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OPTICAL CHARACTERISTICS OF LASER SAFETY DEVICES

By

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Final Report

US Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362

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ADDENDUM: USAARL Report No. 77-17

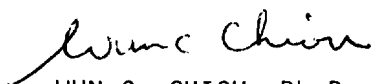
TITLE: "Optical Characteristics of Laser Safety Devices"

AUTHOR: Chiou, Wun C., Ph.D.

CONTENT: The third sentence in the abstract and the summary of the above report was misprinted as "Type GG-9 and Type OG530 can be used to protect the He-Ne laser (@633 nm)," The correct statement should read, "Type GG-9 and Type OG530 can be used to protect the He-N (nitrogen) laser (@335 nm),"

CO₂ (@1060 nm) at the fourth sentence should be CO₂ (@10600 nm).

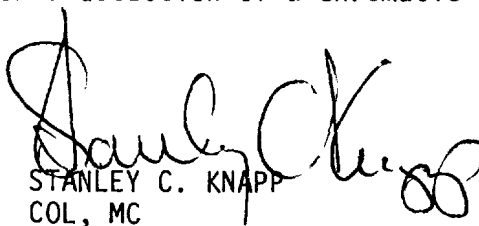
It is important to insert the corrected pages and discard the old pages because of a potential health hazard.



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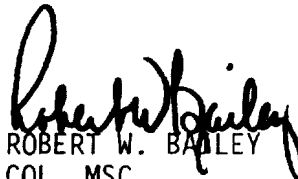
SUMMARY

Six types of laser protective eyewear were evaluated in terms of their optical properties and spectral characteristics. These six types cover the protection for almost the entire visible spectrum. Type GG-9 and Type OG530 can be used to protect the He-N (nitrogen) laser (@335 nm), type OG-590 and type RG-610 are for Argon laser (@500 nm). Type BG-18 is for Ruby laser (@694 nm) and type KG-3 are for Nd: glass laser (@1060 nm) or CO₂ laser (@10600 nm). The optical properties and spectral characteristics are investigated by means of average and full spectral transmittance as well as their corresponding CIE chromaticity coordinate values. Results suggested that one type of the protective device should be used only for the specific laser. Furthermore, the device should not be used when a detection of a chromatic display or light source is required.


STANLEY C. KNAPP
COL, MC
Commanding

SUMMARY

Six types of laser protective eyewear were evaluated in terms of their optical properties and spectral characteristics. These six types cover the protection for almost the entire visible spectrum. Type GG-9 and Type OG530 can be used to protect the He-Ne laser (@ 633 nm), type OG-590 and type RG-610 are for Argon laser (@ 500 nm). Type BG-18 is for Ruby laser (@ 694 nm) and type KG-3 are for Nd: glass laser (@ 1060 nm) or CO₂ laser (@ 1060 nm). The optical properties and spectral characteristics are investigated by means of average and full spectral transmittance as well as their corresponding CIE chromaticity coordinate values. Results suggested that one type of the protective device should be used only for the specific laser. Furthermore, the device should not be used when a detection of a chromatic display or light source is required.



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COL, MSC
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INTRODUCTION

In a previous study¹, we have examined several optical properties and dark adaptation problems of two types of He-Ne laser safety devices. Recently, we have obtained six additional types of laser safety devices (Figure 1). These are (1) GG-9 (transmit light from uv to 420 nm), (2) OG-530 transmit light to 500 nm, (3) OG-590 transmit light to 560 nm, (4) RG-610 transmit light to 570 nm, (5) BG-18 (from 690 to 1300 nm) and (6) KG-3 (from 900 to 12,000 nm). These six types can be used to provide protection against most lasers other than He-Ne laser. Figure 2 shows dominant wavelengths of various types of lasers and the effective spectral ranges of these six laser safety devices. (Note: LGS-HN has been evaluated in the previous study.)

Envall, et al² have studied seventeen commercially available laser protective eyewears. Among them, eight were intended to provide protection against argon laser and nine were intended against Nd: YAG laser. Both lens and frame materials were exposed to the direct CW laser beam at increasing power density values up to 12 w/cm². They described in detail the eyewear test systems and structural changes in the materials.

The purpose of this study is provide spectral transmission characteristics from 400 to 1100 nm and to provide the colorimetric characteristics of these six samples. Results from this study will enable the users to compute the amount of energy being transmitted through the safety devices. Some spectral transmittance data are available³ from

200 to 750 nm and from 950 to 4050 nm. Nevertheless, those data are incomplete as references. For example, continuous spectral information including 750 to 950 nm is required in the application of a laser protection study of electro-optical devices such as AN/PVS-5 night vision goggles which have a continuous sensitivity range from 400 to 1000 nm.

METHOD

Samples - Six samples used in this study were supplied by Fred Reed Optical Company, Albuquerque, New Mexico. These samples were plano and were manufactured by Schott filter glass. (One can obtain prescription lenses ranging from one to six diopters spherical power.) Each sample was masked in 1 1/2 x 2 1/2 inch rectangles (shown in Figure 1).

Apparatus - The light source used was a Macbeth daylight lamp. The automatic data acquisition/analysis system has the following subunits: (1) Rapid Scan Spectrometer (RSS), (2) Digital Processing Oscilloscope (DPO) with 4K storage memory by itself in this subunit, (3) PDP 11/05 with 24K memory and a cassette I/O drive and (4) Tektronix 4010-1 Teletype and 4610 hardcopier.

