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**TEK** ADDENDUM

Part No. 061-3147-00  
Product Group 16

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**4110/4120  
OPTION 19  
4690 SERIES  
COLOR GRAPHICS  
COPIER INTERFACE  
ADDENDUM  
FOR VERSION 6**

*Please Check for  
CHANGE INFORMATION  
at the Rear of This Manual*

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First Printing JUL 1985  
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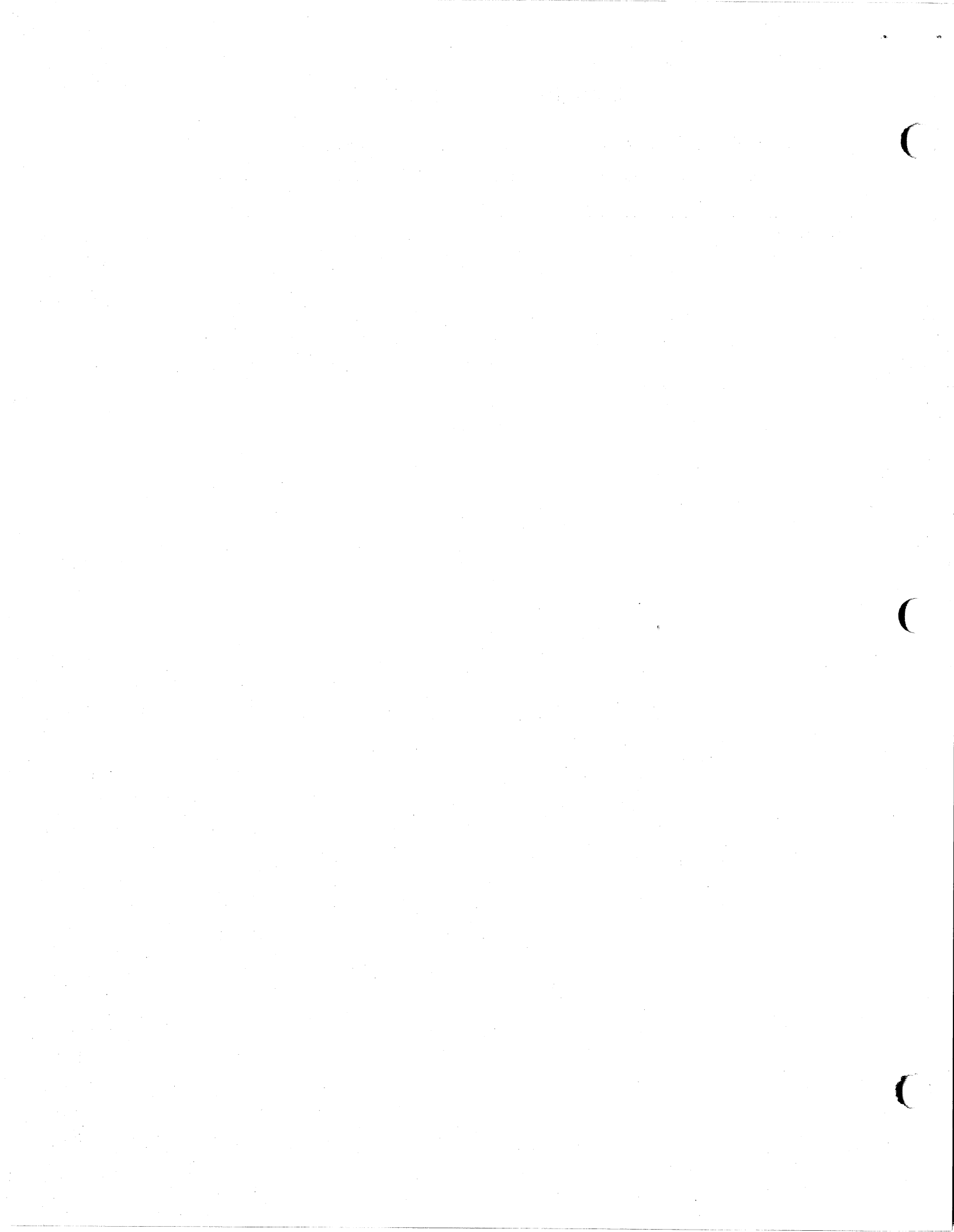
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# MANUAL REVISION STATUS

**PRODUCT: 4110/4120 Option 19 4690 Series Color Graphics Copier Interface**

This manual supports the following versions of this product: Firmware Version 6 and up.

REV DATE	DESCRIPTION
JUL 1985	Original Issue
SEP 1985	Revised



# ADDENDUM FOR VERSION 6, 4110/4120 OPTION 19 4690 SERIES COLOR GRAPHICS COPIER INTERFACE

## INTRODUCTION

Firmware Version 6 adds an improved dithering algorithm and a new color matching algorithm to the Option 19 Interface. These features let you better reproduce on paper the gradual color transitions of 3D smooth shaded images on the 4129 Terminal and more closely approximate the screen colors. The modified interface is compatible with the 4113B, 4115B, and the 4120 Series of Tektronix Terminals.

Follow these steps to determine the firmware version of your color copier interface:

1. Remove the terminal from Setup.
2. Enter Local mode.
3. Type in  $\text{FcIQ19}$  (this won't be echoed on the screen).

The last digit of the report displayed on the screen is the firmware version.

This addendum documents the commands that control dithering and color matching. It should be used with the operators manual, the *4110/4120 Series Command Reference With 3D Manual*, and the *4110/4120 Series Host Programmers With 3D Manual* accompanying your terminal.

You'll find in this addendum:

- Firmware Version 6 Changes
- Dithering and Color Matching Control
  - SET-COLORHARDCOPY-DITHERING Command
  - SET-COLOR-COPIER-DATA-RESOLUTION Command
  - Screen Buffer Device for COPY Command
- Concepts
  - Color Matching
  - Replication
  - Dithering
- Hints
- Computing Reachable Colors
- SC: Data Format
- Error Codes

## FIRMWARE VERSION 6 CHANGES

Previously, the SET-COLORHARDCOPY-DITHERING command affected just the 4691 and 4695 Copiers. Firmware Version 6 extends the command to support color matching, and control the 4692 Copier as well. The impact of the SET-COLOR-COPIER-DATA-RESOLUTION command has been modified and the SC: source device format extended.

Approximately 5K bytes more terminal memory are set aside at power up for dithering and color matching. A small amount of additional memory is also used at copy time for data buffers.

Dithering will have a greater impact on 4692 copy time than on 4691 or 4695 copy time. Without dithering enabled, the 4692 Copier will use its own 216 colors. This allows the 4692 to make faster shaded copies than the 4691 and 4695 Copiers which rely on the Option 19 interface for any dithering. For dithering, however, the 4692 Copier relies on the expanded color palette provided by the Option 19 Interface.

Color matching requires only two seconds more in copy time over dithering.

## DITHERING AND COLOR MATCHING CONTROL

Only the changes to the SET-COLORHARDCOPY-DITHERING and SET-COLOR-COPIER-DATA-RESOLUTION commands and the screen buffer source device are described in this addendum. You can find the entire copier command descriptions in the *4110/4120 Series Command Reference With 3D Manual*.

