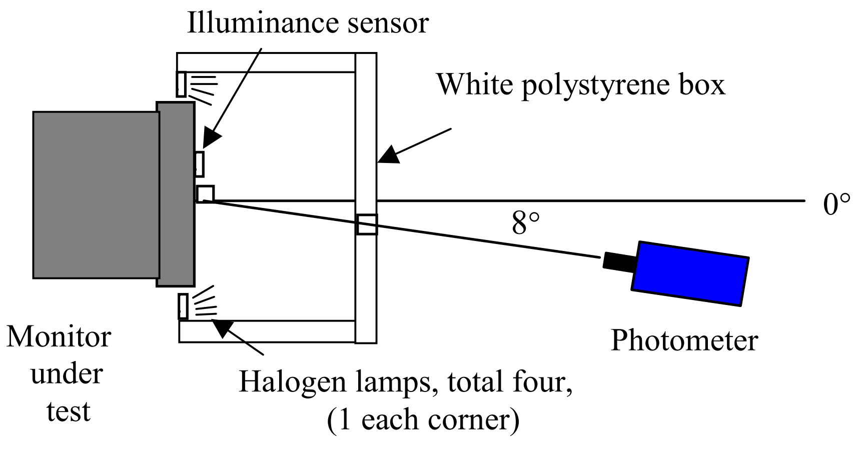


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

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

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20.4 fc
Reflected Luminance	1.17 fL
Faceplate Reflectance	5.7 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 24.8 dB in a dark room to less than 22 dB (the absolute threshold for IEC) in 2 fc diffuse ambient illumination.

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

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.10 fL.

Ambient Illumination	Displayed Addressable Format 1600 x 1200
0 fc (Dark Room)	24.8 dB
1 fc	22.8 dB
2 fc	21.5 dB
3 fc	20.5 dB
4 fc	19.7 dB
5 fc	19.0 dB
6 fc	18.4 dB
7 fc	17.9 dB
8 fc	17.4 dB
9 fc	17.0 dB
10 fc	16.6 dB

II.2. Maximum Luminance (Lmax)

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

The highest luminance for Lmax was 30.4 fL measured at screen center in 1600 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

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

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). 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	9246K	0.281	0.302	30.4 fL

II.3. Luminance (Lmax) and Color Uniformity

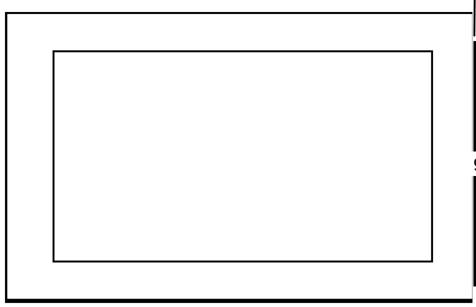
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 7.2% across the screen. Chromaticity variations were less than 0.003 delta u'v' units.

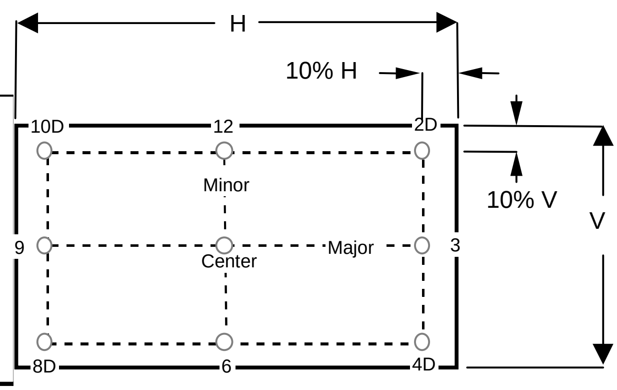
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

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



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



Nine screen test locations.
Figure II.3-2

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

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

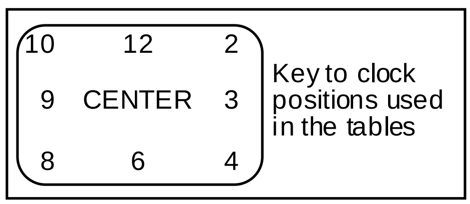
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

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	9246	0.281	0.302	30.6
2	9457	0.280	0.299	28.4
3	9507	0.279	0.300	28.5
4	9500	0.280	0.298	28.5
6	9687	0.278	0.298	30.0
8	9555	0.278	0.301	28.9
9	9691	0.277	0.300	28.5
10	9415	0.280	0.300	28.8
12	9415	0.280	0.300	30.4



1600 x 1200

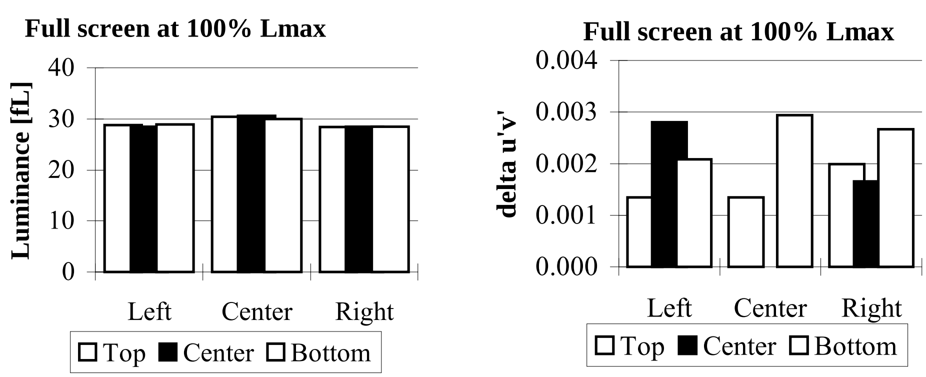


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

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

Halation was 5.55 % +/- 0.5% on a small black patch surrounded by a large full white area.

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

Equipment:
- Photometer
- Video generator

Test Pattern:

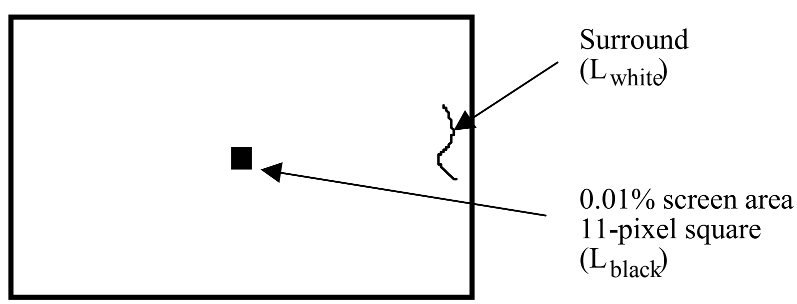


Figure II.4-1 *Test pattern for measuring halation.*

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

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

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

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer 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
Lblack	1.264 fL ± 4%	1.213 fL to 1.315 fL
Lwhite	22.78 fL ± 4%	21.87 fL to 23.69 fL
Halation	5.55% ± 0.5%	5.12% to 6.01%

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 9246K which 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.