Experimental Design and Procedure - The spectral transmittance is defined as the quotient of the transmitted spectral intensity through a sample versus the incident spectral intensity. The data acquisition

processing steps are as follow: (1) Obtain energy power spectrum without sample through the RSS and store in the DPO memory location A, (2) Obtain energy power spectrum transmitted through a test sample and store in location B. (3) Obtain energy power spectrum of ambient and background light and store in location C. (4) Let location D = $(PB - PC)/(PA - PC)$. Each continuous spectrum has been digitized in the DPO and the computation processes were achieved in the PDP 11/05 computer through the control of several computer programs.

RESULTS

Figures 3 through 8 show spectral power distribution curves (from 400 to 800 nm) of six samples respectively. The upper curve of each figure represents the power distribution with no sample in the optical path. The lower curve is the one with the sample. Figures 9 through 14 show spectral power distribution curves (from 700 to 1100 nm) of six samples respectively. Again, the upper/lower curve of each figure represents the one without/with sample accordingly. Notice that some of the upper curves are in different scale factors. This is because the digitizer has the automatic scaling selection built-in for its electronic components to select the best scale to fit the screen.

Figures 15 and 16 represent the spectral transmittances of sample GG-9 from 400 to 800 nm and from 700 to 1100 nm respectively. The following 10 figures are for the rest of the samples respectively. On the

**TO 420 NM
(YELLOW-GREEN)**

GG-9

**TO 500 NM
(YELLOW)**

OG-530

**TO 560 NM
(LIGHT RED)**

OG-590

**TO 570 NM
(DARK RED)**

RG-610

**690 TO 1300
(BLUE-GREEN)**

BG-18

**900 TO 12,000 NM
(TRANSPARENT)**

KG-3

FIGURE 1. LASER SAFETY DEVICE SAMPLES

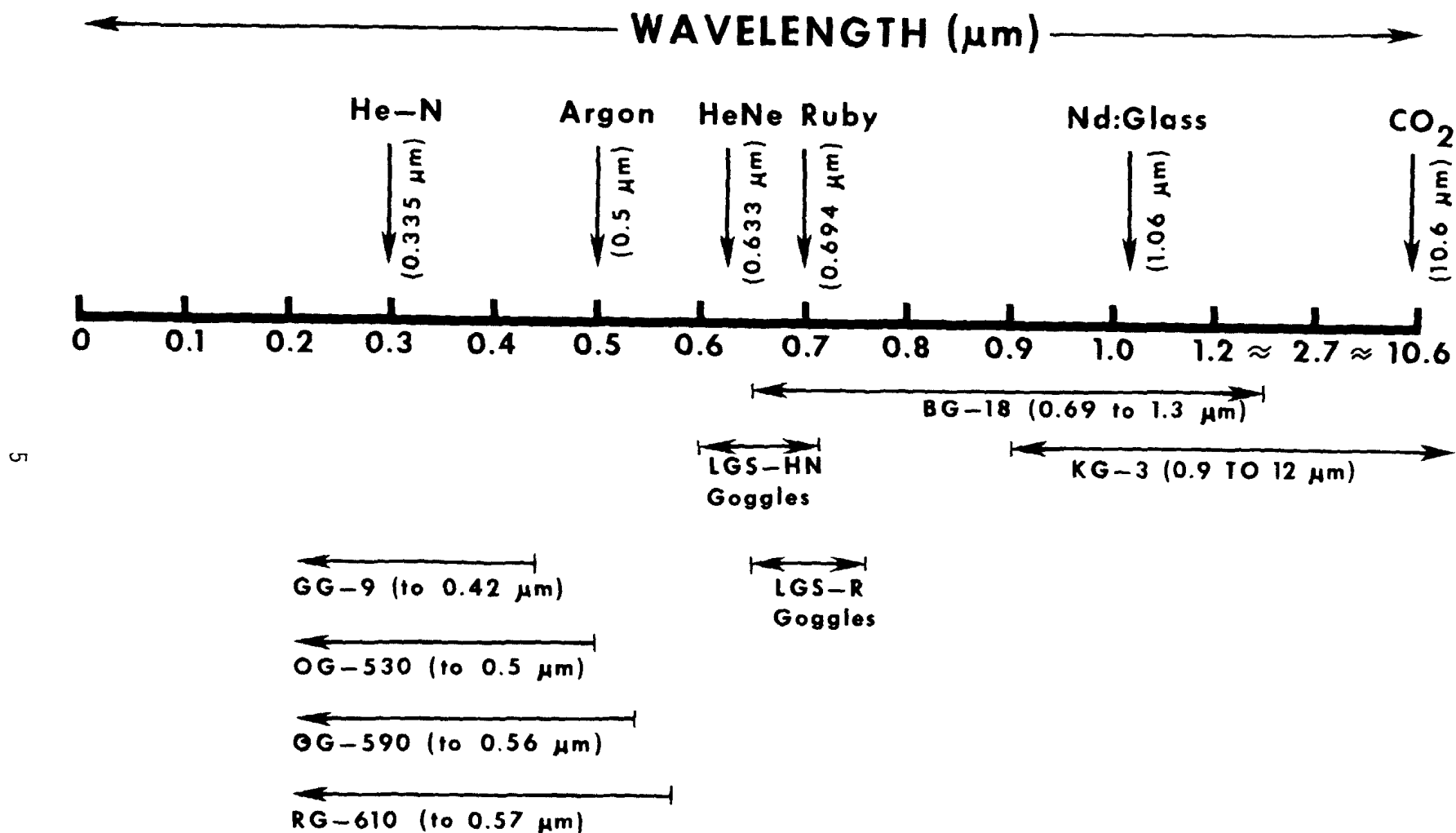


FIGURE 2. LASER SAFETY DEVICES RANGES AND DOMINANT WAVELENGTHS OF VARIOUS LASERS.

upper left corner of each figure, the XM represents $\times 10^{-3}$ vertical factor. For example, 100M means each division is 0.1 (or 10% transmittance). The -3 Div on the lower right of each figure indicates that the baseline starts at the third line below the middle line (or the second line above the bottom line). Sample 1 (i.e. GG-9) starts to transmit light from $0.42 \mu\text{m}$ or 420 nm. Sample 2 (i.e. OG530) starts at $0.50 \mu\text{m}$ or 500 nm, and so on. (The numerical value of each sample was written at the upper right hand side of each figure. Notice that in Figure 24 the curve is not smooth. Since the scale factor is only 20M (i.e. 0.02 or 2% per division, this means that there existed a lot of noise in this measurement.)