## SET-COLORHARDCOPY-DITHERING COMMAND

A third choice (2 or MATCH) has been added for the *dither-code* parameter of the SET-COLORHARDCOPY-DITHERING command to enable color matching:

### Host Syntax

```
EcQM int: dither-code
```

### Setup Syntax

```
HCDITHER dither-code
```

### Parameters

*dither-code* (0, 1 or 2)

Setup mode parameters are NO, YES, and MATCH

- 0 NO      disabled
- 1 YES     dithering only enabled
- 2 MATCH   color matching and dithering enabled

## SET-COLOR-COPIER-DATA-RESOLUTION COMMAND

The action of SET-COLOR-COPIER-DATA-RESOLUTION depends on whether dithering is disabled or enabled, and on the source device SC: parameter for the COPY command.

If dithering is not enabled, the SET-COLOR-COPIER-DATA-RESOLUTION command setting designates the color resolution only for the 4692 Copier. In this case, the 4692 uses its built-in dithering, and the SET-COLOR-COPIER-DATA-RESOLUTION command determines whether the 4692 uses 64 or 216 colors to shade the image. (Without dithering enabled, the 4691 and 4695 Copiers are restricted to eight colors.)

When dithering is enabled, the SET-COLOR-COPIER-DATA-RESOLUTION command setting designates the color resolution only if the image is transferred using the COPY command with SC: or SC:0 as the source device.

## SCREEN BUFFER DEVICE FOR COPY COMMAND

The source device SC: for the COPY command specifies the contents of the terminal's screen buffer. Its parameter determines the action of the SET-COLOR-COPIER-DATA-RESOLUTION command on the format of the copied image:

- SC:0 — formats the image with either one or two byte color resolution, depending on the SET-COLOR-COPIER-DATA-RESOLUTION setting, which determines the number of colors the copier will use to shade the image.

(Note: SC: is equivalent to SC:0)

- SC:1 — ignores the SET-COLOR-COPIER-DATA-RESOLUTION setting; formats and sends the image at full color resolution, which uses over 16 million colors to shade the image.

When you COPY an image to a file on disk using SC: or SC:0 as the source device, the SET-COLOR-COPIER-DATA-RESOLUTION setting is stored as part of the file. When the image is SPOOLED from disk to hard copier, this setting overrides the current terminal SET-COLOR-COPIER-DATA-RESOLUTION setting.

### NOTE

*If you use SC: or SC:0 as a source device when color matching is enabled, an error message will be displayed. If this happens, simply reset the dither-code parameter of the SET-COLORHARDCOPY-DITHERING command to disable color matching. Then, issue the COPY or SPOOL command again.*

Table 1 summarizes the interaction of the two commands and the SC: source device parameter. When a copy is made by pressing the HARD COPY key or issuing the HARDCOPY command, it is as if you were making a copy using the COPY command with SC:1 as the source device.

**Table 1**  
**NUMBER OF COLORS EMULATED**

SET-COLORHARDCOPY-DITHERING	SET-COLOR-COPIER-DATA-RESOLUTION	DEVICE	4691/4695 COLOR PALETTE	4692 COLOR PALETTE
None	1 Byte	SC:/SC:0	8	64
None	1 Byte	SC:1	8	64
None	2 Bytes	SC:/SC:0	8	216
None	2 Bytes	SC:1	8	216
DITHER	1 Byte	SC:/SC:0	64	64
DITHER	1 Byte	SC:1	> 16 Million	> 16 Million
DITHER	2 Bytes	SC:/SC:0	4096	4096
DITHER	2 Bytes	SC:1	> 16 Million	> 16 Million
MATCH	1 Byte	SC:/SC:0	Error	Error
MATCH	1 Byte	SC:1	> 16 Million	> 16 Million
MATCH	2 Bytes	SC:/SC:0	Error	Error
MATCH	2 Bytes	SC:1	> 16 Million	> 16 Million

## CONCEPTS

To send an image from the terminal to the copier, Option 19 looks at each screen pixel, matches it if color matching is turned on, replicates it, then dithers it. The result is a smoothly shaded image on paper with colors which more closely approximate those of the screen image.

### COLOR MATCHING

With color matching enabled, Option 19 more closely approximates the screen colors on the hard copy. It does this by using the colors in the terminal color map as inputs to a conversion algorithm which computes the colors to send to the copier, based on the coated surface of the paper and the inks being used on the copier.

The color matching provided by Option 19 is set up for the Tektronix 4115B and 4120 Series Terminals, and the Tektronix 4692 Color Copier with Tektronix inks and coated paper. An image's colors on the 4691 with Tektronix inks will be close, however. Because the 4695 Copier uses substantially different types of ink, its image match will not be as close.

Color matching is an approximate process because the terminal display produces a luminent image using red, green, and blue phosphors, while the color copier produces an image seen with reflected light with black, cyan, magenta, and yellow inks. It is impossible to exactly match colors between the two different systems.

Due to the physical differences in producing colors, some of the terminal colors are simply outside the range of copier colors (see the section later *Computing Reachable Colors*). If the terminal color can't be reproduced by the copier, the interface selects a reasonable hard copy color. Extra processing makes sure the perceptual differences in similar unreachable terminal colors are preserved in the selected copier colors.

Because the terminal emits light while the copier paper reflects light, some terminal colors are lighter than what can be achieved on a copier. If the hard copy color cannot match the lightness of the terminal color, the interface adds more white space between the colored ink dots. Although the added white increases the lightness of the copier color, it also decreases the color's vividness.

### REPLICATION

Any time any copy is produced on the copier, it may be expanded. Whether it is or not depends on the size of the pixel area being copied and the size of the area available on the copier paper.

Option 19 expands an image by *replicating* each pixel from two to a maximum of four times. That is, a two by two replication would reproduce each pixel twice in both the x and y coordinates; a four by four replication would reproduce each pixel four times in both directions.

If the smaller of the x-axis ratio and y-axis ratio between the paper copy area and the pixel viewport is less than two, the screen image is copied on a one to one basis. If the maximum ratio is between two and three, Option 19 replicates each screen pixel twice. Between three and four, the image will be replicated three times, and any minimum ratio over four will be replicated a maximum of four times.

If the replication does not completely fill the paper copy area, Option 19 borders the image with white.

### DITHERING

Since the color copiers can produce only eight colors of dots — white, yellow, magenta, cyan, black, red, green, and blue — the interface *dithers* to copy a color that is not one of these colors. Using the intensities directly from the terminal's color map as inputs to a 16 × 16 magic square, the dithering algorithm mixes the eight colors to approximate the color you see on the screen.

Because the dithering is performed on a pixel-by-pixel basis, the Option 19 Interface will continuously alter the ink dot colors and densities to reflect changes in the color and intensity of the screen pixels. A smoothly shaded image on the screen will appear as a smoothly shaded image on the copier.



## HINTS:

Applications that perform smooth color shading and want vivid colors, but don't need a close match between terminal colors and copier colors should set the SET-COLORHARDCOPY-DITHERING parameter to dithering.

Cartography, textile design, and other applications that want to preserve the selected colors on paper should set the SET-COLORHARDCOPY-DITHERING parameter to color matching. The COPY source device should be set to SC:1.

To retain compatibility with images created with earlier versions of Option 19, set the SET-COLORHARDCOPY-DITHERING parameter to smooth shading, set the SET-COLOR-COPIER-DATA-RESOLUTION for the desired number of colors, and COPY the image using the SC: or SC:0 source device parameter.