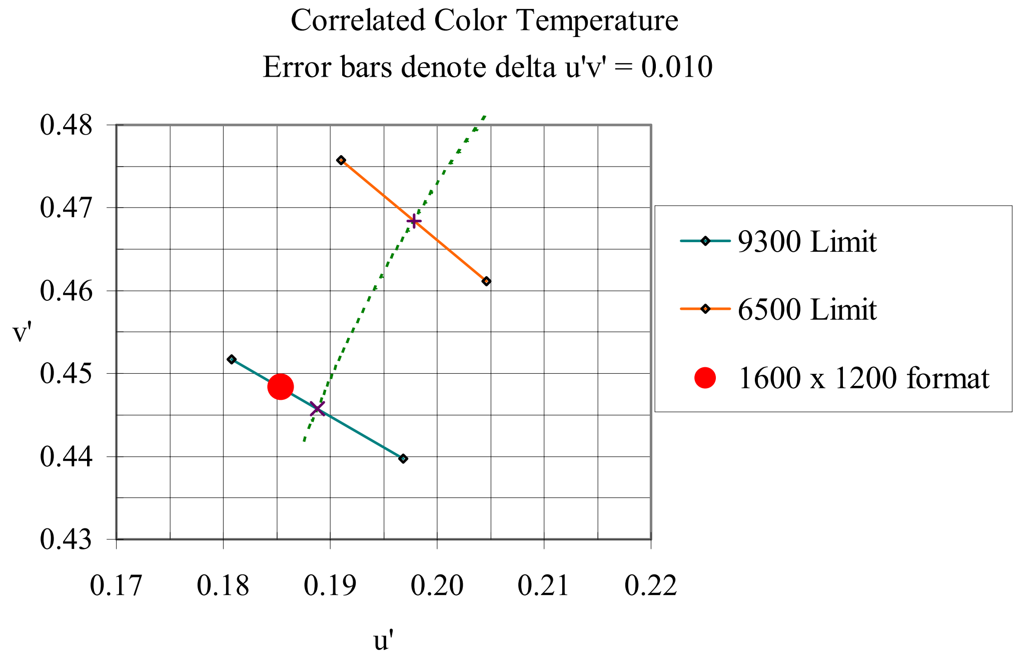


Figure II.5-1. *The CCT of the measured white point is within the boundaries required by IEC.*

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	0.281
CIE y	0.301
CIE u'	0.185
CIE v'	0.448
CCT	9246
delta u'v'	0.004

II.6. Bit Depth

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

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.

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

Equipment: Photometer

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

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

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

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

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

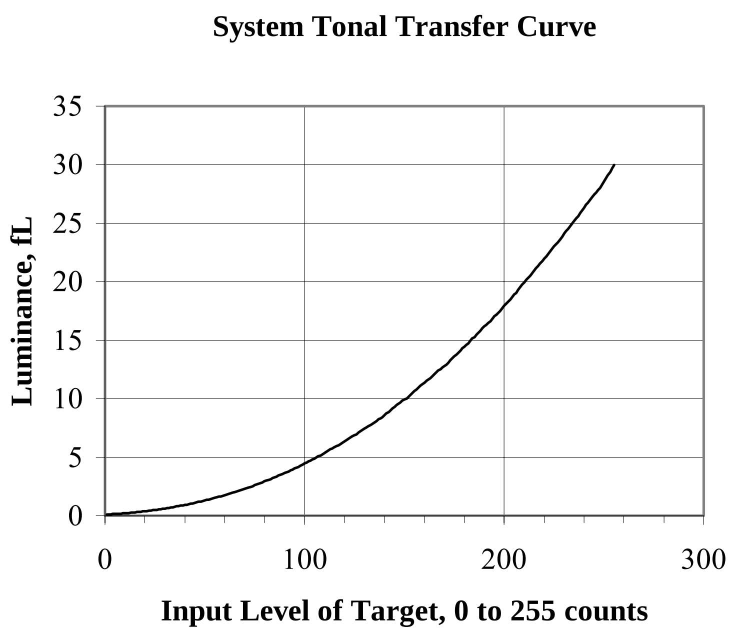


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

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

Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.101	0	0
39	1	0.109	0.010	3
39	2	0.119	0.010	2
39	3	0.129	0.011	2
40	4	0.139	0.010	2
40	5	0.149	0.012	2
41	6	0.16	0.011	3
41	7	0.172	0.013	2
41	8	0.184	0.012	2
42	9	0.196	0.013	2
42	10	0.211	0.015	3
42	11	0.225	0.013	2
43	12	0.241	0.015	2
43	13	0.256	0.015	2
43	14	0.271	0.016	2
44	15	0.288	0.016	2
44	16	0.309	0.019	3
44	17	0.327	0.018	2
45	18	0.347	0.019	3
45	19	0.367	0.018	2
45	20	0.385	0.018	2
46	21	0.406	0.020	2
46	22	0.426	0.020	2
46	23	0.45	0.021	2
47	24	0.471	0.022	3
47	25	0.496	0.021	2
48	26	0.518	0.024	2
48	27	0.543	0.021	2
48	28	0.564	0.024	2
49	29	0.591	0.025	3
49	30	0.621	0.026	2
49	31	0.646	0.027	2
50	32	0.673	0.026	2
50	33	0.704	0.026	2
50	34	0.731	0.028	3
51	35	0.753	0.029	2
51	36	0.794	0.028	2
51	37	0.825	0.031	2
52	38	0.853	0.031	3
52	39	0.888	0.031	2
52	40	0.924	0.031	2
53	41	0.949	0.033	2
53	42	0.986	0.036	2
53	43	1.031	0.029	2
54	44	1.057	0.038	3
54	45	1.097	0.036	2
55	46	1.143	0.038	2
55	47	1.177	0.040	2
55	48	1.229	0.033	2
56	49	1.259	0.046	3
56	50	1.298	0.042	2
56	51	1.347	0.041	2
57	52	1.391	0.038	2
57	53	1.438	0.042	2
57	54	1.481	0.041	3
58	55	1.532	0.048	2
58	56	1.574	0.039	2
58	57	1.622	0.044	2
59	58	1.667	0.053	2
59	59	1.714	0.049	3
59	60	1.767	0.046	2
60	61	1.807	0.047	2
60	62	1.856	0.053	2
60	63	1.918	0.049	2

Back ground	Target	L, fL	Diff, fL	Diff, JND
61	64	1.968	0.049	2
61	65	2.023	0.052	2
62	66	2.076	0.045	2
62	67	2.134	0.048	2
62	68	2.185	0.059	2
63	69	2.247	0.062	2
63	70	2.305	0.061	2
63	71	2.365	0.058	3
64	72	2.414	0.051	1
64	73	2.473	0.062	3
64	74	2.542	0.068	2
65	75	2.604	0.056	2
65	76	2.659	0.064	2
65	77	2.726	0.061	2
66	78	2.786	0.067	2
66	79	2.861	0.067	2
66	80	2.934	0.061	2
67	81	2.998	0.068	2
67	82	3.067	0.080	2
67	83	3.142	0.067	2
68	84	3.211	0.070	2
68	85	3.269	0.070	2
69	86	3.348	0.061	2
69	87	3.421	0.088	2
69	88	3.486	0.070	2
70	89	3.569	0.079	2
70	90	3.642	0.061	2
70	91	3.721	0.093	2
71	92	3.797	0.065	2
71	93	3.876	0.090	2
71	94	3.952	0.079	2
72	95	4.037	0.084	2
72	96	4.121	0.076	2
72	97	4.182	0.090	2
73	98	4.286	0.089	2
73	99	4.372	0.096	2
73	100	4.463	0.079	2
74	101	4.547	0.096	2
74	102	4.638	0.090	2
74	103	4.708	0.076	2
75	104	4.787	0.097	2
75	105	4.886	0.087	2
76	106	4.985	0.099	2
76	107	5.067	0.089	1
76	108	5.152	0.081	2
77	109	5.271	0.111	2
77	110	5.358	0.110	2
77	111	5.447	0.103	2
78	112	5.571	0.090	2
78	113	5.668	0.085	1
78	114	5.753	0.116	3
79	115	5.842	0.126	2
79	116	5.934	0.082	1
79	117	6.042	0.113	2
80	118	6.144	0.114	2
80	119	6.248	0.111	2
80	120	6.345	0.105	2
81	121	6.459	0.105	2
81	122	6.579	0.112	1
81	123	6.681	0.122	2
82	124	6.784	0.117	2
82	125	6.865	0.125	2
83	126	6.952	0.117	2
83	127	7.102	0.108	2