Finally, the chromaticity diagrams and their corresponding coordinate values are shown from Figures 27 through 32 respectively. The X, Y and Z values of each sample are shown at the top of each figure. Table 1 summarizes these values for comparison purposes. Notice that the sum of each set equals unity.

DISCUSSION AND CONCLUSION

Army Regulation 40-46 tabulates protection standards for typical lasers such as the ruby laser (commonly used in the rangefinder or the designator), neodymium laser, CW Argon laser, CW He-Ne laser, Erbium laser, CW neodymium laser and CW carbon-dioxide laser. Those values are

listed in terms of the dominant lasing wavelengths, exposure durations and protection criteria. In the previous study,¹ the use of spectral transmittance data for computing the protection criteria have been shown in detail. An empirical datum on He-Ne laser has also been given previously.

Caution has to be taken into serious consideration when detection and/or viewing of a red display or object is required. Types of protective eyewear should not be interchangeable. In other words, type GG-9 should not be used for He-Ne laser or type BG-18 for He-N (Helium-Nitrogen) laser, or vice versa.

In summary, this study has provided optical characteristics for six types of laser protective eyewear. GG-9 and OG 530 can be used for He-N laser. OG-590 and RG 610 can be used for Argon laser. BG-18 can be used for ruby laser and KG-3 can be used for Nd: glass laser or CO₂ laser. The spectral transmittance from 400 to 1100 nm and its corresponding CIE chromaticity coordinate values have been given. It is strongly recommended that one type of safety device be used for only one or two specific types of lasers. Furthermore, the device should not be used when a detection of a chromatic display or light source is required.

SLIS 13

IN REMARK SPECTRAL POWER DISTRIBUTION CURVE OF LASER EYEWEAR

PERIOD

4REN

4REN PA/PS/PC

600NM

40NM

TYPE GG-9(TO 0.42UM)

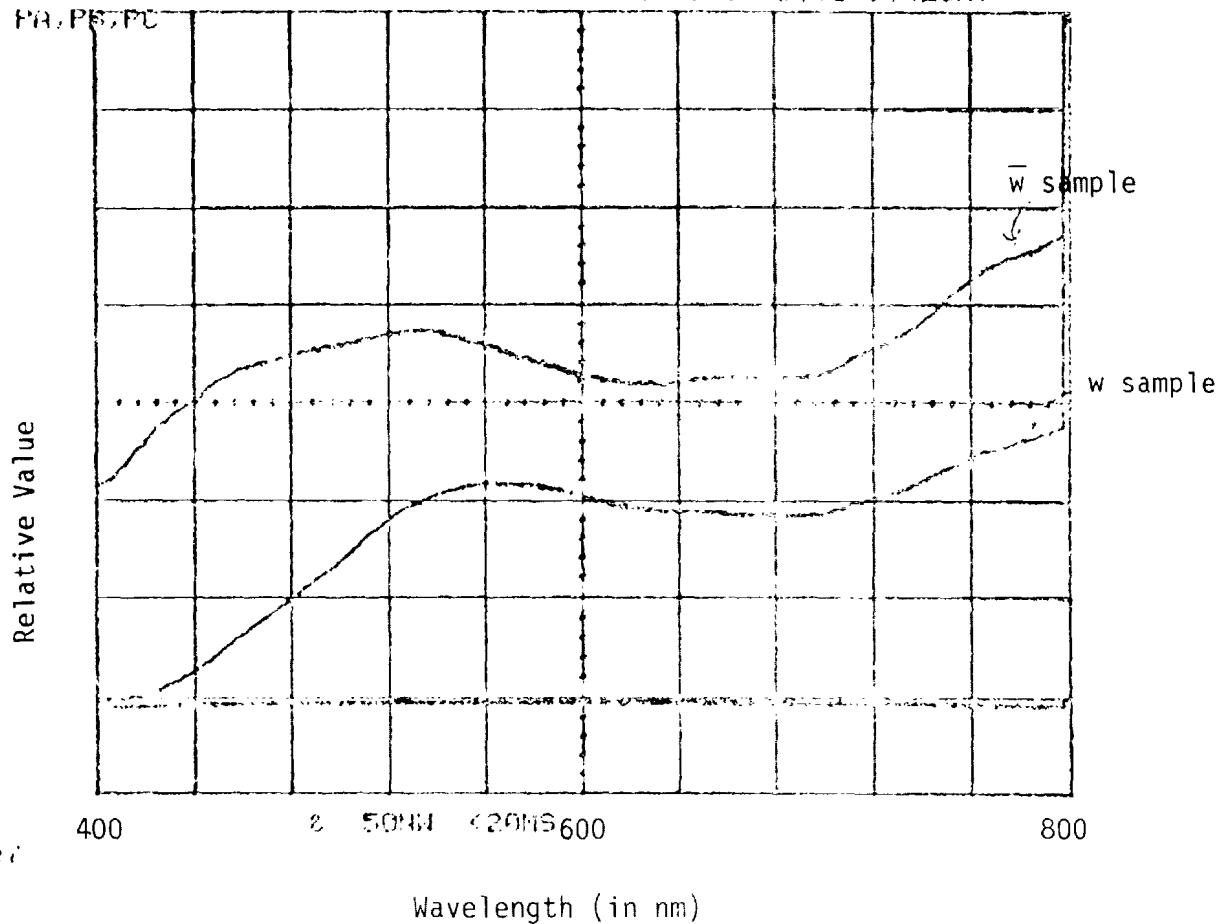


FIGURE 3. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE GG-9
(From 400-800 nm)