To make faster copies on the 4692 by using its built-in shading, set the SET-COLORHARDCOPY-DITHERING parameter to disable dithering or color matching. Set the SET-COLOR-COPIER-DATA-RESOLUTION for the desired number of colors.

## COMPUTING REACHABLE COLORS

You can select a palette of colors which the terminal can display and which the copier can reproduce. The method is based on the CIE color matching functions, in particular the 1931 chromaticity diagram. You do not need to understand the methods to use it.

Figures 1a. through 1d. show the gamut of colors reachable by the terminal and copier, by levels of lightness (L), in steps of 0.2 based on white as 1.0. Figures 2a. through 2e. show the same information for Munsell values 3, 4, 5, 6, and 8 (lightnesses .066, .120, .198, .301, .598).

The best colors will be found in the range of lightness from 0.1 to 0.6 (Munsell values 4 to 8). Below a lightness of 0.1 all colors are quite dark, and above a lightness of 0.6 they become pale.

Table 2 gives the machine RGB (Color Mode 4) entries for 36 colors reachable by both the terminal and the copier. They cover the recommended lightness range and are ordered with respect to both hue and lightness.

# COLORS REACHABLE BY LEVELS OF LIGHTNESS

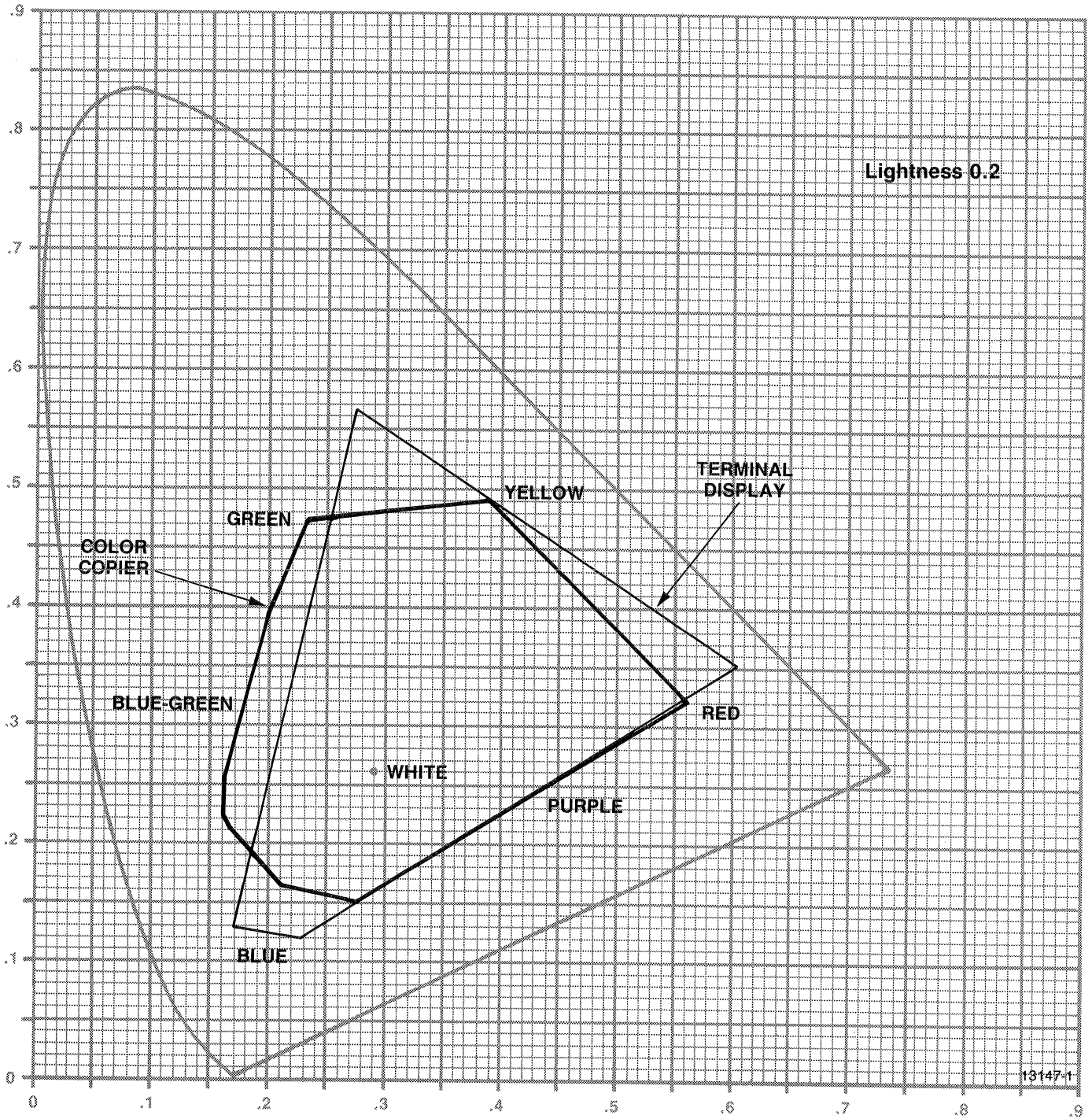


Figure 1a

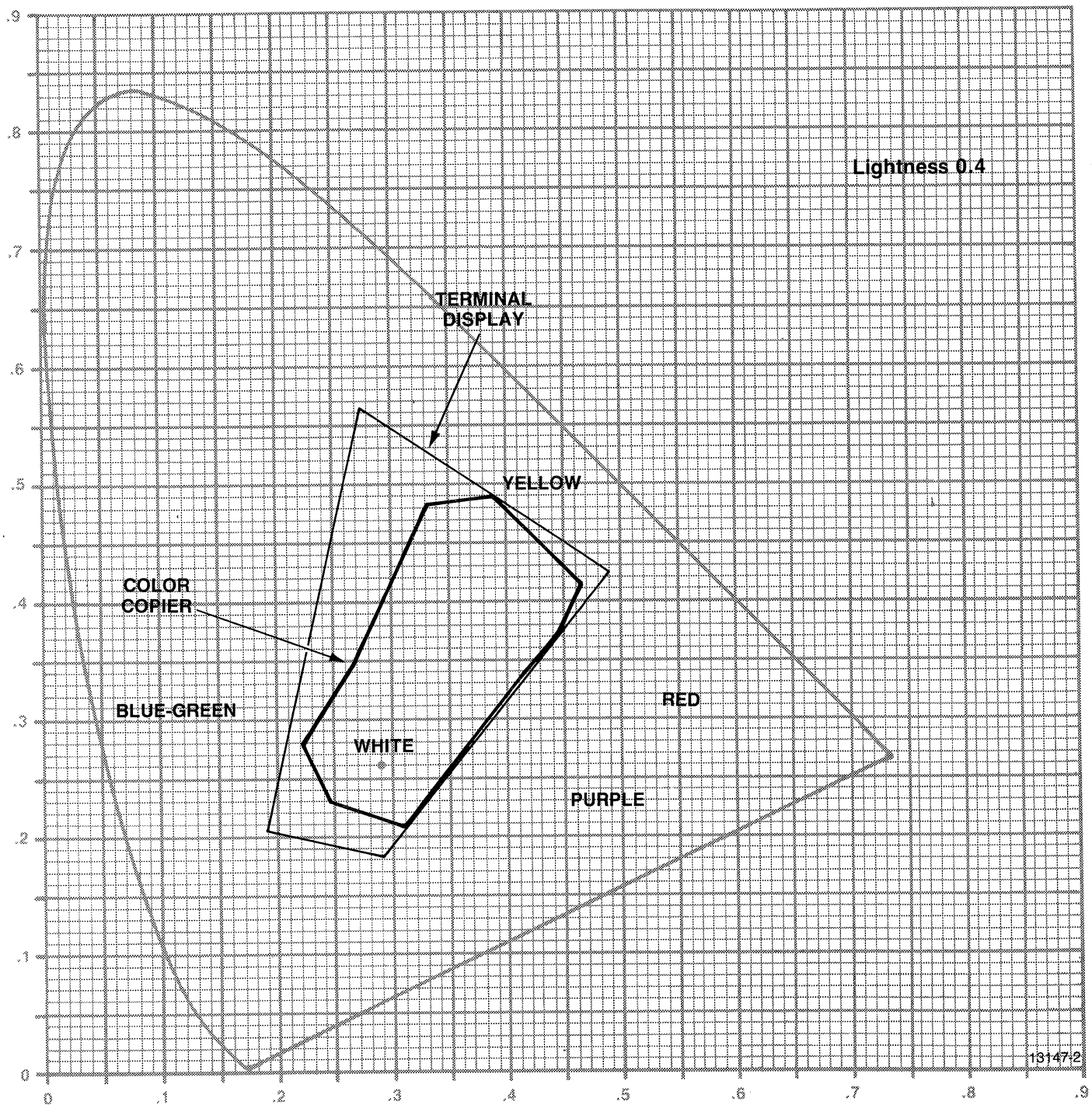


Figure 1b

13147:2

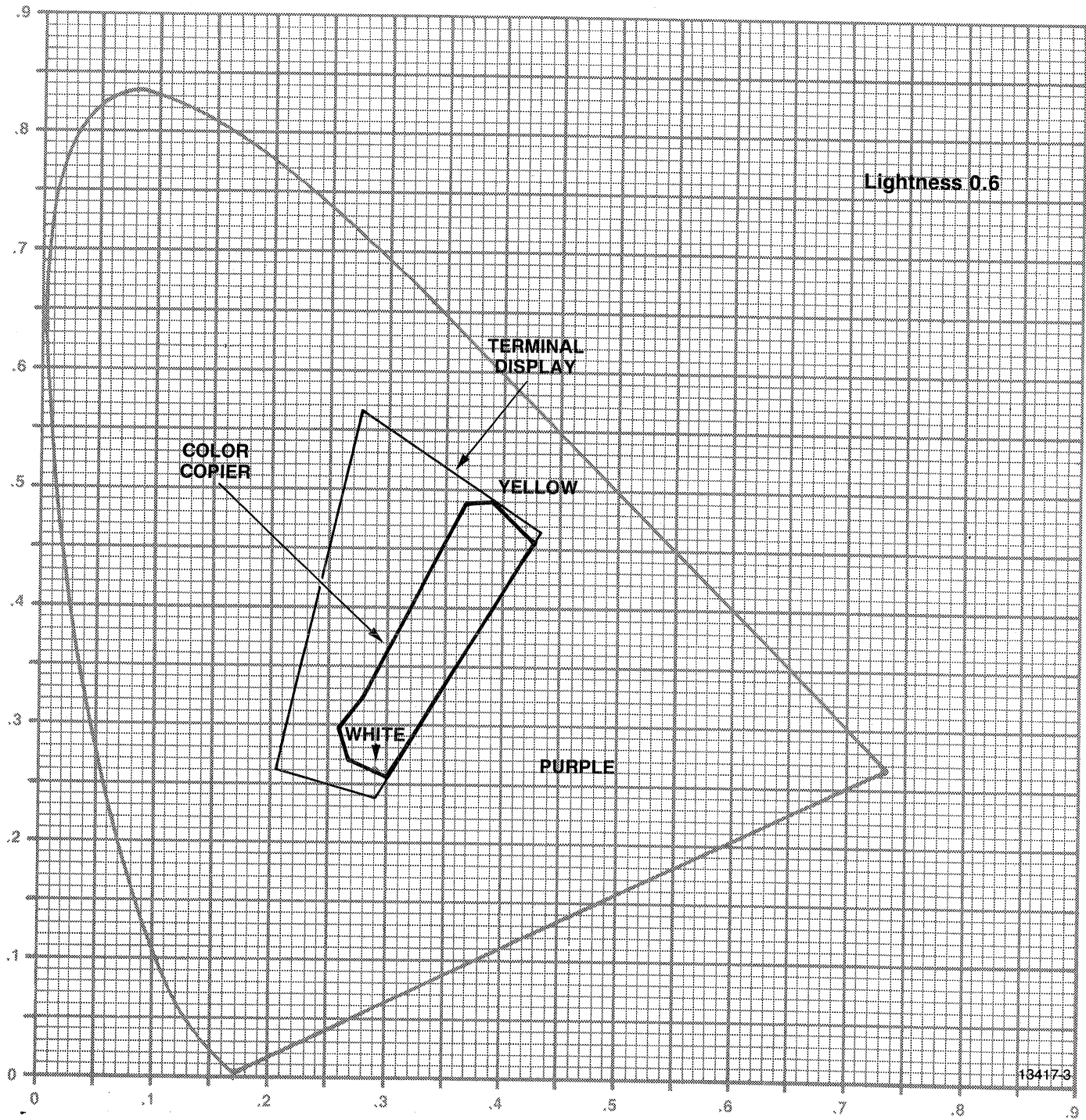


Figure 1c

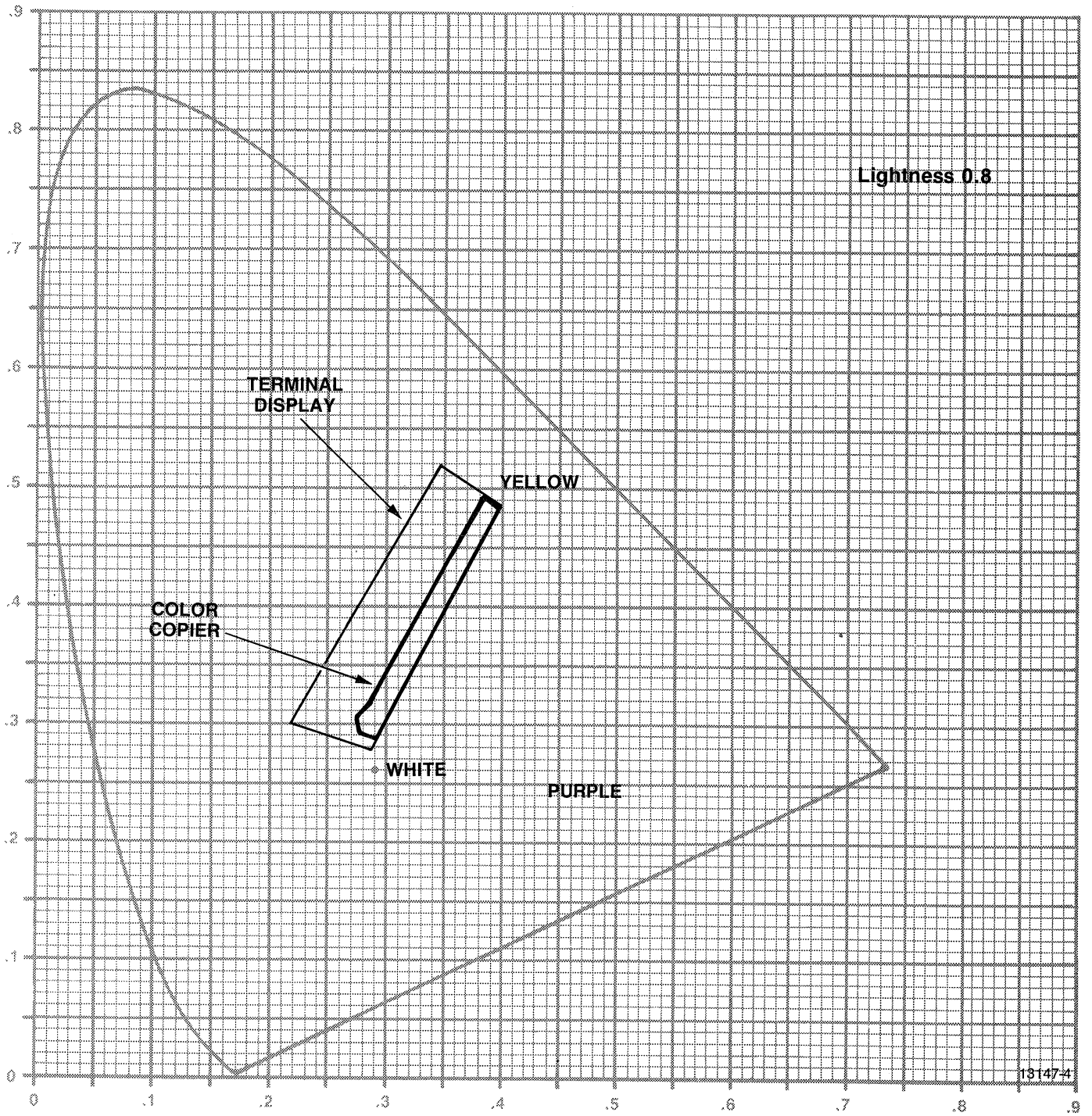