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

Background	Target	L, fL	Diff, fL	Diff, JND
83	128	7.215	0.08	1
84	129	7.317	0.13	2
84	130	7.434	0.13	2
84	131	7.557	0.13	1
85	132	7.682	0.14	2
85	133	7.769	0.12	2
85	134	7.892	0.14	2
86	135	7.998	0.13	2
86	136	8.114	0.09	1
86	137	8.239	0.16	2
87	138	8.291	0.13	2
87	139	8.449	0.14	2
87	140	8.572	0.12	1
88	141	8.762	0.13	2
88	142	8.846	0.14	1
88	143	9.017	0.16	2
89	144	9.197	0.16	2
89	145	9.307	0.14	2
90	146	9.439	0.14	2
90	147	9.593	0.13	1
90	148	9.682	0.16	2
91	149	9.818	0.12	1
91	150	9.954	0.10	2
91	151	10.03	0.19	2
92	152	10.18	0.15	1
92	153	10.36	0.14	2
92	154	10.51	0.16	2
93	155	10.64	0.15	1
93	156	10.78	0.15	2
93	157	10.92	0.16	2
94	158	11.10	0.14	1
94	159	11.26	0.16	2
94	160	11.38	0.17	1
95	161	11.53	0.15	2
95	162	11.65	0.16	1
95	163	11.77	0.16	2
96	164	11.92	0.18	2
96	165	12.08	0.18	2
97	166	12.24	0.16	1
97	167	12.39	0.14	1
97	168	12.53	0.16	2
98	169	12.68	0.20	2
98	170	12.78	0.16	1
98	171	12.92	0.19	2
99	172	13.09	0.13	1
99	173	13.27	0.16	1
99	174	13.48	0.16	2
100	175	13.62	0.20	1
100	176	13.76	0.18	2
100	177	13.92	0.23	2
101	178	14.12	0.17	1
101	179	14.33	0.18	2
101	180	14.46	0.19	1
102	181	14.59	0.19	2
102	182	14.73	0.20	2
102	183	14.92	0.16	1
103	184	15.16	0.16	1
103	185	15.25	0.23	2
104	186	15.47	0.18	1
104	187	15.62	0.21	2
104	188	15.79	0.21	1
105	189	16.02	0.16	2
105	190	16.20	0.21	1
105	191	16.32	0.22	2
106	192	16.48	0.21	1
106	193	16.62	0.20	2
106	194	16.86	0.35	2
107	195	17.04	0.22	2
107	196	17.17	0.24	1
107	197	17.33	0.18	2
108	198	17.52	0.21	1
108	199	17.74	0.07	0
108	200	17.93	0.16	1
109	201	18.12	0.18	2
109	202	18.32	0.14	1
109	203	18.51	0.26	1
110	204	18.71	0.16	1
110	205	18.92	0.32	2
111	206	19.04	0.12	1
111	207	19.28	0.18	1
111	208	19.51	0.33	2
112	209	19.74	0.29	2
112	210	19.97	0.11	1
112	211	20.19	0.29	1
113	212	20.33	0.14	1
113	213	20.52	0.29	2
113	214	20.73	0.27	2
114	215	20.92	0.18	1
114	216	21.16	0.29	1
114	217	21.32	0.14	1
115	218	21.53	0.32	2
115	219	21.76	0.26	1
115	220	21.98	0.17	1
116	221	22.17	0.18	1
116	222	22.36	0.36	2
116	223	22.6	0.22	2
117	224	22.82	0.18	0
117	225	23.02	0.26	2
118	226	23.18	0.34	2
118	227	23.37	0.14	0
118	228	23.61	0.12	1
119	229	23.82	0.34	2
119	230	24.09	0.39	2
119	231	24.31	0.13	0
120	232	24.51	0.24	2
120	233	24.73	0.26	1
120	234	24.94	0.26	1
121	235	25.18	0.32	2
121	236	25.44	0.26	1
121	237	25.62	0.18	1
122	238	25.86	0.27	1
122	239	26.07	0.28	1
122	240	26.29	0.27	2
123	241	26.59	0.16	0
123	242	26.73	0.35	2
123	243	26.98	0.30	1
124	244	27.16	0.21	1
124	245	27.44	0.23	1
125	246	27.61	0.31	2
125	247	27.81	0.40	2
125	248	28.02	0.20	1
126	249	28.27	0.40	1
126	250	28.54	0.15	1
126	251	28.81	0.20	1
127	252	29.12	0.25	1
127	253	29.35	0.35	1
127	254	29.69	0.25	1
128	255	29.98	0.30	2