13
 13 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (400-800 NM)
 REMARK
 REMARK
 REMARK PA-PCPC

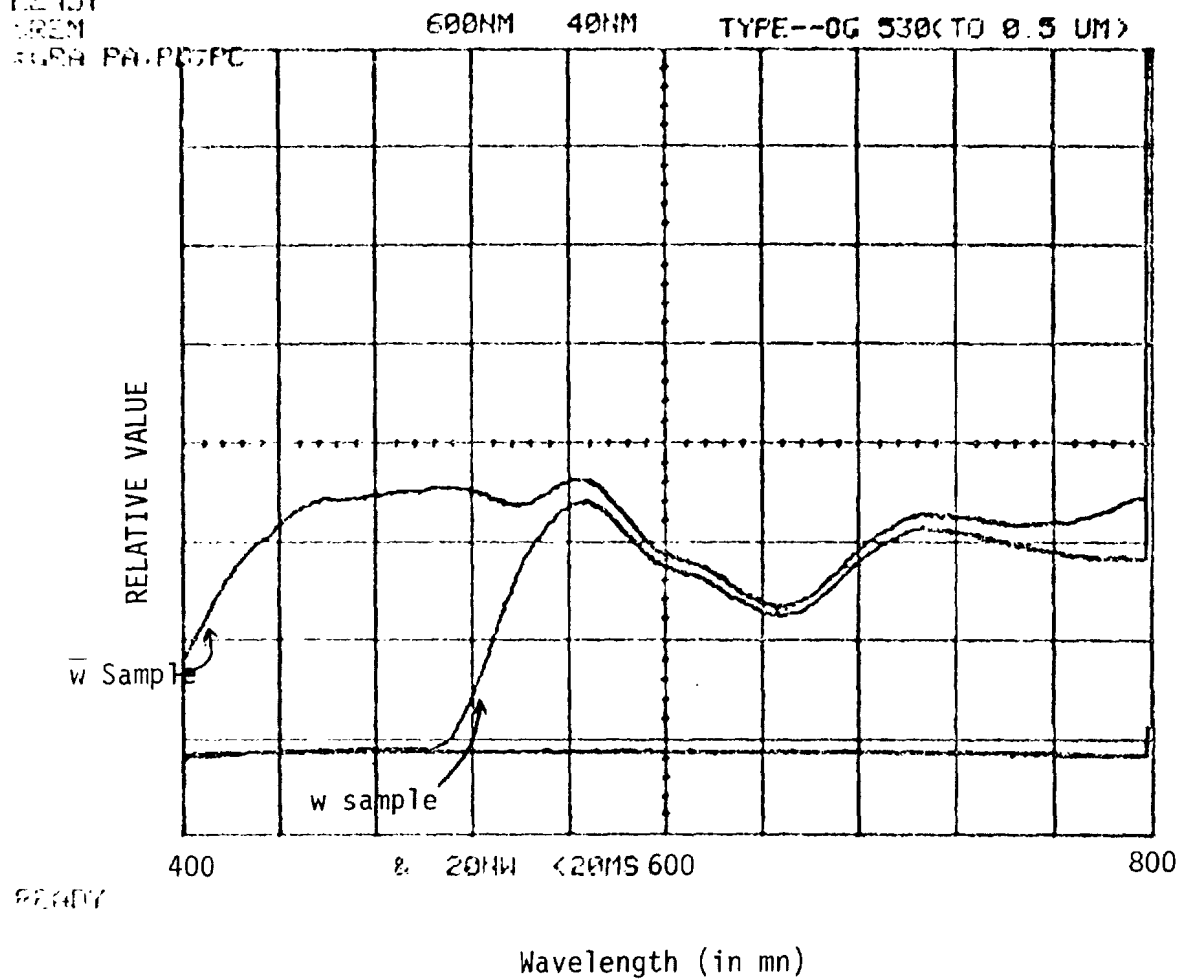


FIGURE 4. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE OG-53C
 (From 400-800 nm)

* 13 13
 13 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (400-800 NM)
 READY
 GREEN
 SUPA PA, PE

