ARMY RESEARCH LABORATORY

Characterization of Fujitsu 42-in. Plasmavision PDS4201 Display Monitor

David Y. T. Chiu and David C. Morton

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Sensors and Electron Devices Directorate

Abstract

This report presents the results of a characterization and evaluation effort on a Fujitsu 42-in. color AC plasma display. The Fujitsu display is a state-of-the-art plasma display with a size and resolution that is commercially available only from a foreign manufacturer. The objective of this effort is to evaluate the latest in foreign display technology. Areas of characterization and evaluation covered in this report are luminance/uniformity measurements, time response characteristics, red, green, and blue (RGB) color spectral scans, RGB Commission Internationale de l'Eclairage (CIE) measurements, and aging effects.

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1. Introduction

The Army identified a need for command post situational awareness displays, the type of displays characterized by large viewing areas and high resolution, that are intended for large audiences. Examples of these displays include projection liquid crystal displays (LCDs), projection cathode ray tubes (CRTs), large CRTs, and large screen AC plasma displays. Among these, AC plasma display has the smallest operational space/volume requirement, and the technology has the highest potential of achieving the ideal "hang-on-the-wall"-type large, flat, thin display. This report describes the results of a characterization and evaluation effort on a Fujitsu 42-in. Plasmavision display monitor, performed by the U.S. Army Research Laboratory (ARL).

Japan is the leader in the research and manufacture of AC color plasma displays. It is the first country to produce commercially available AC full-color plasma displays, and its manufacturers are about 2 to 3 years ahead of the U.S. in the research and development (R&D) of AC color plasma panels. There is currently no U.S. manufacturer of the technology. The Fujitsu 42-in. plasma display described in this report represents the latest state-of-the-art (at the time the display was purchased), commercially available large color plasma display of such screen size.

We characterized the Fujitsu 42-in. Plasmavision display in terms of

- luminance/uniformity measurement,
- time response characteristic,
- spectral scan on each red/green/blue (RGB) color,
- Commission Internationale de l'Eclairage (CIE) measurement on each RGB color, and
- effects of aging.

2. Display

The detailed specification for the display is shown in the appendix. A complete description of the display can be found on the Fujitsu website at http://www.fujitsu.com/plasma.html. Some main features of the display are a viewing area of 36.5 × 21 in. (42 in. diagonal), with an aspect ratio of 16:9; resolution of 852 × 480 pixels, with a color depth of 16.7 million (256 for each RGB color); and an overall dimension of 40.4 × 25.2 × 5.9 in. The display provides inputs for analog RGB, NTSC, S-Video, RS232C, and audio. It comes with its own PCI graphics controller card and software drivers for Windows 3.1, 98, NT3.51, and NT4.0. The PCI controller outputs various resolutions, including 640 × 480, 800 × 600, 1024 × 768, 1280 × 1024, 1600 × 1200, and 852 × 480. All measurements in the report were performed in 852 × 480 resolution, unless otherwise specified.

The display comes with hardware for wall (both vertical and horizontal position) and desktop-stand mounting. The tests were performed with the display mounted on the desktop stand in a 90°, upright position.

3. Test Equipment

The main measurement equipment used was the Spectra Pritchard PR-1980B Spectroradiometer from Photo Research. It provided measurements for luminance, uniformity, and spectral scanning. A Micron Millennir 150-MHz PC was used as a host to control the operation of the photometer through the IEEE-488 interface. The photometer was connected to a control console that, in turn, connected to the host PC. MOD10, a DOS-based, menu-driven program from Photo Research, provided the software interface and controls.

The dedicated graphics controller card, supplied by Fujitsu, was installed in a Pentium PC and connected to the plasma display through the analog DB15 connector. Test patterns were generated using Microsoft Paint. The program allowed us to control the output of different shades and mixtures of the RGB colors required for the different measurements.

A Tektronix TDS-784A digitizing scope was used for the time-response characteristic measurements.

4. Test Results

4.1 Luminance/Uniformity Measurement

Dependence of luminance output on information/image content.—The luminance output of the display is heavily dependent on the information/ image content displayed on the screen at the time of the measurement. What is being displayed on the screen has a significant effect on the measurement data. For example, three significantly different luminance measurements were obtained at the same spot, with the same brightness and contrast settings, but with different surrounding images. The typical luminance readings were 8.3, 15.7, and 29.1 FL, respectively, when 100 percent (screen fully on), 50 percent, and 5 percent of the screen was lit. Table 1 summarizes the results.

Settling time.—A settling time of approximately 5 to 8 min was observed on the luminance output of the display before it became stable. The rate of settling appeared to be exponential, settling relatively fast during the first 0.5 to 1 min or so, then stabilizing slowly as time progressed. Off readings in excess of 20 to 30 percent of the final stabilized values are not uncommon during the first minute of settling. This is especially true for high luminance levels.

As such, unless otherwise specified, all luminance measurements performed in this report were taken with the display uniformly lit and after its brightness had fully stabilized.

Uniformity measurements.—Uniformity measurements were taken before the life test by measuring the luminance outputs at 40 locations uniformly spaced on the screen as shown in figure 1. Measurements were performed first with the photometer aimed at the center of each dot on figure 1, and

Table 1. Effect of information/image content on displayed luminance.

Percentage of screen on	Luminance reading
100	8.3 FL (28.44 Cd/m^2)
50	15.7 FL (53.79 Cd/m^2)
5	29.1 FL (99.7 Cd/m^2)

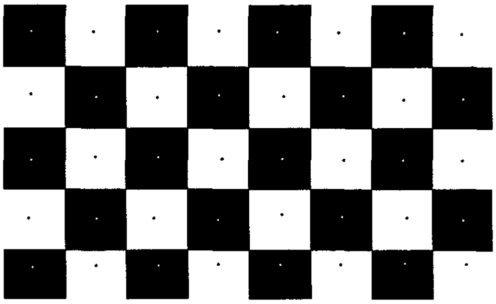


Figure 1. Uniformity measurement of 40 measurement spots on screen.

then with the image of figure 1 removed and replaced with a full-on screen image (all pixels fully on), so that the same information/image content was maintained during all measurements. Three sets of measurement were made at each spot, namely, at maximum, middle, and minimum settings on both the brightness and contrast controls of the display. The results are shown in table 2. As the table shows, there is a slight increase in luminance toward the bottom and around the center of the screen; nevertheless, the display appears fairly uniform.

4.2 Time Response Characteristic

The measurement setup for the luminance response characteristic is shown in figure 2. As shown, the luminance signal was taken from the video output of the photometer, while the photometer was looking at the display with the screen fully lit (all RGB colors on). The vertical synchronization (sync) signal was used as the triggering source to the scope, to look at the luminance response of the plasma display for one frame time period.

For comparison purposes, two sets of measurements were performed, one on the Fujitsu plasma and the other on a typical CRT monitor, specifically, the HP UltraVGA 1280 (the same monitor used on the PC that generated the test patterns for this characterization effort). Figures 3 and 4 show the results of the luminance response characteristic for the plasma and CRT display, respectively.