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

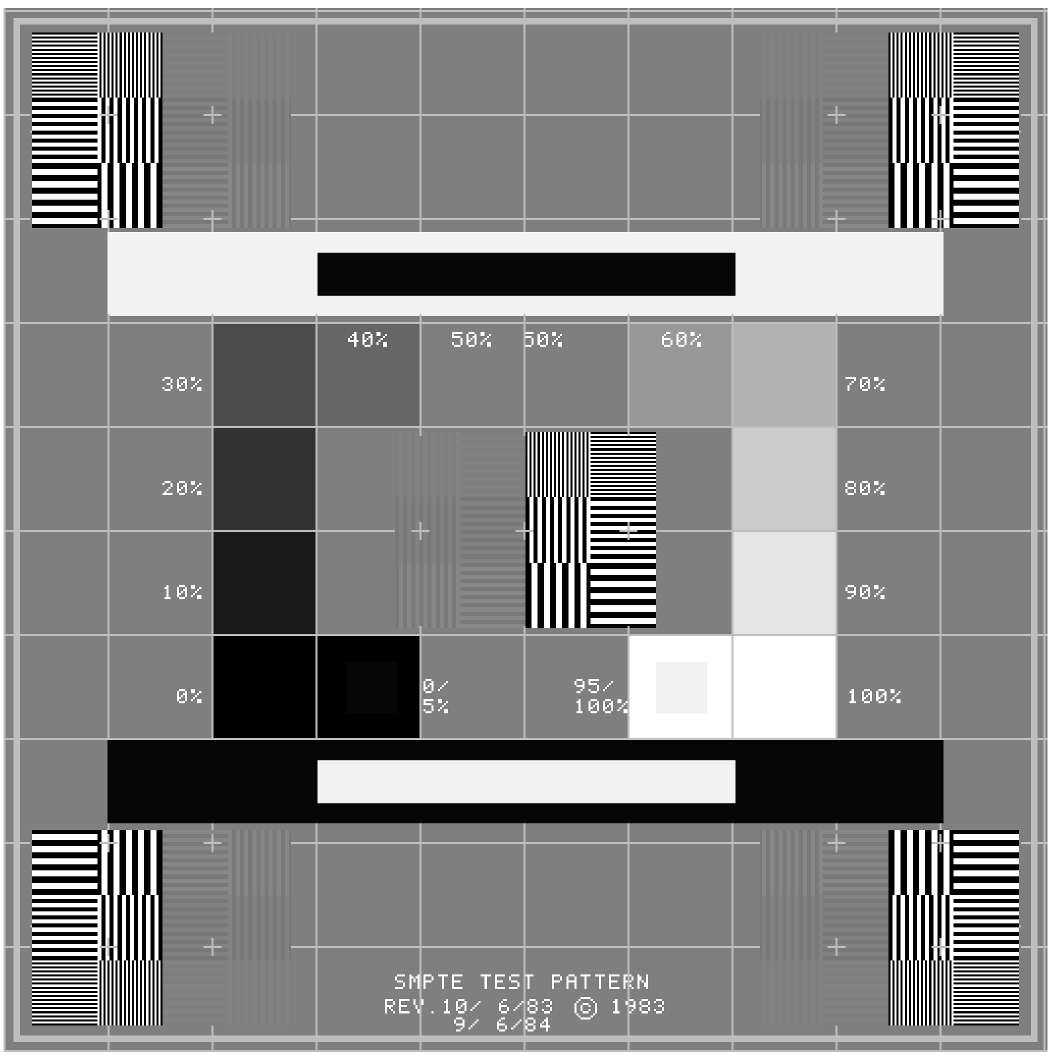


Figure II.8-1. SMPTE Test Pattern.

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

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the ViewSonic PF815 monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

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

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200 x 75 Hz, and 1024 x 1024 x 110 Hz.

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

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

Procedure: The number of addressed pixels are to be 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. The PF815 monitor was tested at 75 Hz for monoscopic mode, surpassing the minimum required 72 Hz. In stereo mode, the PF815 monitor was limited to 110 Hz (55 Hz per eye) and failed to meet the IEC minimum required 120 Hz. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals.

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

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200 x 75 Hz	1024 x 1024 x 110 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 0.7%.

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. Data are taken from straightness measurements.

	Monoscopic Mode
Addressability (H x V)	**1600 x 1200**
H x V Image Size (inches)	15.873 x 11.826
H x V Pixel Spacing (mils)	9.92 x 9.85 mils
H x V Pixel Aspect Ratio	H = V + 0.67%

II.11. Screen Size (Viewable Active Image)

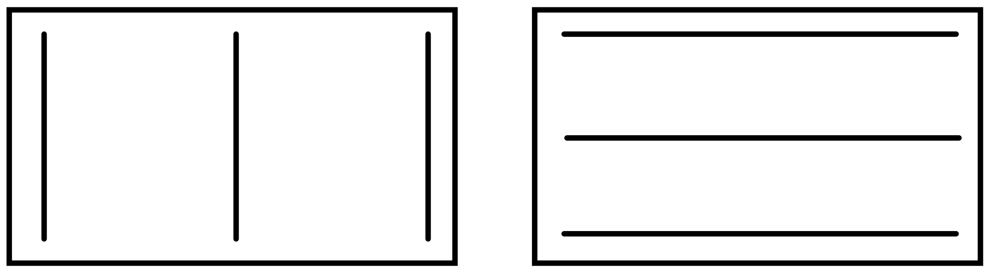
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size for 1600 x 1200 format was 19.794 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 overscanned 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 Modes
Addressability (H x V)	1600 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	15.873 x 11.826 19.794

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 = 55% in Zone A of diameter 7.6 inches, and 51% for Zone A diameter of 9.78 inches (40% of image area). Cm exceeded 47% in Zone B. Moiré cancellation was not used for these measurements.

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 (1600 x 1200 x 75 Hz, 1024 x 1024 x 110 Hz) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

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

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 55% in Zone A, and is equal to or greater than 47% in Zone B.

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

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

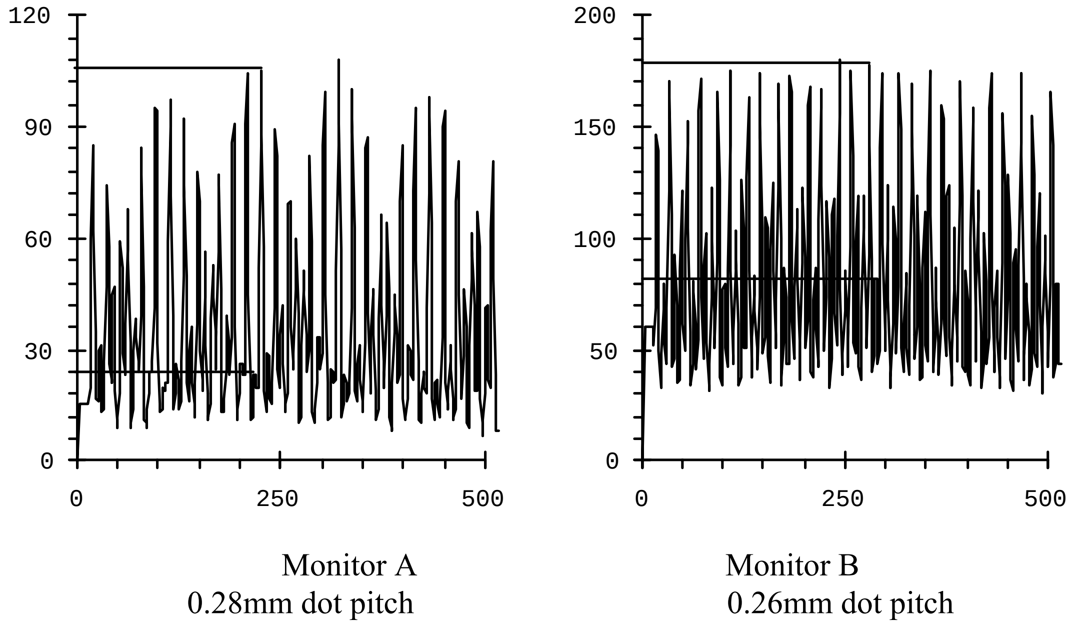


Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation

Corrected for lens flare and Zone Interpolation

Moiré Cancellation OFF

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches viewing distance

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	73%	67%			49%	71%			73%	67%
			70%	77%	56%	75%	70%	77%		
Major	82%	68%	75%	76%	68%	83%	75%	76%	83%	70%
			65%	73%	55%	77%	71%	75%		
Bottom	59%	58%			47%	74%			74%	62%

Zone A = 9.79-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	73%	67%			49%	71%			73%	67%
			71%	75%	52%	73%	71%	75%		
Major	82%	68%	77%	74%	68%	83%	77%	75%	83%	70%
			64%	70%	51%	75%	71%	72%		
Bottom	59%	58%			47%	74%			74%	62%

II.13. Pixel Density

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

Pixel density was 101 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 H x V Pixel Density, ppi	15.873 x 11.826 101 x 101 ppi

II.14. Moiré

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

Phosphor-to-pixel spacing ratios are less than 1.0 at screen center for the 1600 x 1200 format. This monitor is equipped with a Moiré cancellation feature that was not evaluated