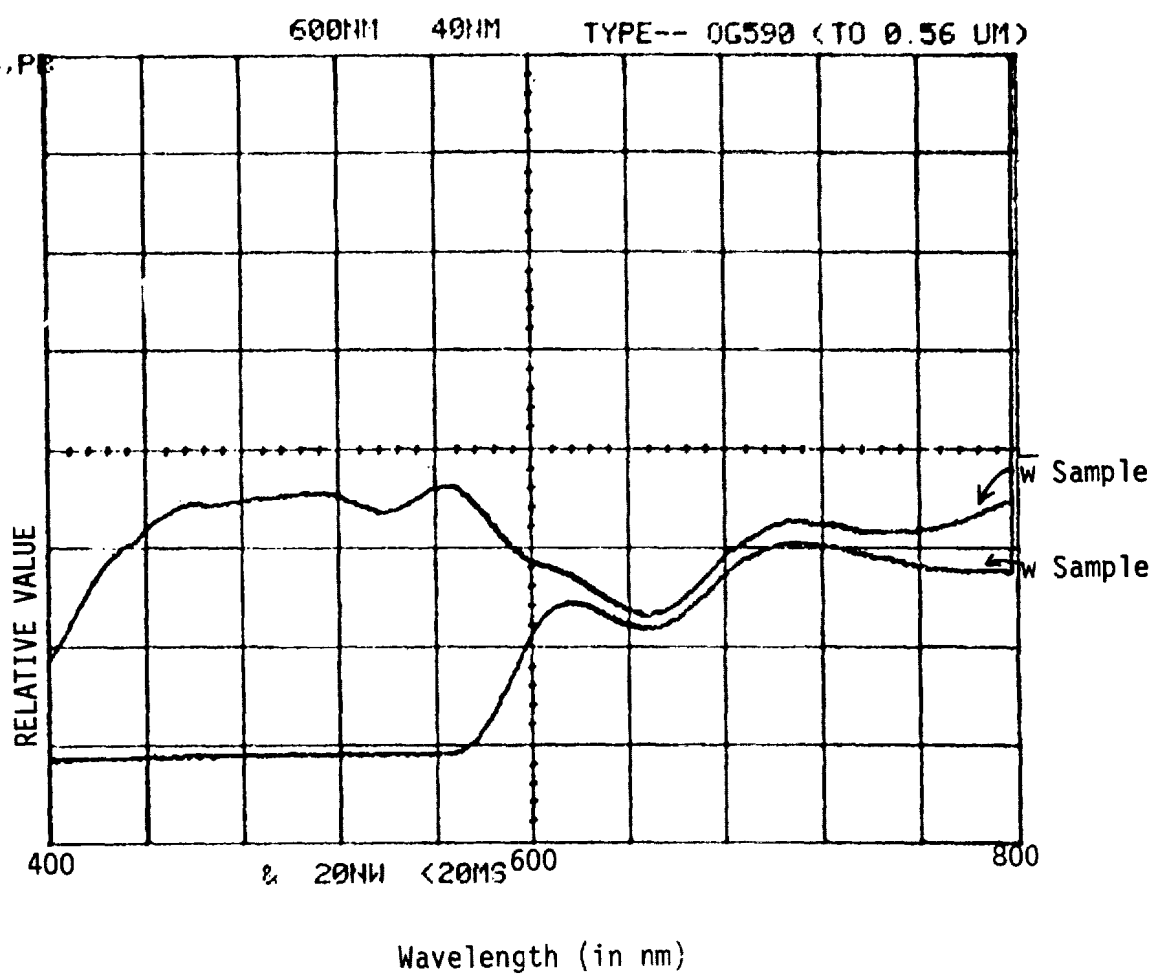


FIGURE 5. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE OG-590
 (From 400-800 nm)

LIS 13

13 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (400-800 NM)

READY

REM

%PPA PA,PS

600NM

40NM

TYPE-- RG 610 (TO 0.57 UM)

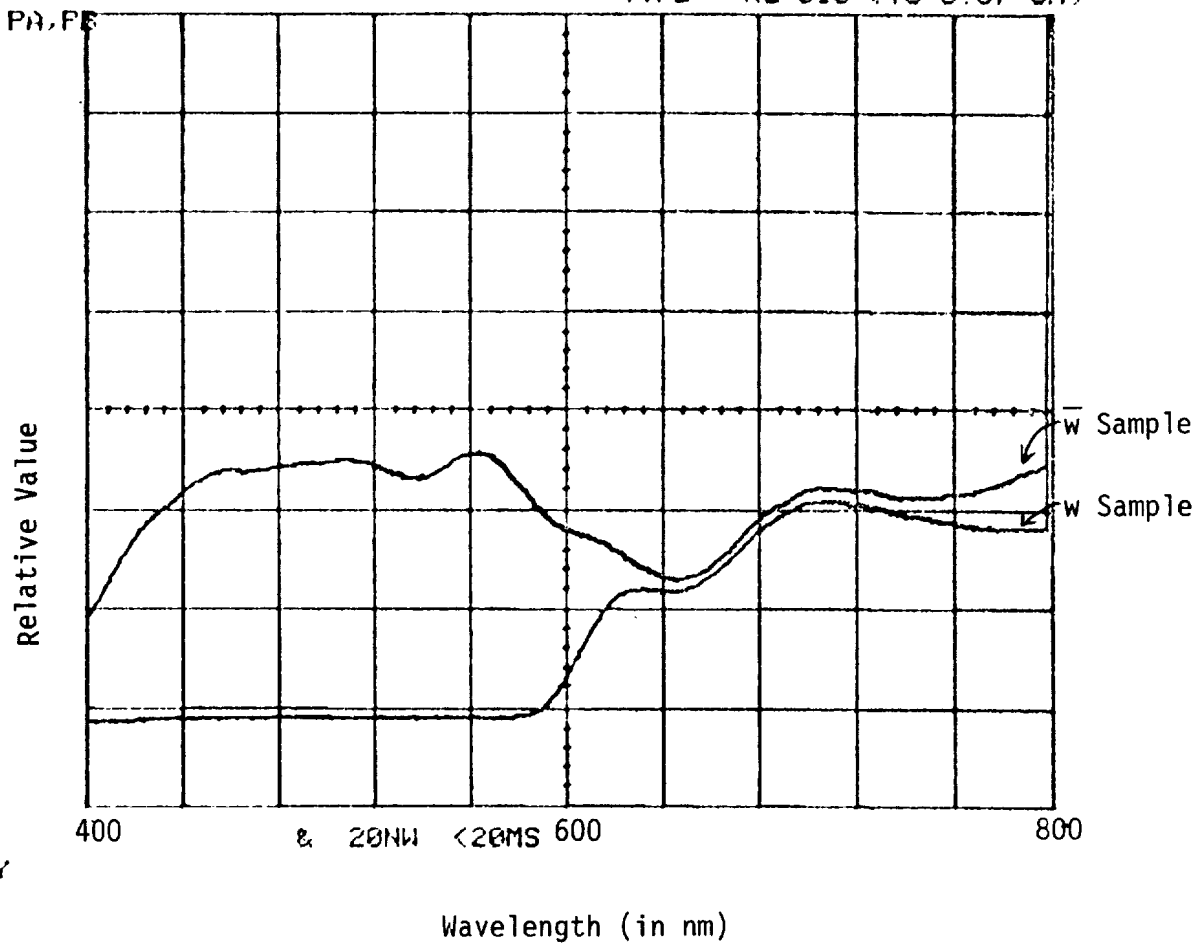


FIGURE 6. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE RG-610
(From 400-800 nm)