Table 2. Result of uniformity measurements on 40 locations of display at maximum, middle, and minimum brightness and contrast settings.

Photometer settings
Rear filter: photopic, front filter: ND2, measurement field: 1°.
Plasma display setting
Gradation: still, mode 2.

Brightness and contrast settings	Measurement spot on Fujitsu 42-in. Plasmavision display (from fig. 1)*							
Maximum	8.0	8.0	8.0	8.1	7.9	7.9	7.8	7.9
Middle	7.5	7.55	7.4	7.6	7.4	7.3	7.4	7.5
Minimum	0.67	0.69	0.68	0.68	0.67	0.65	0.66	0.68
Maximum	7.8	8.1	7.9	8.0	7.9	8.2	7.8	7.8
Middle	7.4	7.55	7.4	7.5	7.3	7.5	7.2	7.3
Minimum	0.66	0.67	0.65	0.67	0.66	0.67	0.65	0.65
Maximum	7.9	8.2	8.1	8.2	8.1	8.1	8.0	8.0
Middle	7.4	7.65	7.5	7.6	7.5	7.5	7.4	7.4
Minimum	0.67	0.7	0.67	0.68	0.69	0.67	0.66	0.67
Maximum	8.2	8.5	8.2	8.4	8.2	8.3	8.2	8.2
Middle	7.7	7.9	7.6	7.8	7.7	7.6	7.5	7.6
Minimum	0.71	0.7	0.67	0.7	0.66	0.67	0.69	0.67
Maximum	8.3	8.5	8.4	8.7	8.5	8.4	8.3	8.3
Middle	7.7	7.9	7.8	8.0	7.8	7.7	7.7	7.7
Minimum	0.71	0.71	0.7	0.71	0.7	0.67	0.71	0.72

**Units are in FL.*

Figure 2. Measurement setup for luminance response characteristic.

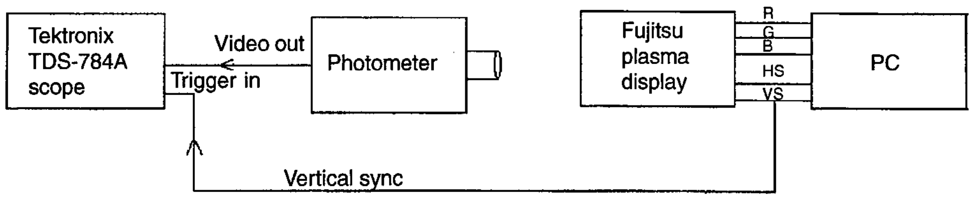


Figure 3. Luminance response of typical CRT display with acquisition mode at average 15.

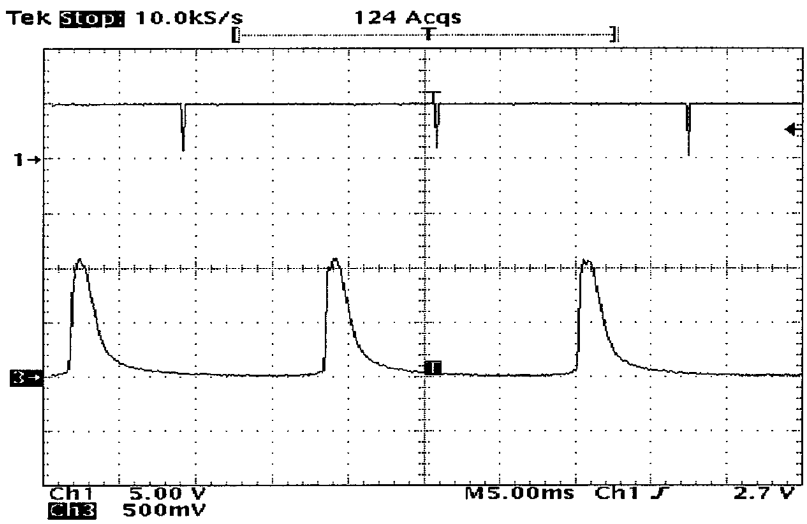
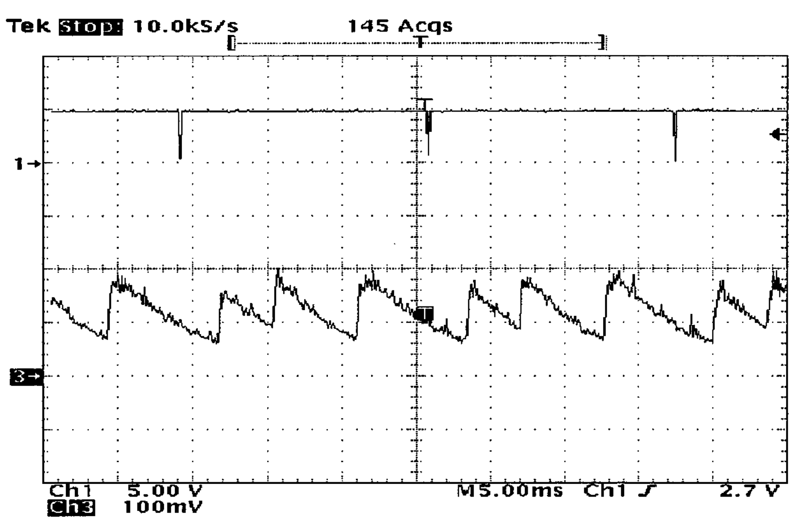


Figure 4. Luminance response of plasma display with acquisition mode at average 15.



Each figure shows two traces. The top trace is the vertical sync signal coming off the PC to the display and the scope. As shown, the time interval between sync signals is approximately 16.67 ms, corresponding to one frame time, or the 60-Hz refresh rate of the display. The bottom trace is the luminance signal from the photometer. In the case of the CRT, it can be seen that a single pulse was responsible for all the light output coming off that frame period. The Fujitsu plasma, however, showed three distinct pulses, with rather fast rise time and slow decay time. Apparently, the unique drive scheme of the plasma was responsible for these pulses. With the scope set to a higher resolution acquisition mode, all three pulses had spikes of significant amplitude on top of them, as shown in figure 5. Response from the CRT did not show such spikes. It should also be pointed out that in addition to the spikes, the plasma waveform also contained noises and other signals running across the scope. Since the frequencies of these signals were unknown, it was not possible to lock onto them to observe their waveforms and determine if they played any role in the overall luminance output of the plasma.

Time responses for each of the RGB colors revealed similar results. The Fujitsu plasma display showed multi-pulses (with different wave shapes for each color, as well as for white) for each color, whereas the CRT showed a single pulse for each color.

4.3 Spectral Scans

With both the MOD10 software and the Pritchard PR-1980B set to spectroradiometer mode, spectral scans were performed on each of the RGB colors on the Fujitsu display. The range of scan was chosen to be from 380 to 780 nm, in steps of 1 nm. For comparison purposes, similar spectral scans on a CRT (the HP UltraVGA monitor) were also performed. Results are shown in figures 6 to 8 (for the plasma display) and 9 to 11 (for the CRT).