Figure 1d



# COLORS REACHABLE BY MUNSELL VALUES

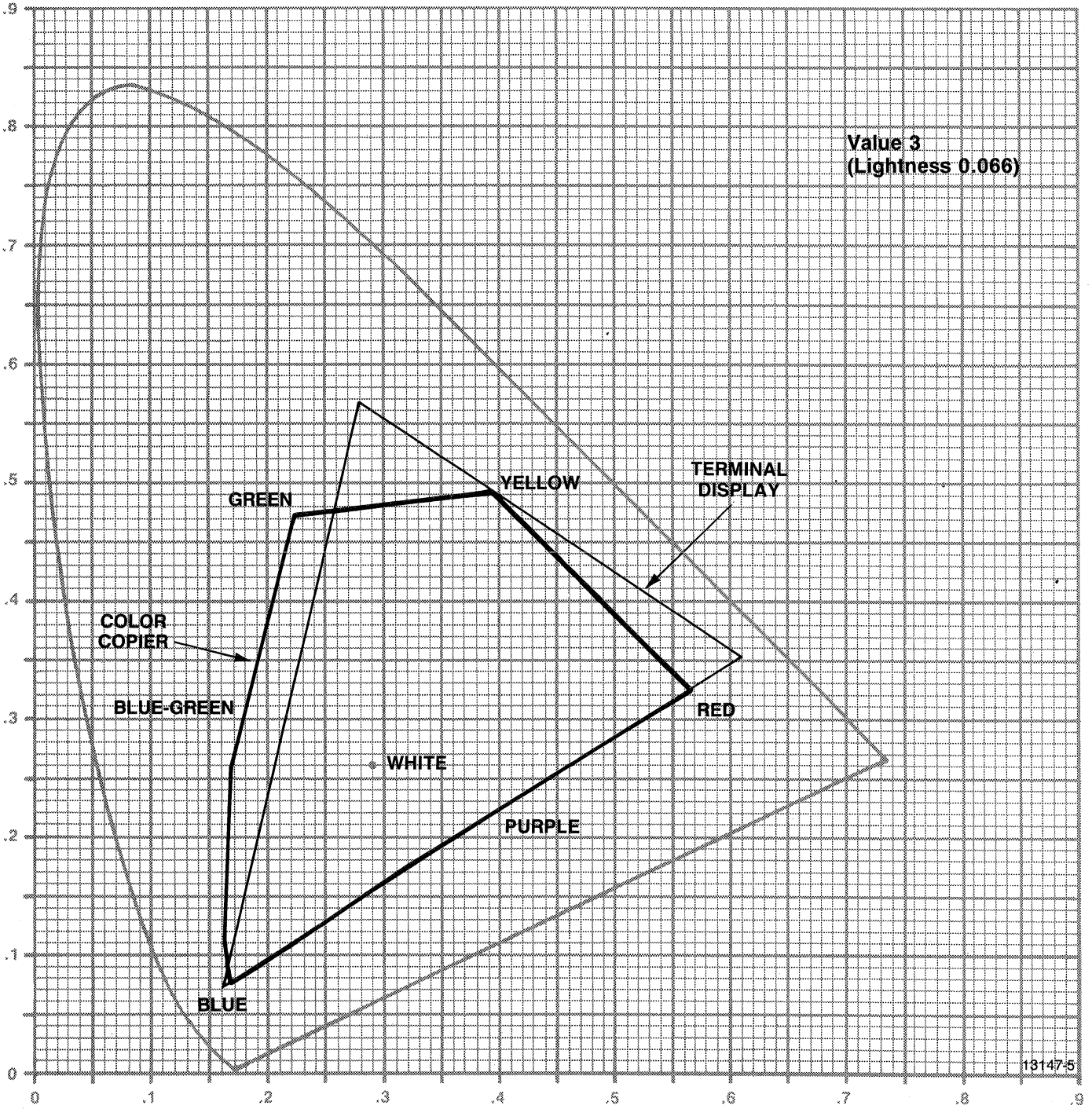


Figure 2a

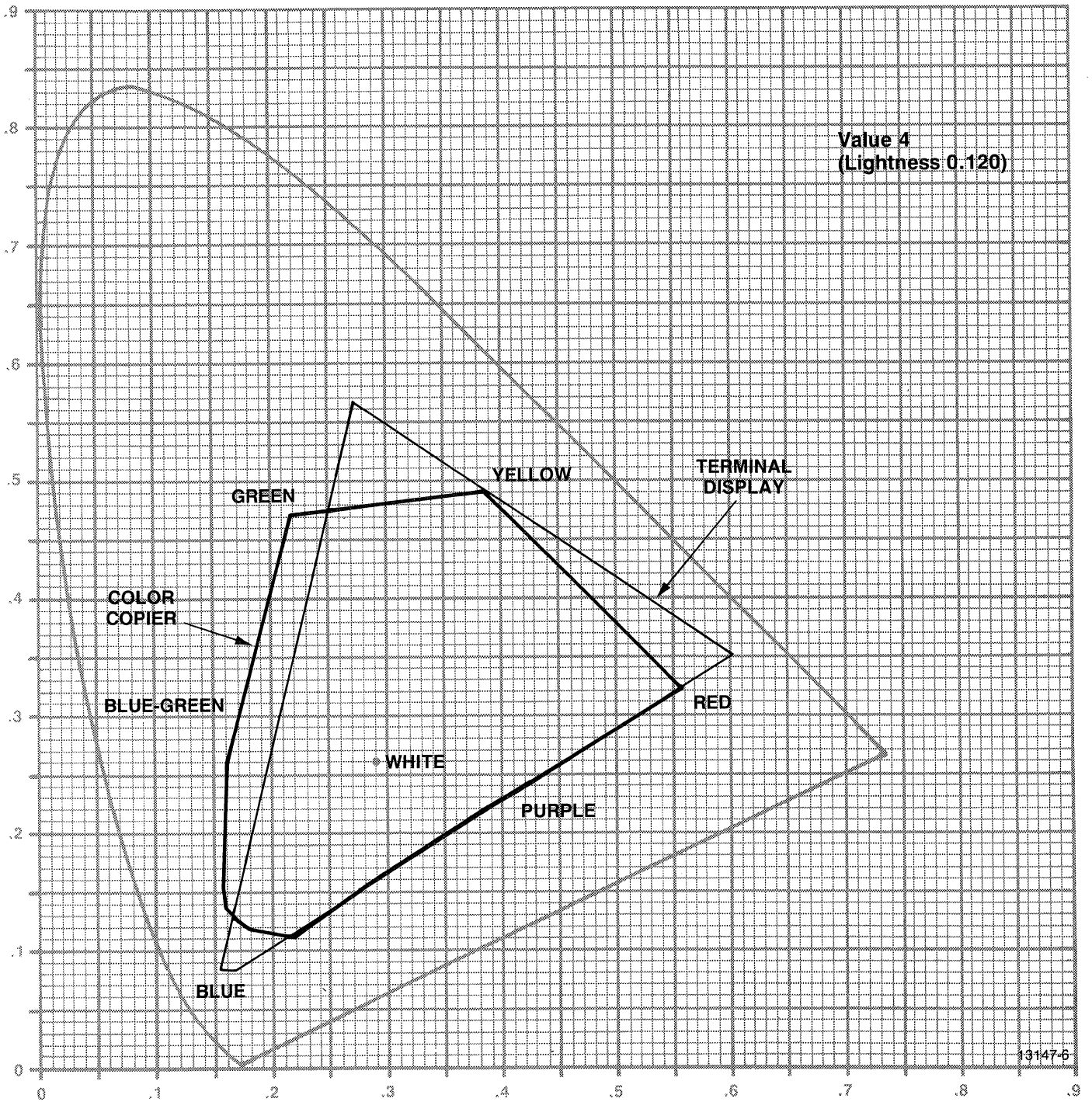


Figure 2b

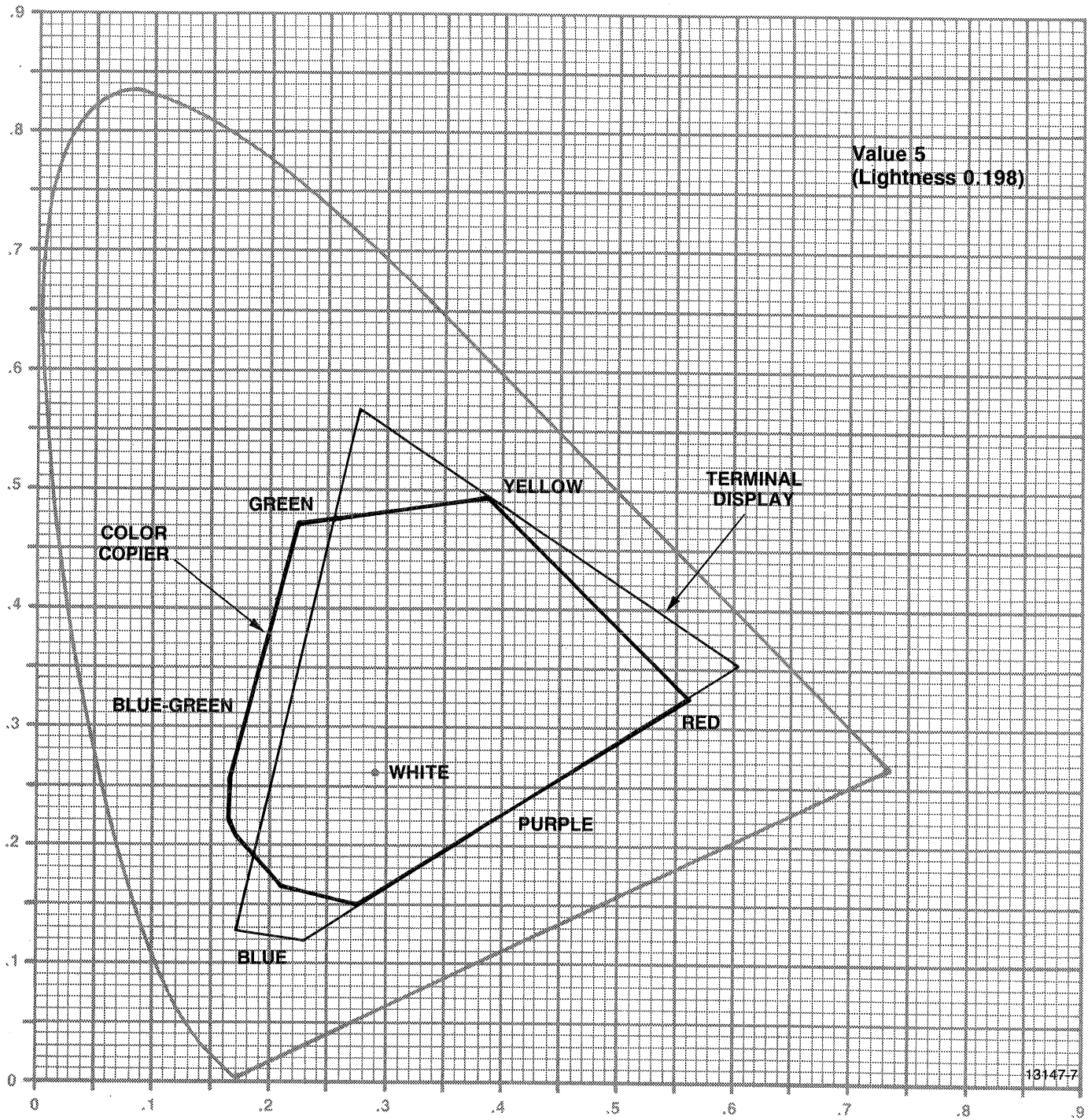


Figure 2c



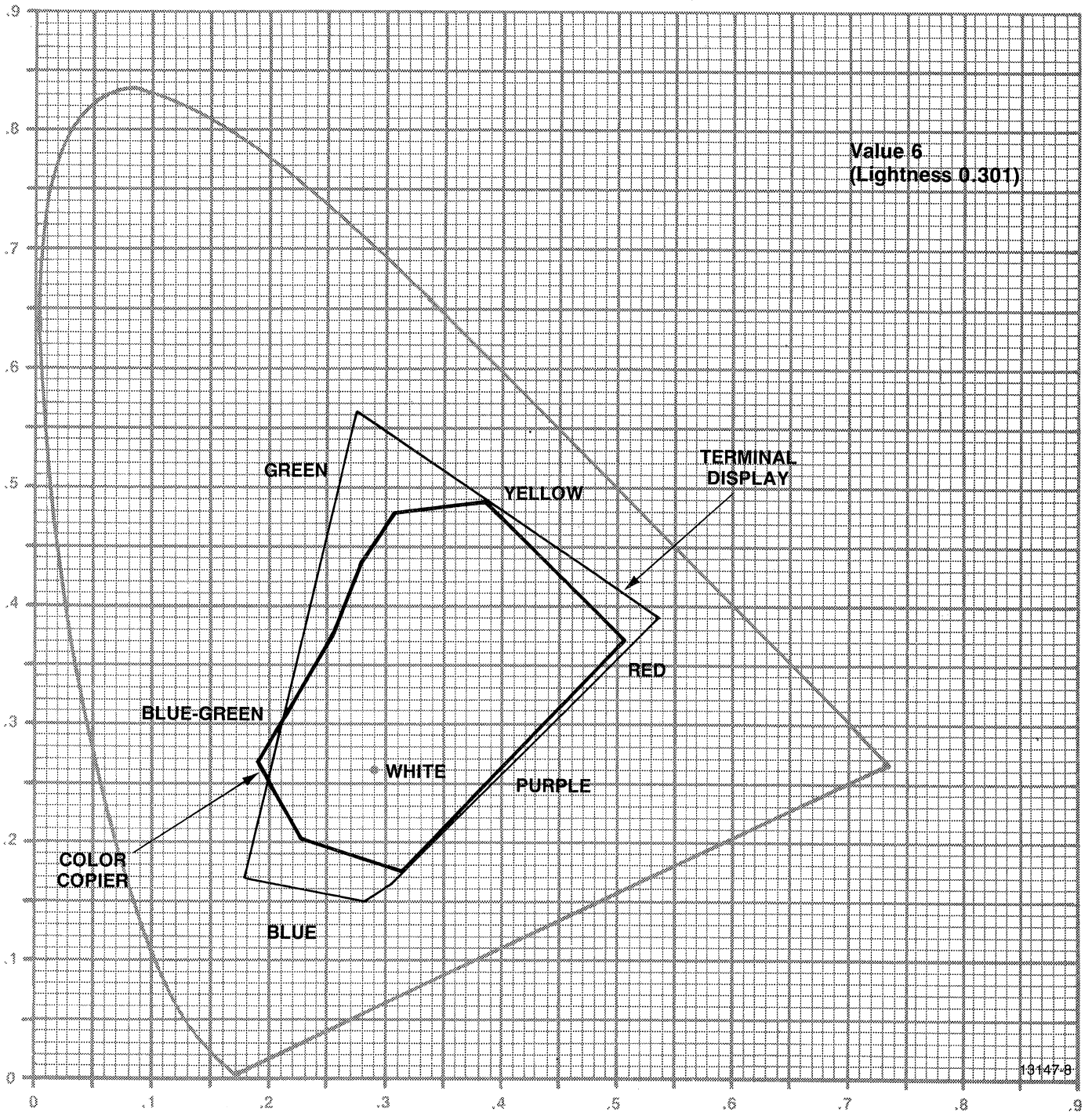


Figure 2d

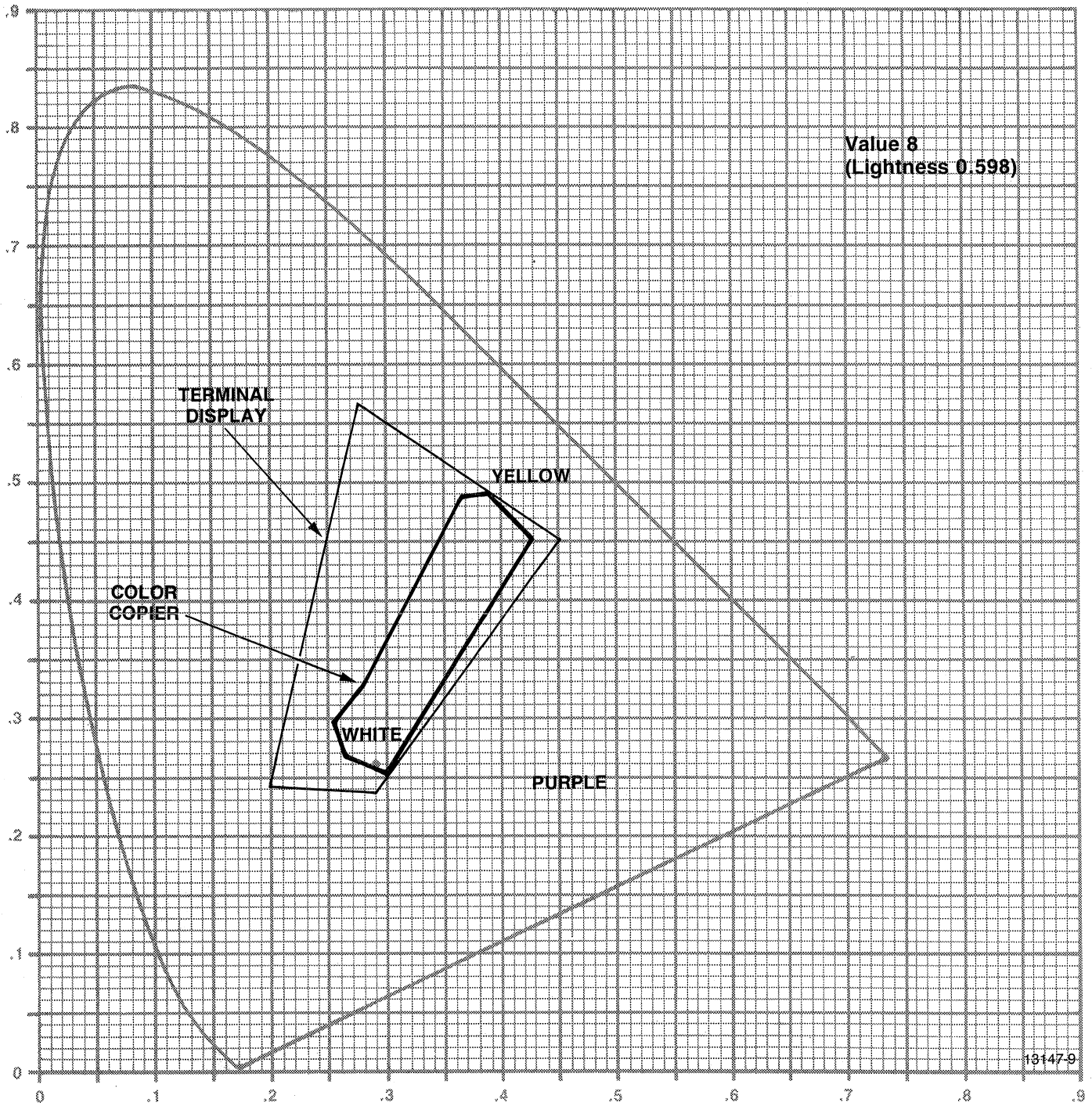


Figure 2e

**Table 2**  
**MACHINE RGB**  
**COLOR COORDINATES**  
**FOR COPIER AND**  
**TERMINAL COLORS**

Index No.	Red	Green	Blue
1	169	65	75
2	163	77	70
3	154	88	69
4	143	97	65
5	130	105	63
6	120	110	59
7	106	113	69
8	89	117	77
9	44	120	84
10	35	120	95
11	35	119	106
12	35	118	117
13	35	115	130
14	109	105	131
15	141	85	137
16	156	68	134
17	159	68	125
18	164	62	115
19	165	65	103
20	168	63	90
21	214	76	88
22	194	106	81
23	35	164	35
24	148	135	67
25	130	140	80
26	47	149	100
27	35	148	130
28	35	146	145
29	134	128	164
30	196	79	167
31	207	71	142
32	213	72	108
33	239	133	138
34	184	168	88
35	124	177	164
36	233	122	201

To create your own palette, follow these steps.