LIS 13

13 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (400-800 NM)

READY

REM

3000 PA-PS

600NM

40NM

TYPE BG-18 (0.69 TO 1.3UM)

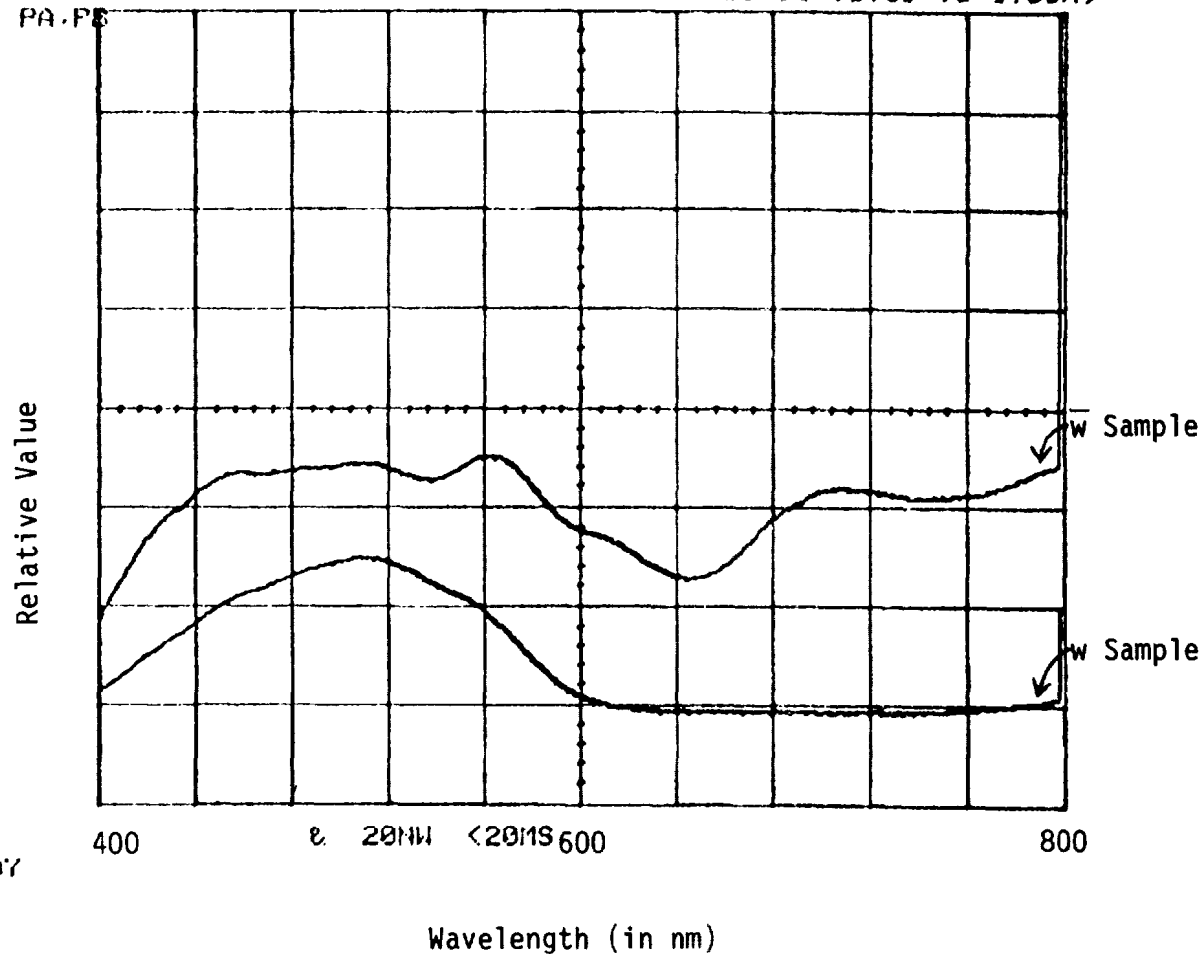


FIGURE 7. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE BG-18
(From 400-800 nm)

LIS 13

13 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (400-800 NM)

READY

*REM

4GRA PA.PP

600NM

40NM

TYPE--KG-3 (0.9 TO 12UM)