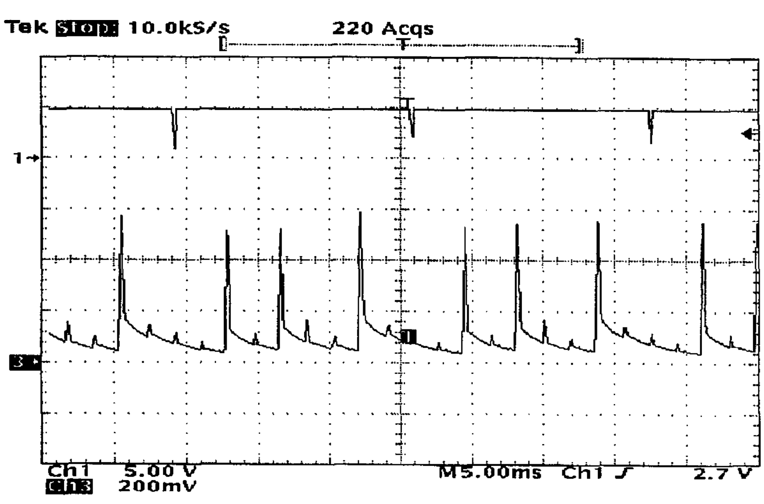


Figure 5. Luminance response of plasma display with acquisition mode at high resolution.

Figure 6. Plasma spectral scan—red.

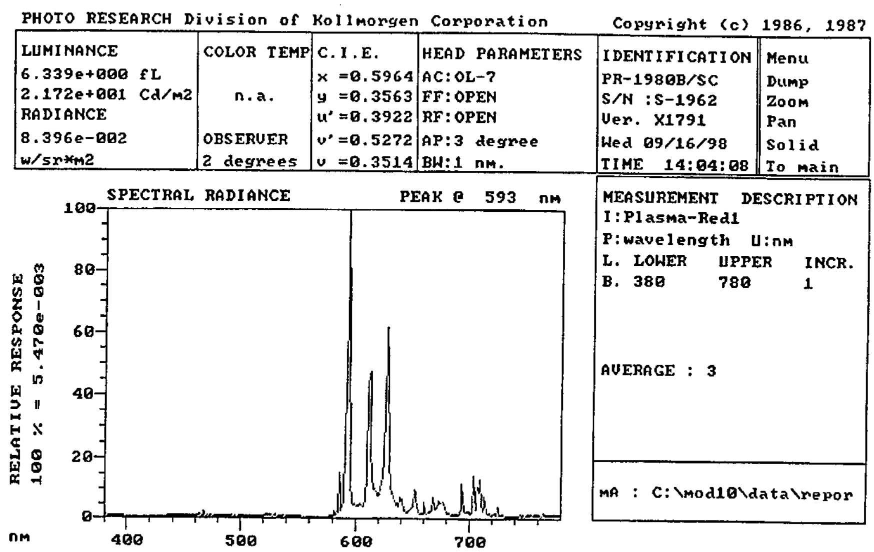


Figure 7. Plasma spectral scan—green.

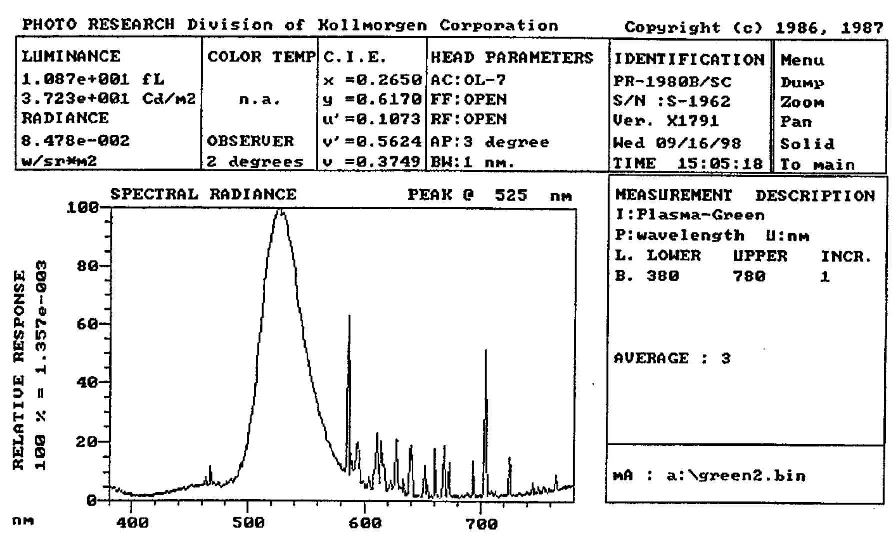


Figure 8. Plasma spectral scan—blue.

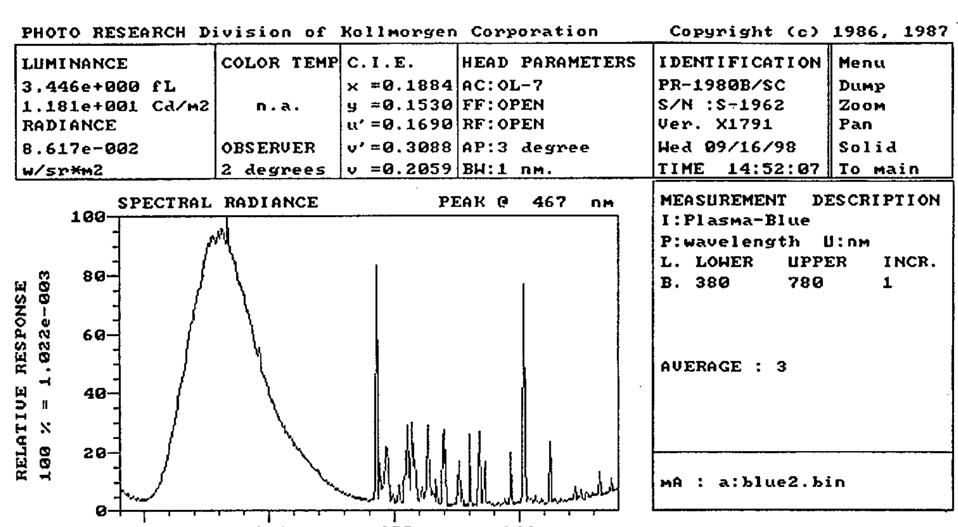


Figure 9. CRT spectral scan—red.