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

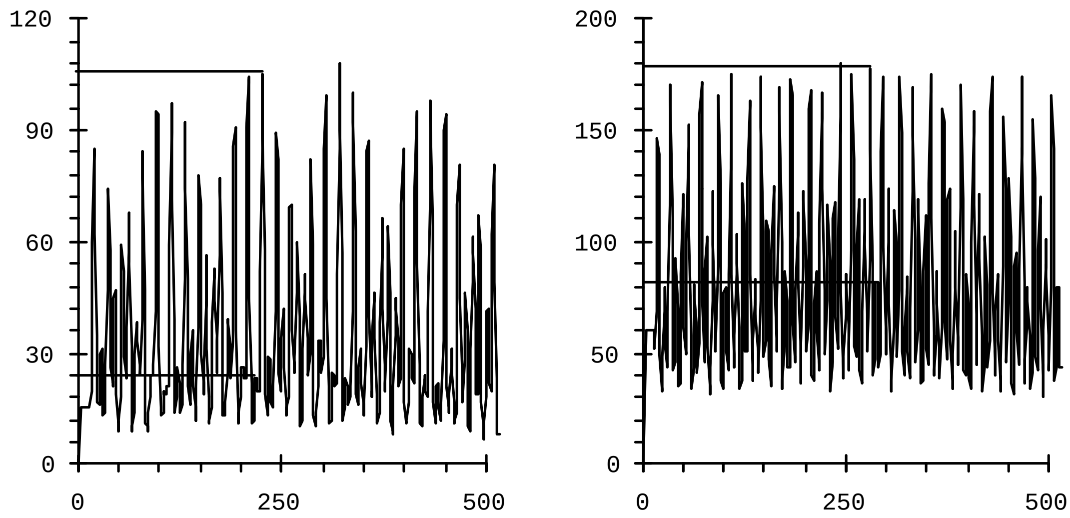
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

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 (Diagonal)	N/A
Phosphor Pitch (H x V) --Aperture grill	0.25-0.27 x 0 mm
Pixel Spacing (H x V)	9.92 x 9.85 mils 0.252 x 0.250 mm
Phosphor-to-Pixel-Spacing (H)	0.99

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



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

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

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

II.15. Straightness

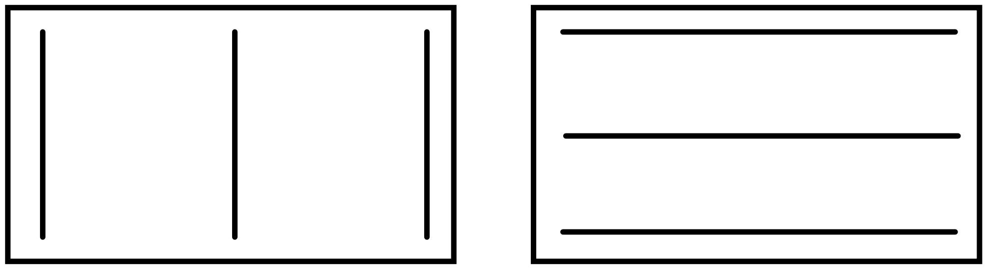
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.16% of the image width or height.

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

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

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



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

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

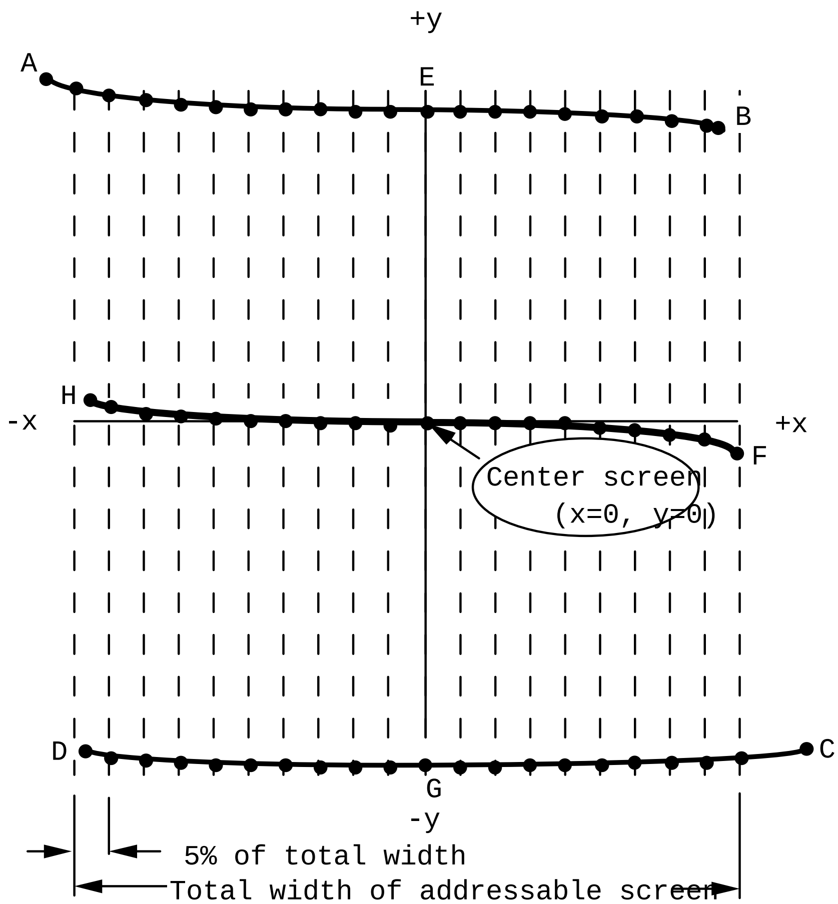


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

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

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

Table II.15-1. Straightness

Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7918	5926	-7921	-5902	-7916	-2	16	5908	-7918	5926	7957	5933
-7200	5924	-7200	-5901	-7200	-1	10	5400	-7918	5400	7952	5400
-6400	5922	-6400	-5898	-6400	0	8	4800	-7918	4800	7953	4800
-5600	5919	-5600	-5892	-5600	1	6	4200	-7918	4200	7955	4200
-4800	5916	-4800	-5890	-4800	1	6	3600	-7917	3600	7960	3600
-4000	5915	-4000	-5887	-4000	3	4	3000	-7918	3000	7963	3000
-3200	5914	-3200	-5886	-3200	3	1	2400	-7919	2400	7965	2400
-2400	5912	-2400	-5886	-2400	2	1	1800	-7918	1800	7966	1800
-1600	5910	-1600	-5888	-1600	1	0	1200	-7917	1200	7965	1200
-800	5909	-800	-5891	-800	1	-1	600	-7917	600	7961	600
0	5908	0	-5894	0	0	0	0	-7916	0	7959	0
800	5907	800	-5898	800	0	-2	-600	-7917	-600	7957	-600
1600	5908	1600	-5904	1600	0	-3	-1200	-7920	-1200	7956	-1200
2400	5911	2400	-5909	2400	0	-5	-1800	-7923	-1800	7957	-1800
3200	5913	3200	-5912	3200	0	-5	-2400	-7926	-2400	7958	-2400
4000	5915	4000	-5914	4000	0	-6	-3000	-7929	-3000	7958	-3000
4800	5919	4800	-5915	4800	1	-5	-3600	-7928	-3600	7958	-3600
5600	5922	5600	-5917	5600	1	-4	-4200	-7925	-4200	7956	-4200
6400	5923	6400	-5917	6400	2	-3	-4800	-7922	-4800	7953	-4800
7200	5920	7200	-5915	7200	3	1	-5400	-7918	-5400	7953	-5400
7957	5914	7948	-5914	7959	3	6	-5894	-7921	-5902	7948	-5914