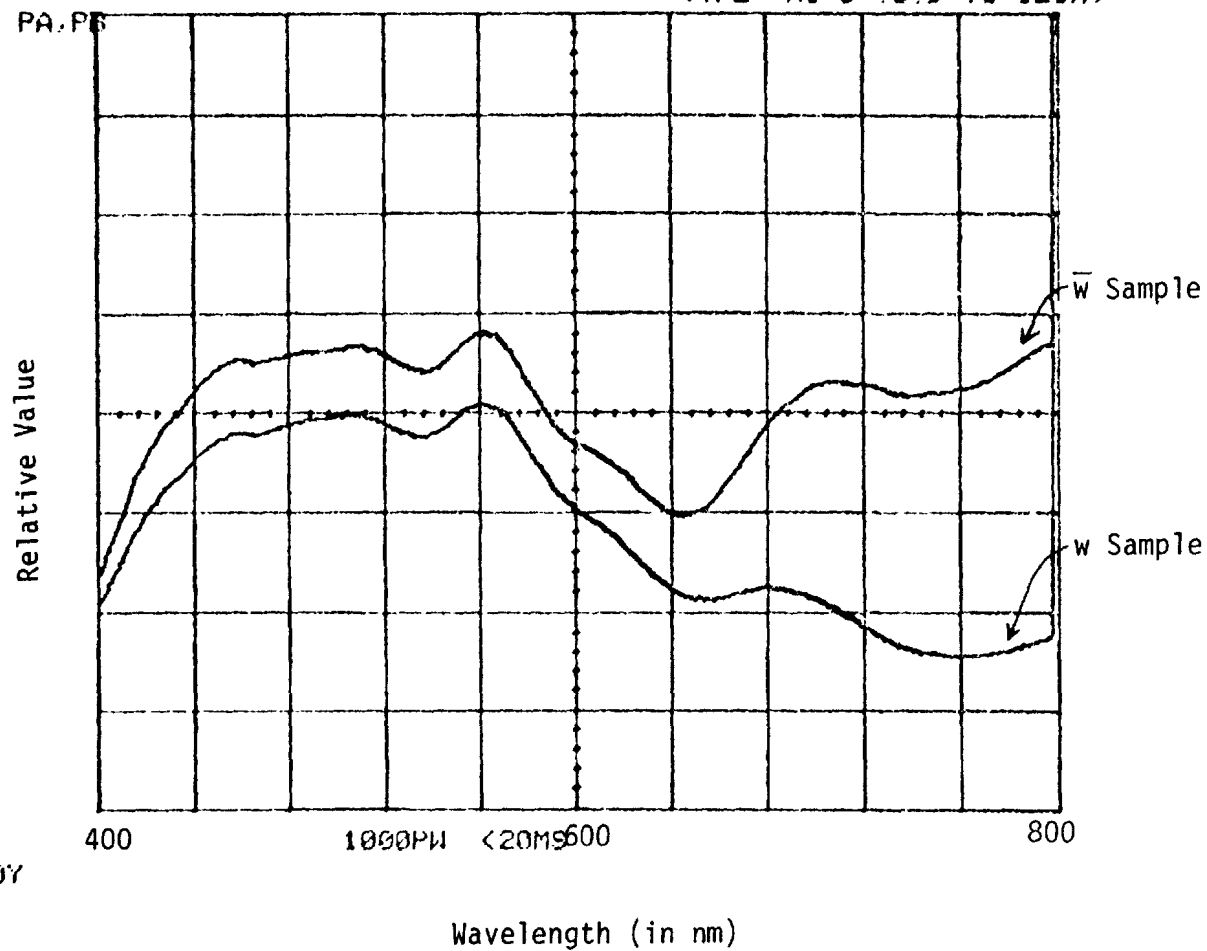


FIGURE 8. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE KG-3
(From 400-800 nm)

REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (700-1100NM)								
WAVELENGTH (NM)	900NM		40NM		TYPE--GG-8(TO 0.42UM)			
ENERGY								
PER MM								
AGRA PA.PC								