- Choose a lightness level. Remember that colors of low lightness will be dull, dark (olive drab, for example), while high lightness colors will be closer to white — not too colorful.
- In the diagram for your selected lightness, pick x,y positions from the area lying within both terminal and copier capabilities. Separate your choices as much as the number of colors you intend to use will allow. These diagrams will suffice for up to 128 colors. The points chosen should be most widely spaced in the upper central regions of the available area, and most closely spaced in the lower left.
- Using the x, y values for one of the lightness levels, perform these calculations.

$$\begin{aligned}
 z &= 1 - x - y \\
 X &= x * (L/y) \text{ (where L is the lightness)} \\
 Y &= y * (L/y) \\
 Z &= z * (L/y)
 \end{aligned}$$

$$\begin{bmatrix} 3.674 & -1.634 & -0.600 \\ -1.179 & 2.029 & -0.052 \\ 0.105 & -0.305 & 0.921 \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} R0 \\ G0 \\ B0 \end{bmatrix}$$

$$\begin{aligned}
 R &= C1*R0^4 + C2*R0^3 + C3*R0^2 + C4*R0 + C5 \\
 G &= C1*G0^4 + C2*G0^3 + C3*G0^2 + C4*G0 + C5 \\
 B &= C1*B0^4 + C2*B0^3 + C3*B0^2 + C4*B0 + C5
 \end{aligned}$$

where:

$$\begin{aligned}
 C1 &= -7.68574E + 02 \\
 C2 &= 1.80704E + 03 \\
 C3 &= -1.50515E + 3 \\
 C4 &= 6.60484E + 2 \\
 C5 &= 57.2
 \end{aligned}$$

(These values need to be rounded to nearest integer before entering.)

Use the SET-COLOR-MODE command to select the machine RGB color system. Then use the SET-SURFACE-COLOR-MAP command to set the color map using the calculated RGB values.

## SC: DATA FORMAT

The host may send data directly to the copier using the HC:, HC:0, HC:1, or HC:2 parameter as the destination device of the COPY command. When HC:, HC:0, or HC:1 is the destination device, the data must be in the format as that generated by the SC: source device.

Tables 3 and 4 document the two different formats.

The SC: or SC:0 data form is marked by clearing the most significant byte of the Copy Command.

**Table 3**  
**SC: OR SC:0 DATA FORMAT**

	7	6	5	4	3	2	1	0	
0	-0-							R	Row-Column
1	0					1			Copy Command
2	1	1	D	D	F	F	1	0	Copy Mode
3	0	-0-						1	Number of Copies
4	1	Horizontal Dimension High 7 Bits							
5	1	Horizontal Dimension Low 7 Bits							
6	1	Vertical Dimension High 7 Bits							
7	1	Vertical Dimension Low 7 Bits							
8	-0-								Checksum
9	-02h-								End of Line

R = 0 — Column Oriented Data  
= 1 — Row Oriented Data

D = 01 — 1 Byte RGB Data (2 bits/color)  
= 10 — 2 Byte RGB Data (4 bits/color)

F = 00 — Horizontal Format  
= 01 — Vertical Bottom Format  
= 10 — Vertical Center Format  
= 11 — Vertical Top Format

The remaining bytes in the file store the pixel data in one of these formats.

### One Byte Color-Data-Resolution

Non-Run Length Encoded	0	1	B3	B2	G3	G2	R3	R2
Run Length Encoded	1	1	B3	B2	G3	G2	R3	R2
COUNT								

### Two Byte Color-Data-Resolution

Non-Run Length Encoded	0	1	B3	B2	G3	G2	R3	R2
	0	0	B1	B0	G1	G0	R1	R0
Run Length Encoded	1	1	B3	B2	G3	G2	R3	R2
	1	0	B1	B0	G1	G0	R1	R0
COUNT								

The SC:1 data format is marked by setting the most significant byte of the Copy Command byte.

**Table 4**  
**SC:1 DATA FORMAT**

	7	6	5	4	3	2	1	0	
0	-0-							R	Row-Column
1	1					1			Copy Command
2	1	1	0	1	F	F	1	0	Copy Mode
3	1	-0-						1	Number of Copies
4	1	Horizontal Dimension High 7 Bits							
5	1	Horizontal Dimension Low 7 Bits							
6	1	Vertical Dimension High 7 Bits							
7	1	Vertical Dimension Low 7 Bits							
8	-0-							Checksum	
9	-02h-							End of Line	

R = 0 — Column Oriented Data  
= 1 — Row Oriented Data

F = 00 — Horizontal Format  
= 01 — Vertical Bottom Format  
= 10 — Vertical Center Format  
= 11 — Vertical Top Format

The remaining bytes of the SC:1 format first store the current terminal color map, then store the index data from the terminal pixel memory in run-length encoded format.

Terminal Color Map	Color Map Size (Low Byte)
	Color Map Size (High Byte)
	Red for first entry
	Green for first entry
	Blue for first entry
	Red for last entry
	Green for last entry
	Blue for last entry
Pixel Data	Index from terminal pixel memory
	Count

## ERROR CODES

To support dithering and color matching, error conditions which the 4110/4120 Series terminals can recognize have been extended or modified. Table 5 summarizes these error conditions.

**Table 5**  
**DITHERING AND COLOR MATCHING ERRORS**

<b>JC</b>	<b>COPY</b> = $\epsilon_c$ JC device string device
JC01	(Level 2): HC: cannot colormatch with data in old SC: format.
JC12	(Level 3): No low RAM for SC: task.
JC32	(Level 3): No low RAM for HC: task.
JC32	(Level 3): No low RAM for Line Out task.
<b>JS</b>	<b>SPOOL</b> = $\epsilon_c$ JS device string device
JS01	(Level 2): HC: cannot colormatch with data in old SC: format.
JS32	(Level 3): No low RAM for HC: task.
JS32	(Level 3): No low RAM for Line Out task.
<b>KH</b>	<b>HARDCOPY</b> = $\epsilon_c$ KH int
KH02	(Level 3): No low RAM for Line Out task.
<b>QM</b>	<b>SET-COLORHARDCOPY-DITHERING</b> = $\epsilon_c$ QM int
QM11	(Level 2): Invalid option code. (Must be 0, 1, or 2.)