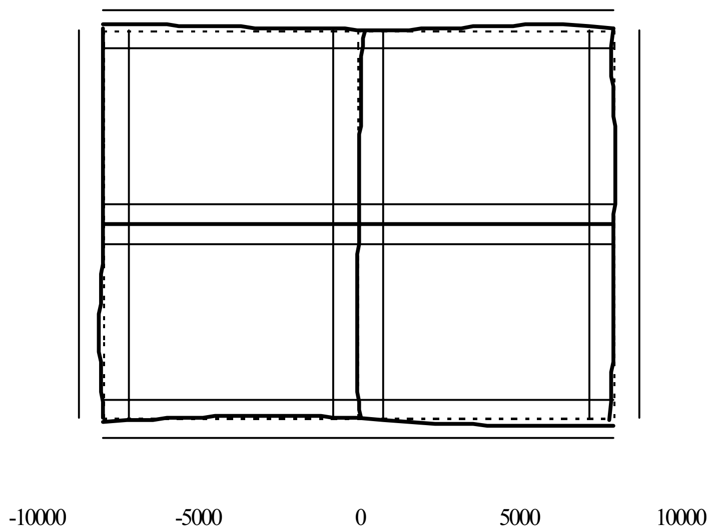


Figure II.15-3 Waviness of ViewSonic PF815 color monitor in 1620 x 1024 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

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 75 Hz. Vertical refresh rate for the 1024 x 1024 stereo format was 110 Hz, limited by the monitor.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

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

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	1600 x 1200	1024 x 1024
Vertical Scan Horizontal Scan	75.0 Hz 93.75 kHz	110 Hz 117.312 kHz

II.17. Extinction Ratio

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

Stereo extinction ratio averaged 17.6 to 1 (17.6 right, 17.6 left) at screen center using StereoGraphics Infrared Crystal Eyes LC shutter eyeglasses operating at 50 Hz per eye. Stereo extinction ratio averaged 10.3 to 1 (10.9 left, 9.7 right) at screen center using StereoGraphics ZScreen 19-inch LCD shutter operating at 55 Hz per eye and viewed through passive polarized eyeglasses. Luminance of white with ZScreen varied by up to 9.7% across the screen, and chromaticity variations of white were less than 0.009 delta u'v' units.

Objective: Measure stereo extinction ratio

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

Stereoscopic-mode measurements were made at screen center using a commercially-available StereoGraphics Infrared Crystal Eyes LC shutter eye glasses.

Stereoscopic-mode measurements were made at nine points across the screen using a commercially-available StereoGraphics Z-Screen 19-inch LCD shutter with passive polarized eyeglasses.

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

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

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

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

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

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

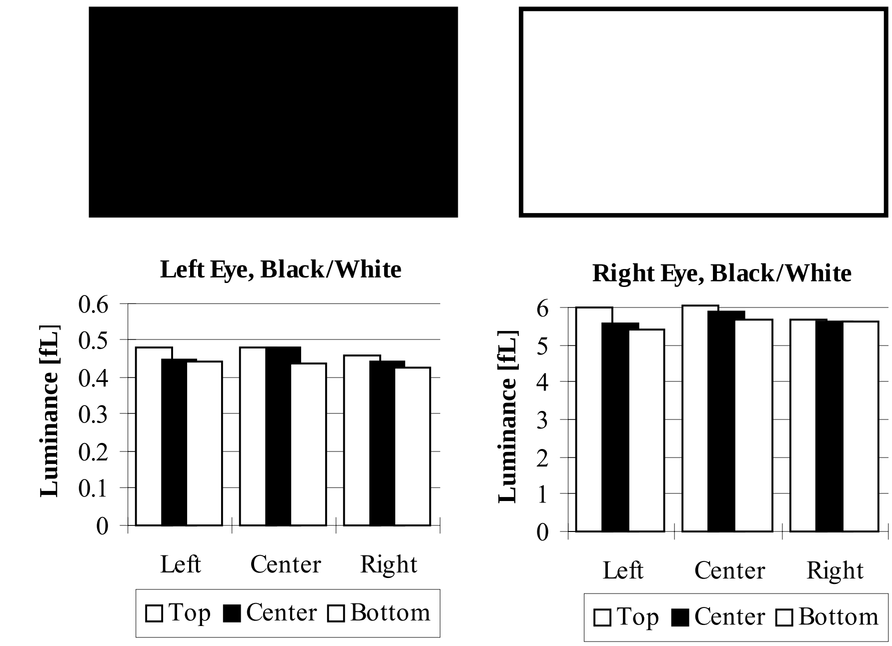


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye using StereoGraphics ZScreen 19-inch LC shutter system with passive polarized eyeglasses.

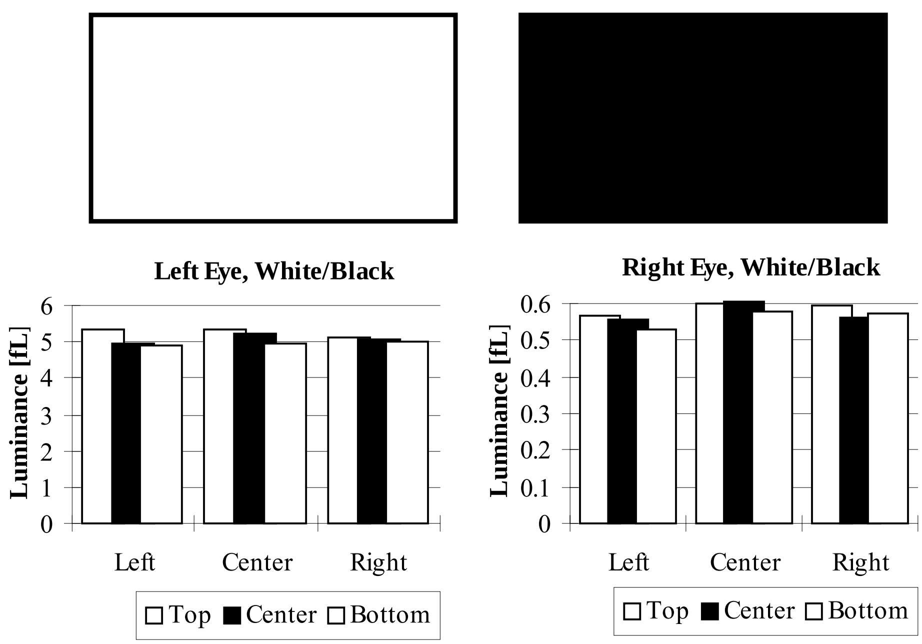


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye using StereoGraphics ZScreen 19-inch LC shutter system with passive polarized eyeglasses.

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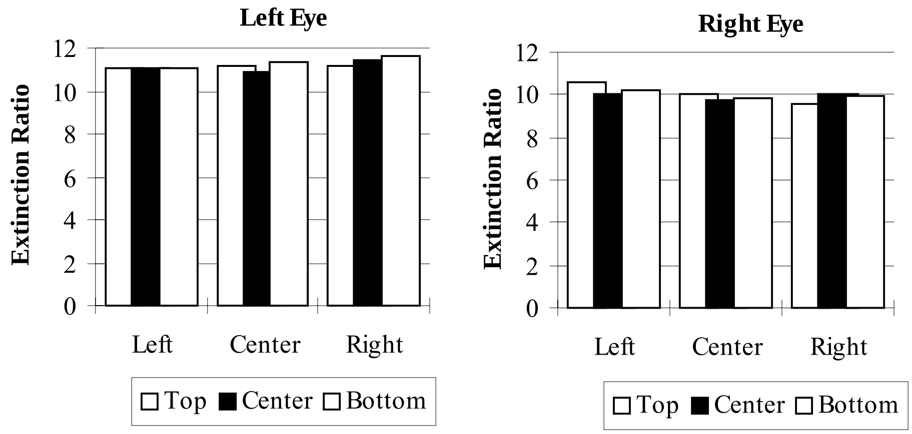

Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode using StereoGraphics ZScreen 19-inch LC shutter system with passive polarized eyeglasses.