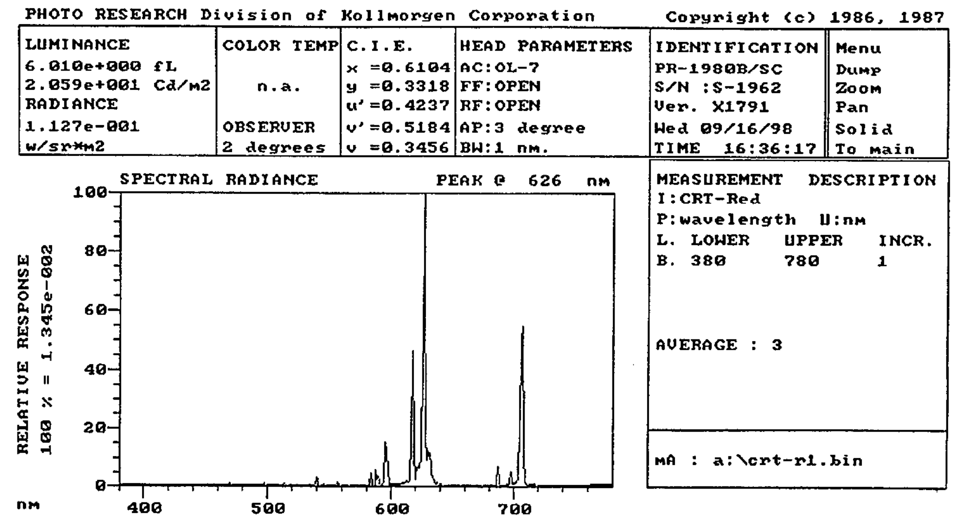


Figure 10. CRT spectral scan—green.

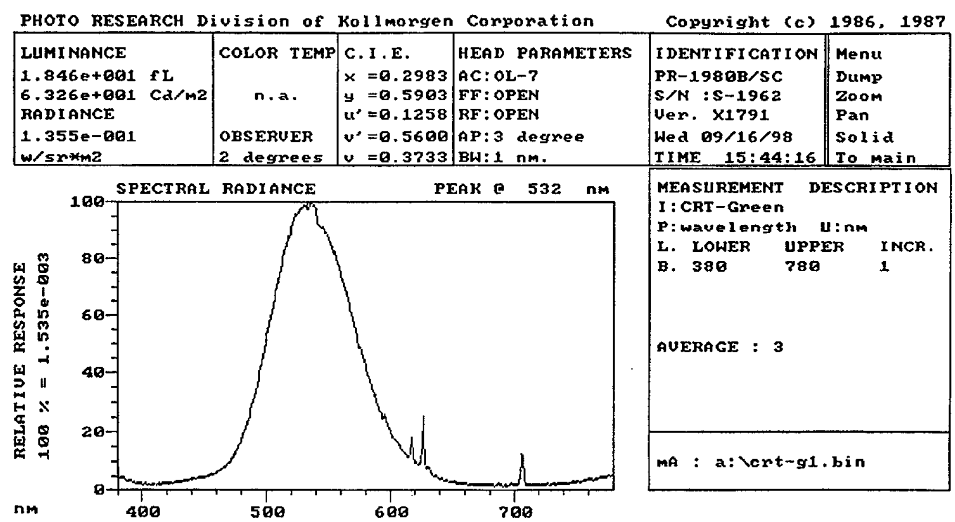
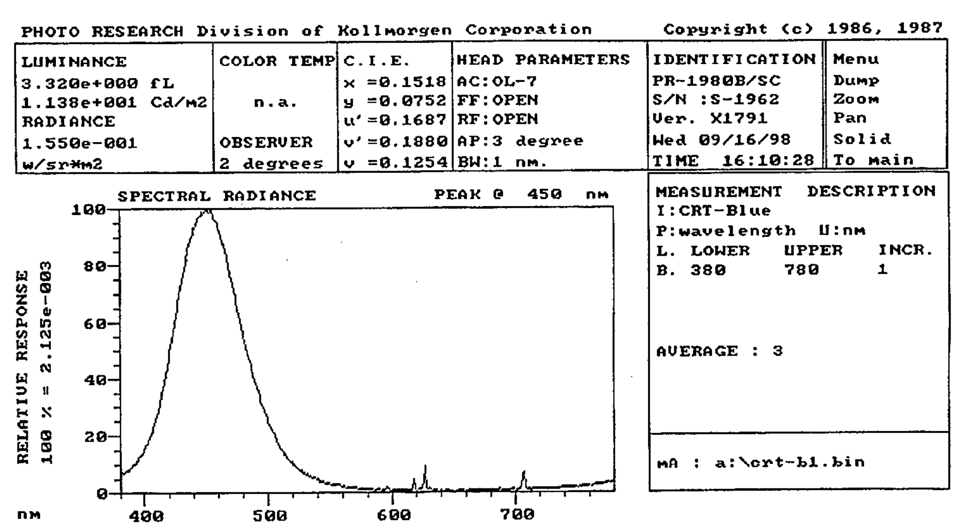


Figure 11. CRT spectral scan—blue.



As these figures show, the CRT scans generally have "cleaner" pulses compared to those of the plasma. Especially for the green and blue, the CRT scans show that a single pulse was more or less responsible for the output for each of the respective green and blue; in the case of the plasma, multiple small pulses other than the dominant pulse outside the color range were responsible for the respective green and blue. The CRT green and blue pulses were also wider than those of the plasma display. As for the red, figure 6 shows that the plasma display has three distinct pulses between 590 and 626 nm, whereas the CRT also has three pulses, but located around 620–630 and 710 nm. All these were narrow pulses. It is also interesting to note that the plasma display has a spike of significant magnitude at around 585 to 590 nm in all three colors.

4.4 CIE Chromaticity

The MOD10 software, a DOS-based program that provided the interfaces and controls for the operation of the Pritchard PR-1980B, generated the CIE chromaticity diagrams from the data taken from the spectral scans. The results are shown in figures 12 to 23. Figures 12 to 14 show the CIE 1976 chromaticity diagrams of the plasma measurements for the red, green, and blue colors, respectively. The corresponding 1931 chromaticity diagrams are shown in figures 15 to 17. Figures 18 to 20 show the CIE 1976 chromaticity diagrams of the CRT measurements for the red, green, and blue colors, respectively. The corresponding 1931 chromaticity diagrams are shown in figures 21 to 23.

Table 3 summarizes the results of these measurements and compares them to the standards of CCIR D65 Rec. 709 and ITU D65 (the current industry standards) for contemporary monitors and high-density television (HDTV). As can be seen in the table, data on the CRT are fairly close to those of the CCIR/ITU standards, whereas the data on the plasma show a notable deviation from the standards for the blue. Visually, though, there was a more noticeable difference between the CRT and the plasma display on the red than on the blue: the red appears more saturated on the CRT than on the plasma, where it appears washed out.

Figure 12. CIE 1976 chromaticity diagram for plasma display—red.

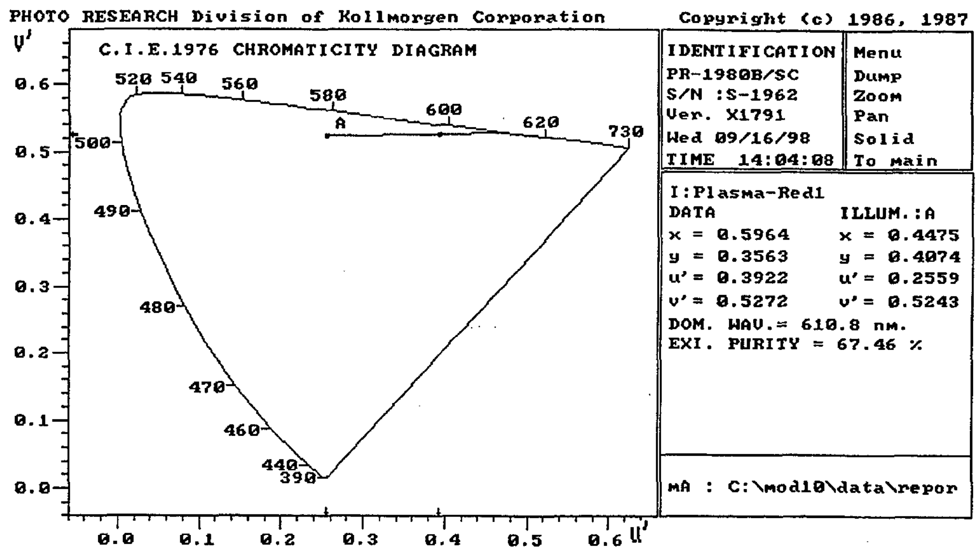


Figure 13. CIE 1976 chromaticity diagram for plasma display—green.

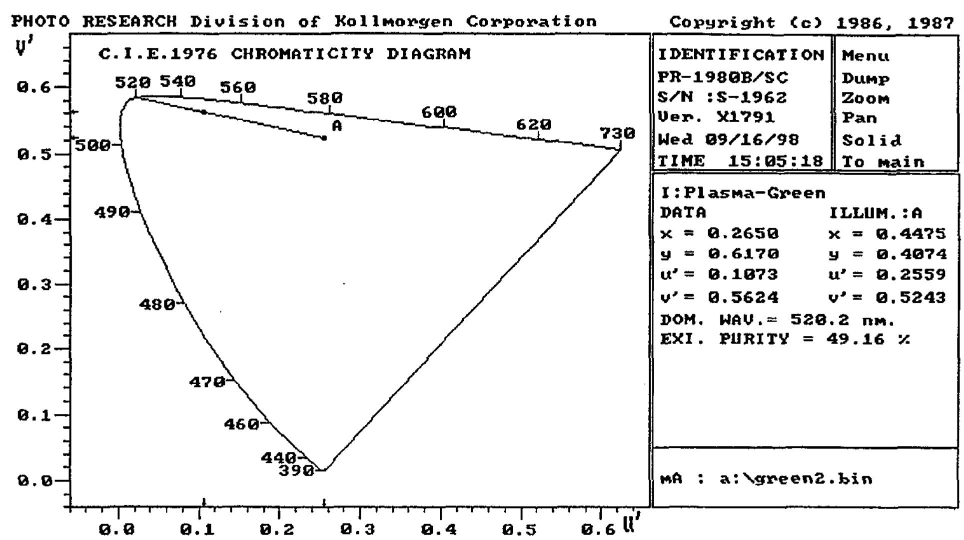
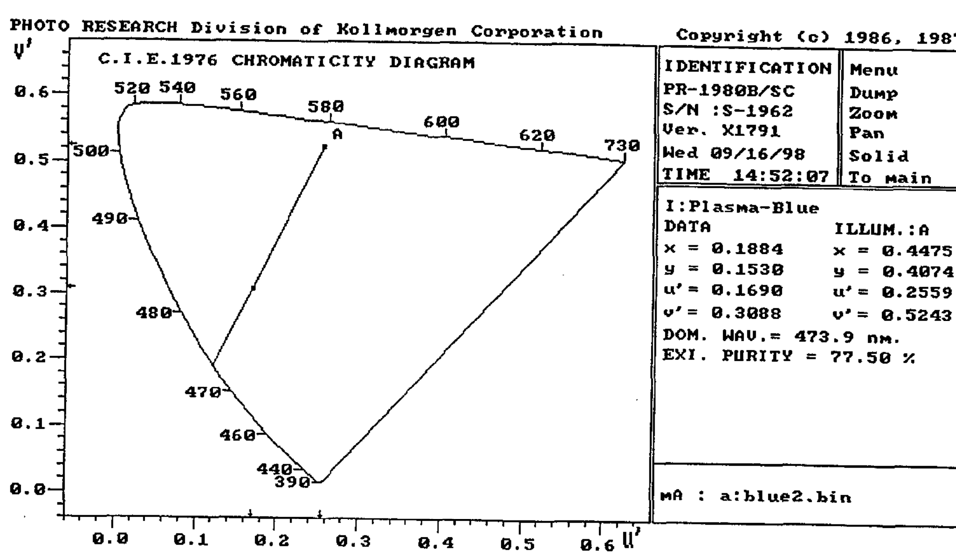


Figure 14. CIE 1976 chromaticity diagram for plasma display—blue.



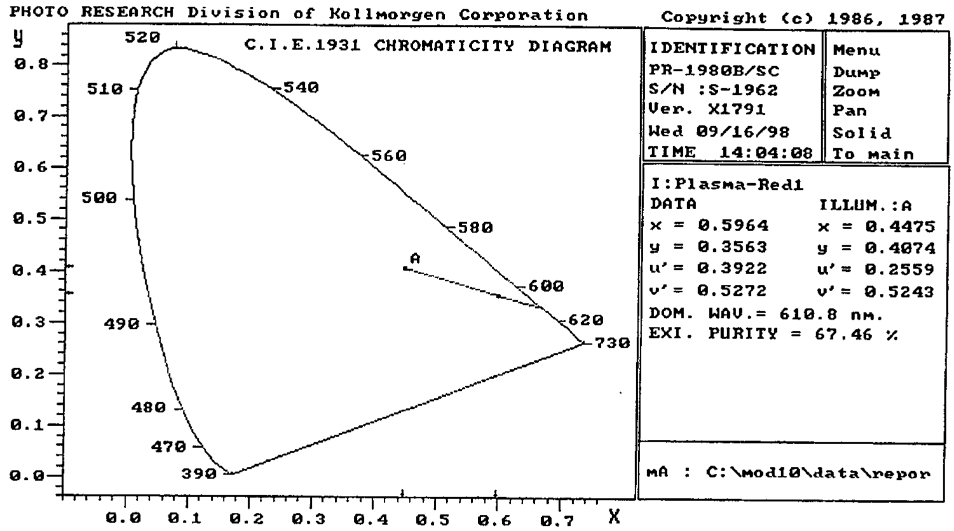


Figure 15. CIE 1931 chromaticity diagram for plasma display—red.