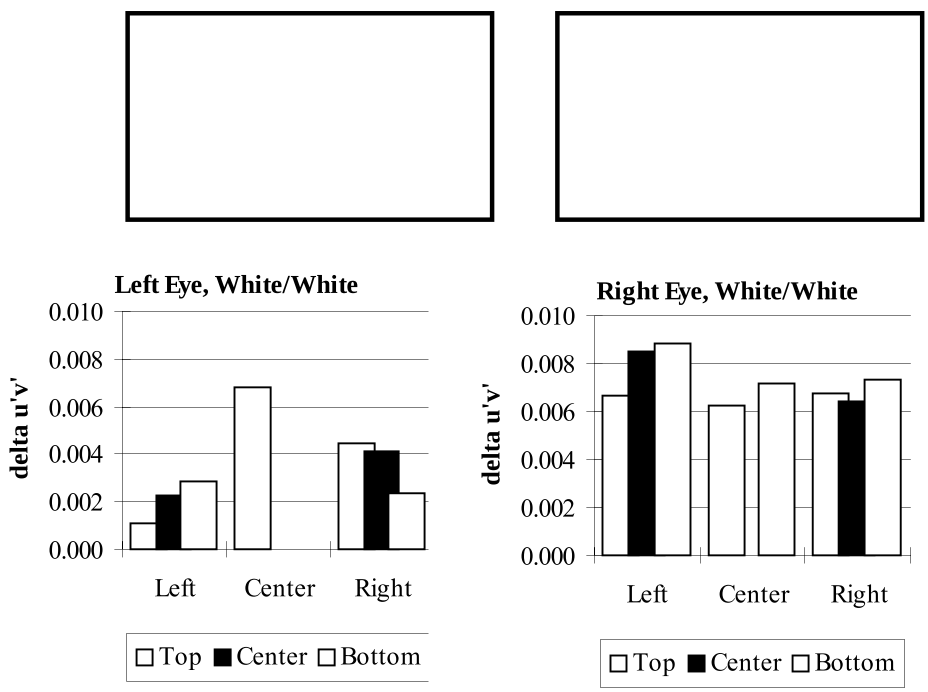

Fig.II.17-4 Spatial uniformity of chromaticity of white in stereo mode using StereoGraphics ZScreen 19-inch LC shutter system with passive polarized eyeglasses.

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II.18. Linearity

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

The maximum nonlinearity of the scan was 0.38% of full screen.

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

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

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

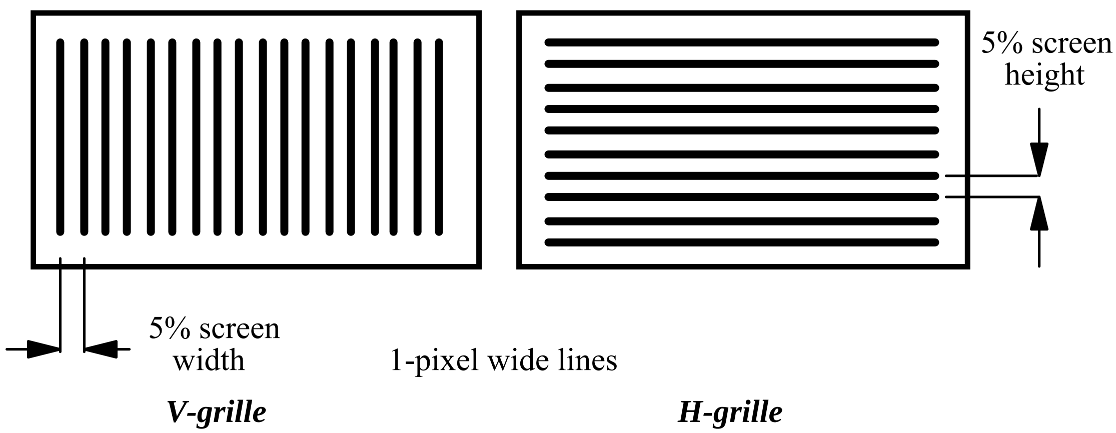


Figure II.18-1. *Grille patterns for measuring linearity*

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

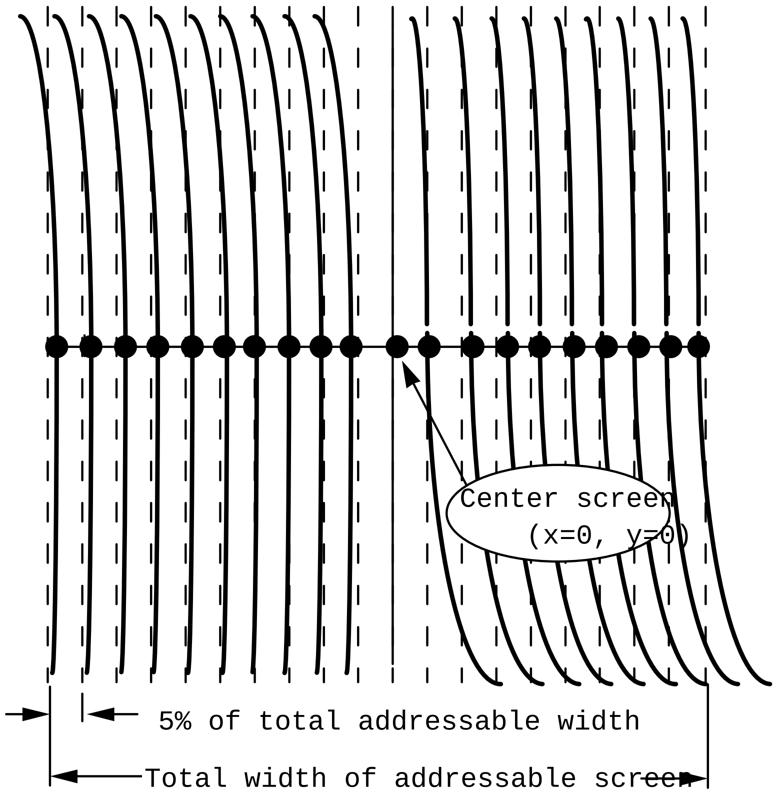


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impact the absolute position of each pixel on the screen and are, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figures II.18-3 and II.18-4.

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

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	0.38%	0.09%	0.27%	0.12%

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
-7803	7839	5805	-5803
-7001	7052	5201	-5223
-6208	6260	4605	-4643
-5433	5470	4020	-4065
-4662	4686	3442	-3487
-3893	3904	2869	-2909
-3125	3130	2299	-2330
-2347	2351	1729	-1748
-1566	1567	1154	-1163
-782	785	578	-580
0	0	0	0

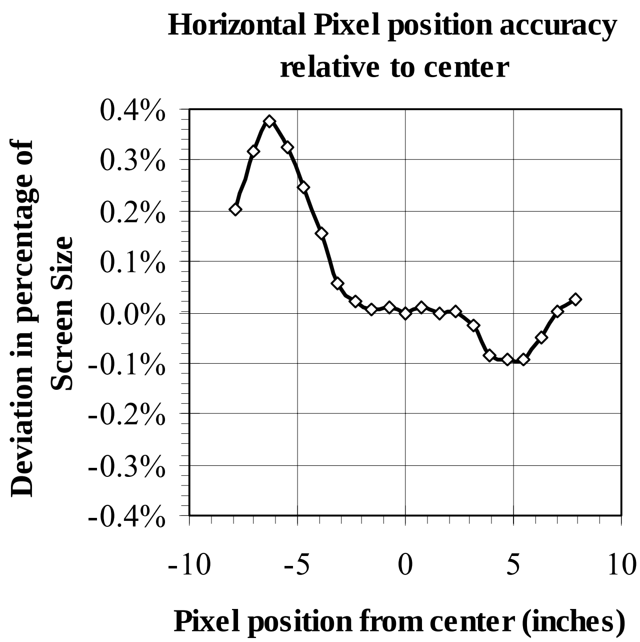


Fig. II.18-3 Horizontal linearity characteristic.