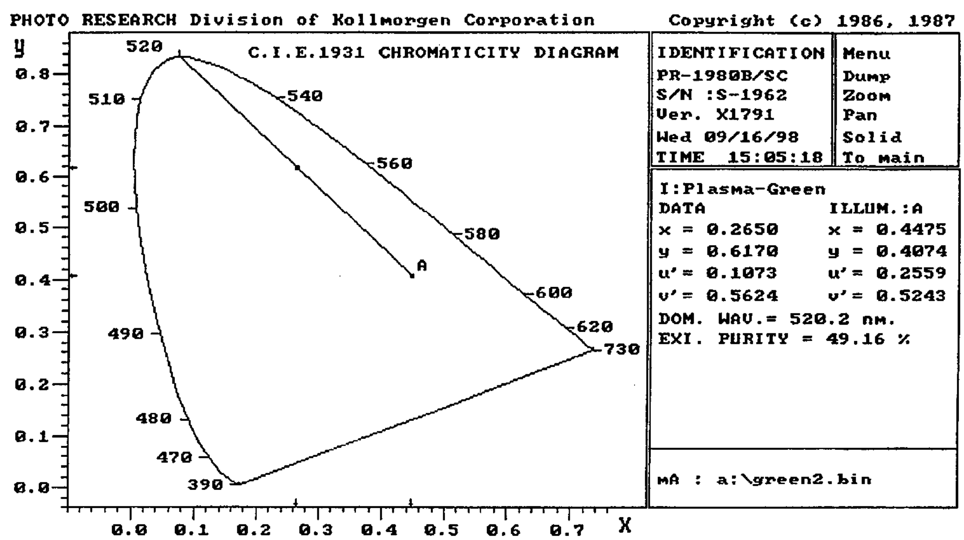


Figure 16. CIE 1931 chromaticity diagram for plasma display—green.

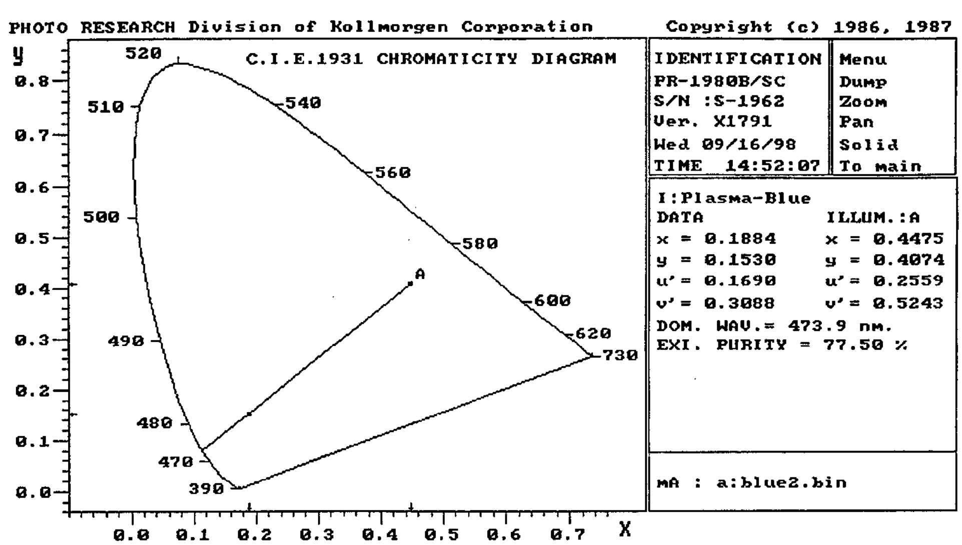


Figure 17. CIE 1931 chromaticity diagram for plasma display—blue.

Figure 18. CIE 1976 chromaticity diagram for CRT—red.

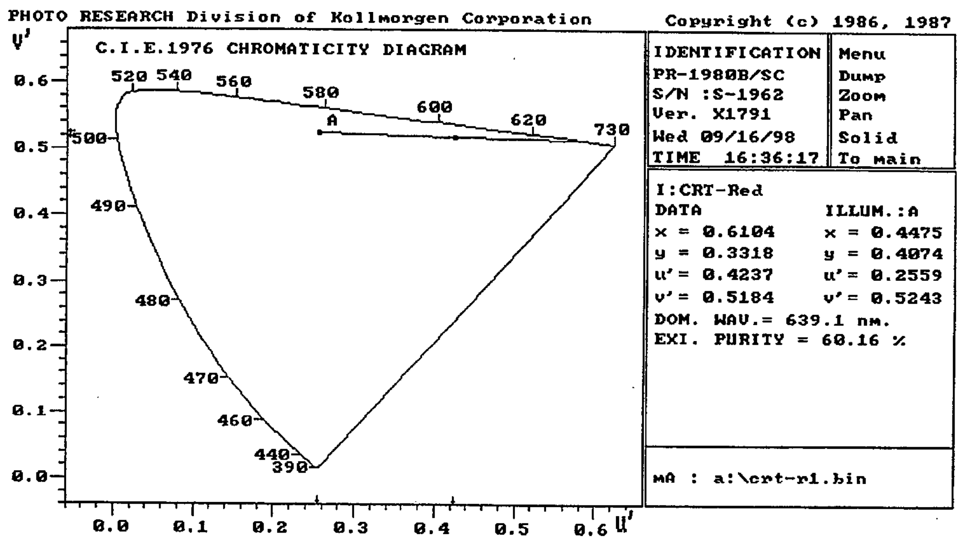


Figure 19. CIE 1976 chromaticity diagram for CRT—green.

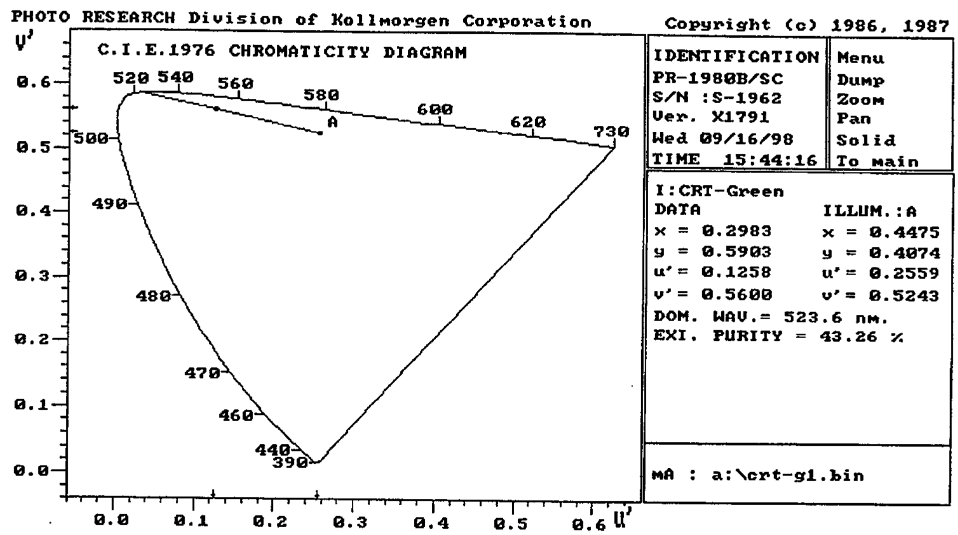


Figure 20. CIE 1976 chromaticity diagram for CRT—blue.

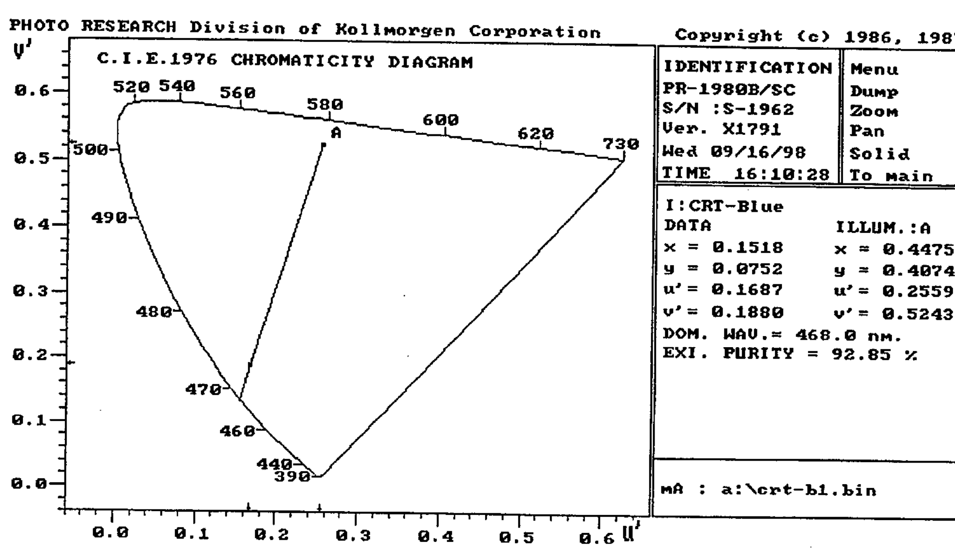


Figure 21. CIE 1931 chromaticity diagram for CRT—red.

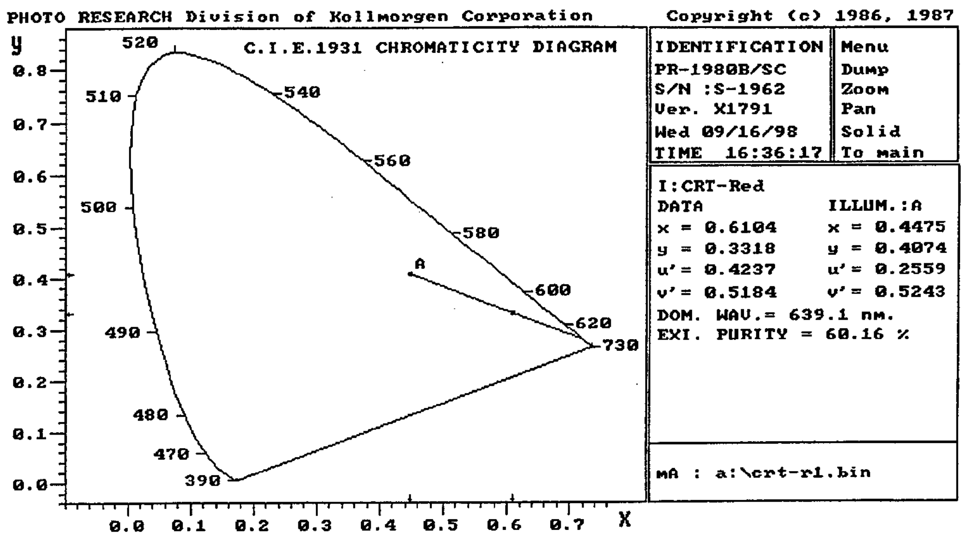


Figure 22. CIE 1931 chromaticity diagram for CRT—green.

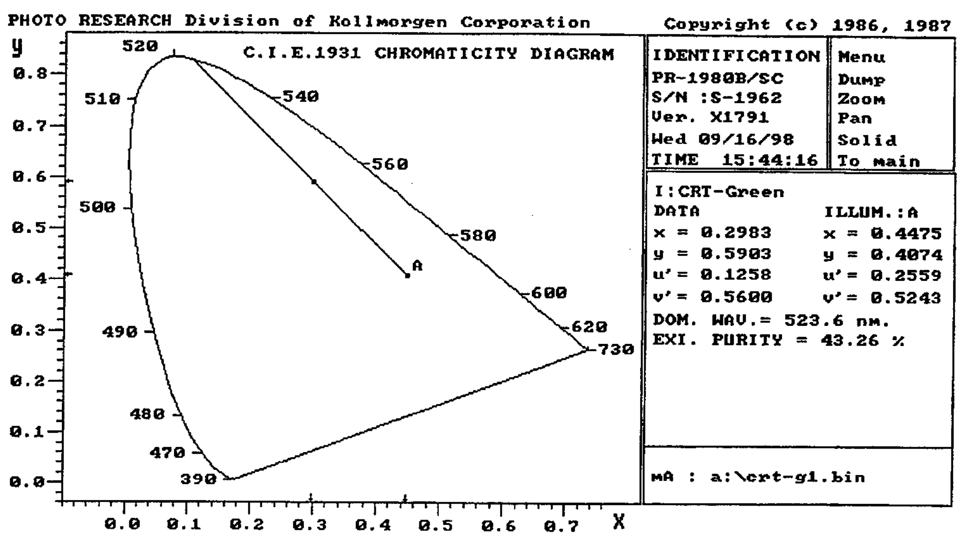


Figure 23. CIE 1931 chromaticity diagram for CRT—blue.

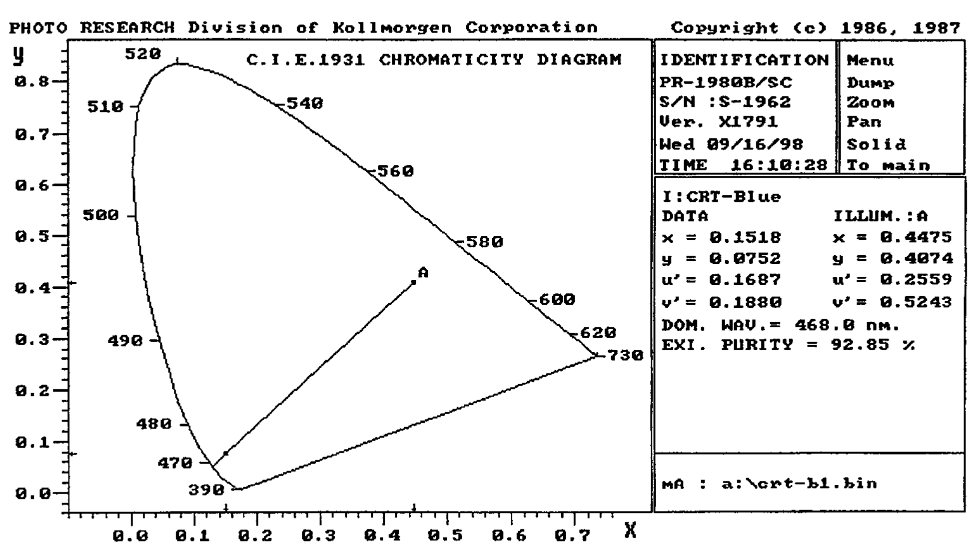


Table 3. Comparison of CIE data on plasma, CRT, and CCIR Rec. 709 or ITU D65 standard.