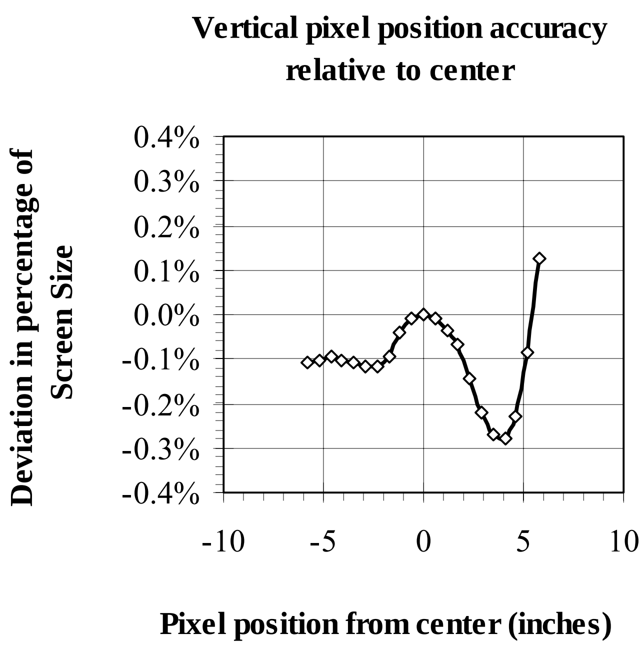


Fig. II.18-4 Vertical linearity characteristic

II.19. Jitter/Swim/Drift

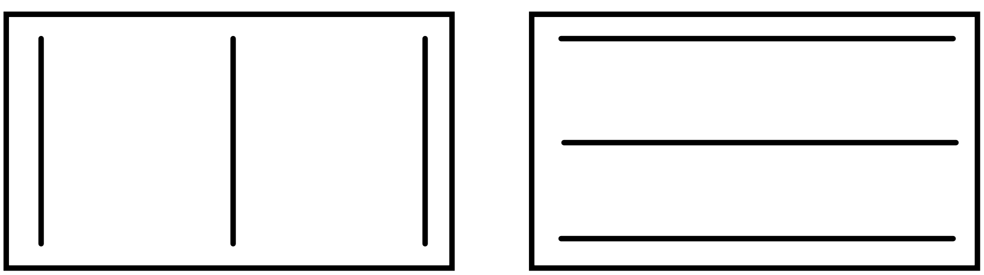
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 2.32 mils and 2.82 mils, respectively.

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

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

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



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

1-pixel wide lines

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

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

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

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

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

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

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

1600 x 1200 x 75Hz

		Upper Left Corner		**Center Screen**		
		H-lines	V-lines	H-lines	V-lines	
10D corner	Max Motions					
	Jitter	2.38	2.57	2.4	1.774	
	Swim	2.9	2.87	2.87	1.84	
	Drift	2.58	2.48	3.08	1.84	
Black Tape	Max Motions					
	Jitter	0.266	0.246	0.224	0.176	
	Swim	0.329	0.271	0.246	0.188	
	Drift	0.315	0.295	0.265	0.204	
Less Tape Motion						maximums
	Jitter	2.11	2.32	2.18	1.60	2.32
	Swim	2.57	2.60	2.62	1.65	2.62
	Drift	2.27	2.19	2.82	1.64	2.82

II.20 Warm-up Period

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

A 17 minute warm-up was necessary for luminance stability of Lmin = 0.1 fL + 10%.

Objective: Define warm-up period

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

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

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

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1600 x 1200 format in graphical form. The luminance remains very stable after 21 minutes.

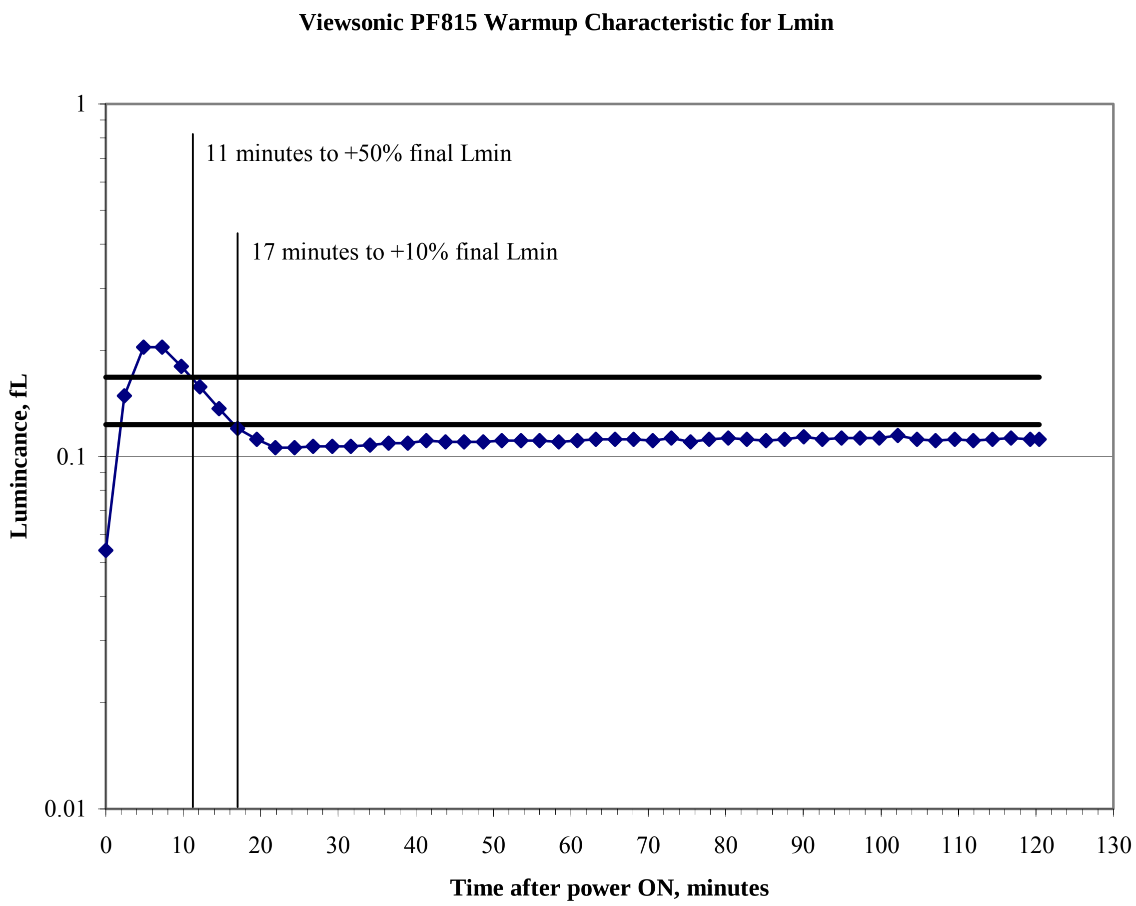


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).