Displays	Red	Green	Blue
Fujitsu Plasmavision	$x = 0.5964$	$x = 0.2650$	$x = 0.1884$
	$y = 0.3563$	$y = 0.6170$	$y = 0.1530$
CRT (HP UltraVGA)	$x = 0.6104$	$x = 0.2983$	$x = 0.1518$
	$y = 0.3318$	$y = 0.5903$	$y = 0.0752$
CCIR Rec. 709 or ITU D65	$x = 0.64$	$x = 0.30$	$x = 0.15$
	$y = 0.33$	$y = 0.60$	$y = 0.06$

4.5 Life Test

As of this writing, the life test is still in progress, and only limited, preliminary results are available at this time. A follow-on report is planned to document final results at the end of the test. The main objectives of the life test are to determine the luminance output of the display before and after the life test, and to observe the effects of "on-aging" and "off-aging" on the panel. On-aging and off-aging refer to the effects of aging on areas of the display where pixels are fully on and off, respectively, during the life test; our objective is to determine what effect aging has on the on and off areas of the display in its luminance output and spectral scans. Figure 24 shows the image pattern for the life test. The black and white areas represent, respectively, areas where pixels are fully off and on during the life test. The settings for both the display's brightness and contrast were at maximum during the life test.

So far, the life test has been conducted for about 2900 hr. Three separate luminance measurements were made on on and off areas of the panel, after 800, 1500, and 2900 hr. The areas were chosen to be the two most centered spots in figure 24. During these measurements, we found that a residual image of the test pattern in reverse (the on-off pattern was reversed) was created and "imprinted" onto the screen. We first noticed the image at the first measurement, after 800 hours. It was visible at all times, and at all brightnesses and contrast settings, and appeared fixed as a background image on the screen even when all pixels were turned off or on. Its effect on the luminance output can be seen in table 4. As the table shows, after 2900 hr, the on area seemed to have a small degradation in luminance, especially at maximum brightness and contrast settings, whereas the off area showed little change. Additional data are needed to confirm this. Spectral scans should also reveal changes, if any, in each of the red, green, and blue colors.

Pending more investigation at the end of the life test, it is worthwhile to determine whether the residual image is a reversible or a permanent process. At least during the approximately 2 hr duration which the luminance measurements were taken, the residual image did not appear to have any significant changes.

Figure 24. Test pattern for life test.

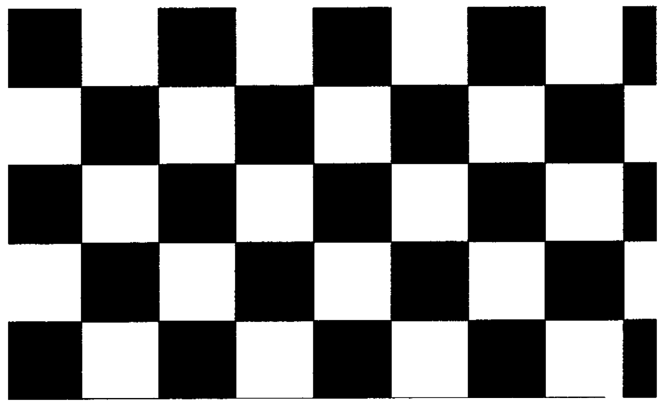


Table 4. Preliminary luminance measurement before and during life test.

Brightness and contrast settings	Before life test	After 800 hr	After 1500 hr	After 2900 hr
On area				
Maximum	8.2	—	8.0	7.87
Middle	7.6	7.6	7.55	7.34
Minimum	0.68	—	0.72	0.685
Off area				
Maximum	8.1	—	8.25	8.15
Middle	7.5	7.65	7.75	7.58
Minimum	0.69	—	0.73	0.695

5. Summary

The uniformity measurements showed a luminance dependence on information/image content that could affect the display's use where night vision and dimming are required. The uniformity measurements showed values of 7.56, with a high of 8.0 and low of 7.2 (at middle brightness and contrast settings). This gives an overall nonuniformity of 10.6 percent, which is within acceptable limits, since the variation was gradual over the whole panel. The response of the panel is fast enough to show moving images. The color of the display appears somewhat washed out, because of the lack of color saturation, as shown by the CIE plots. This lack of saturation would not significantly affect the display's performance, however.

Limited preliminary data from the life test show measurable effects on the luminance output, and a residual image as a result of the on-off aging pattern. Further investigation and measurements at the end of the test will determine the exact extent of the on-off aging's effect on the display's luminance uniformity, as well as the color plots, and will show whether the residual image is a permanent or reversible process.

Appendix.—Detailed Specifications for Fujitsu 42-in. Plasmavision Display

Specifications

Model name	PDS4201
Screen dimensions	36.2 W × 20.4 in. H (92 W × 51.8 cm H) (42-in. diagonal)
Aspect ratio	16:9 wide (width to height ratio of screen)
Weight	Approx. 87 lb (approx. 39.5 kg)
Dimensions	40.7 W × 25.2 H × 5.9 D in. (103.5 W × 64 H × 15 D cm)
Power source	120 to 240 Vac, 50/60 Hz
Power consumption	350 W
Number of pixels	852 horizontal × 480 vertical pixels
Display modes	*Wide*: Displays wide VGA video horizontal expansion of 4:3 video image for full-screen display *Normal*: 4:3 video image displayed in center of screen *Zoom*: Overall expansion of 4:3 video image for full-screen display (top and bottom of image are cut) *Nonlinear wide*: nonlinear horizontal expansion of 4:3 video image for full-screen display *Auto*: Wide, zoom, etc, are automatically selected, depending on video image input
Displayable colors	16.7 million colors (RGB 256 hues)
Service life	30,000 hr
Viewing angle	160°
Audio output	4 W (2 W + 2 W)
External connectors	Video Video input BNC coaxial × 1 S video input S terminal × 1 V: 1 Vp-p/75 Ω C: 0.286 Vp-p/75 Ω Video system NTSC, PAL, SECAM RGB Analog RGB Input mD-Sub15 pin (3 array) × 1 Video signal: 1 Vp-p 75 Ω Sync signal: TTL level/1 kΩ display frequency Horizontal frequency: 15.73 to 37.9 kHz Vertical frequency: 50 to 75 Hz Audio Audio input Pin jack (L/R) × 1 150m: Vrms/more than 22 kΩ Control RS-232C D-SUB 9 pin × 1
Operating conditions	Temperature: 32° to 104 °F (0° to 40 °C) Humidity: 20 to 80 percent

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This report presents the results of a characterization and evaluation effort on a Fujitsu 42-in. color AC plasma display. The Fujitsu display is a state-of-the-art plasma display with a size and resolution that is commercially available only from a foreign manufacturer. The objective of this effort is to evaluate the latest in foreign display technology. Areas of characterization and evaluation covered in this report are luminance/uniformity measurements, time response characteristics, red, green, and blue (RGB) color spectral scans, RGB Commission Internationale de l'Eclairage (CIE) measurements, and aging effects.

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