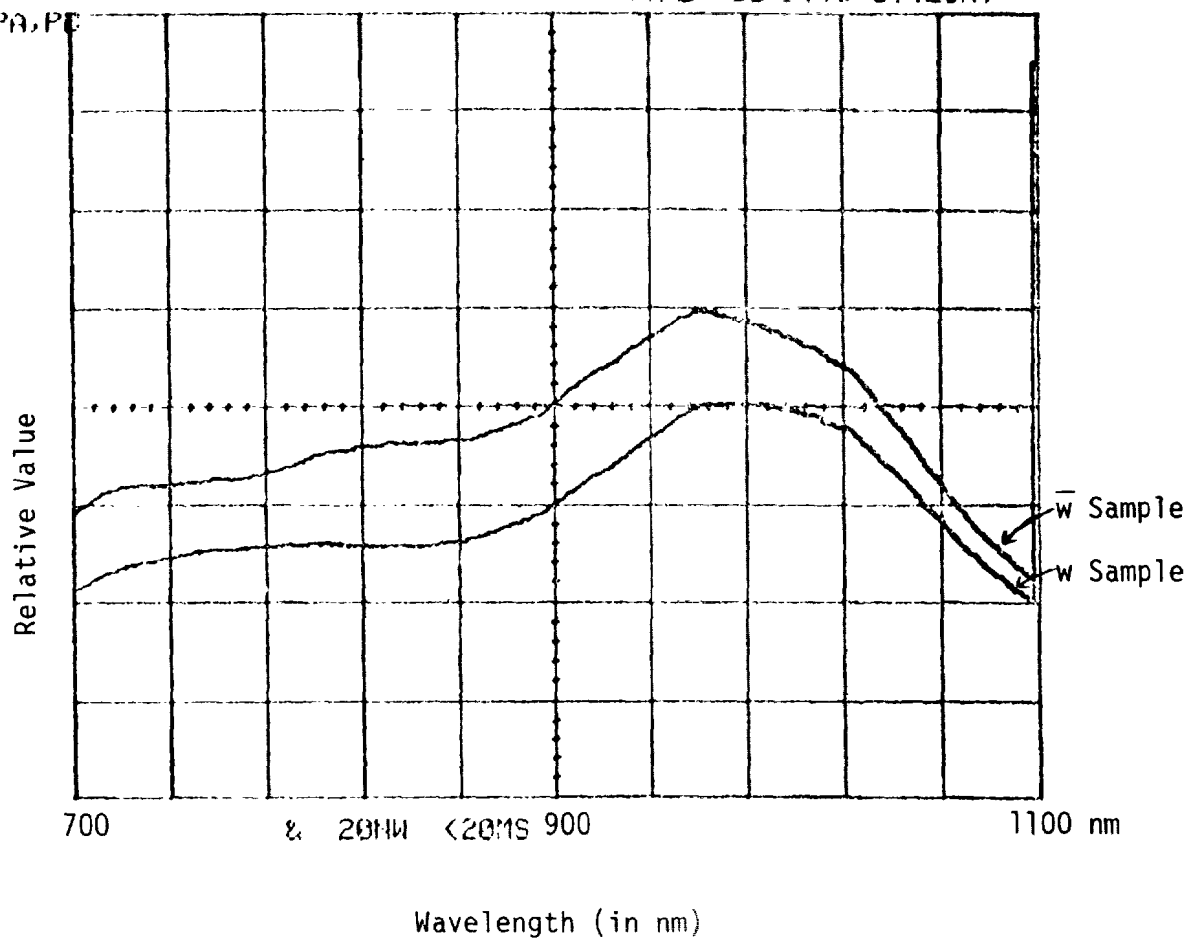


FIGURE 9. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE GG-9
(From 700-1100 nm)

LIS 19

19 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (700-1100NM)

PEADY

*REM

*GRA PA,PS,PC

900NM

40NM

TYPE--OG 530(TO 0.90UM)

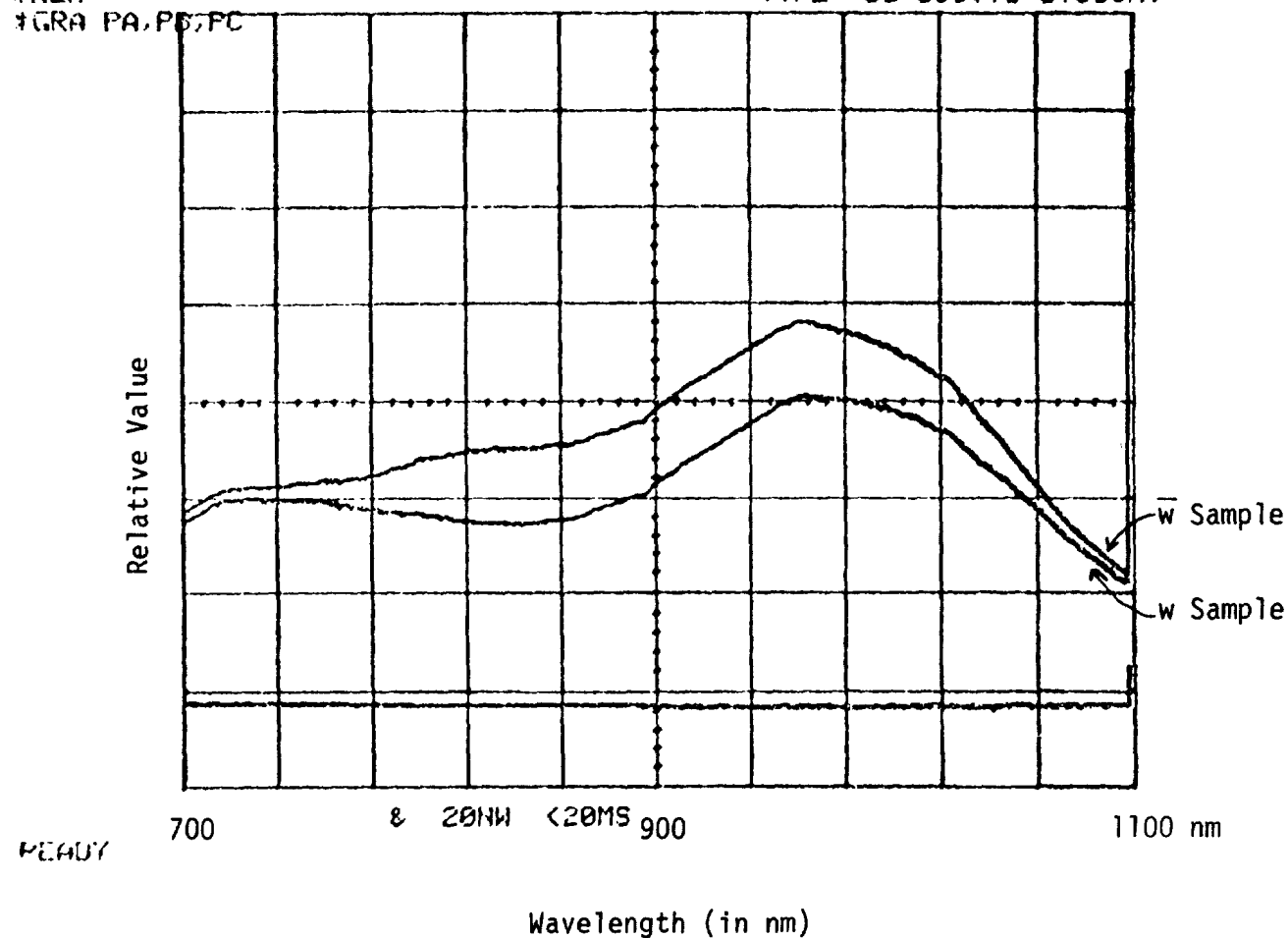


FIGURE 10. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE OG-530
(From 700-1100 nm)

LIE 19

13 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (700-1100NM)

READY

REM

FGPA PA/PE

900NM

40NM

TYPE--OG 590 (TO 0.56UM)

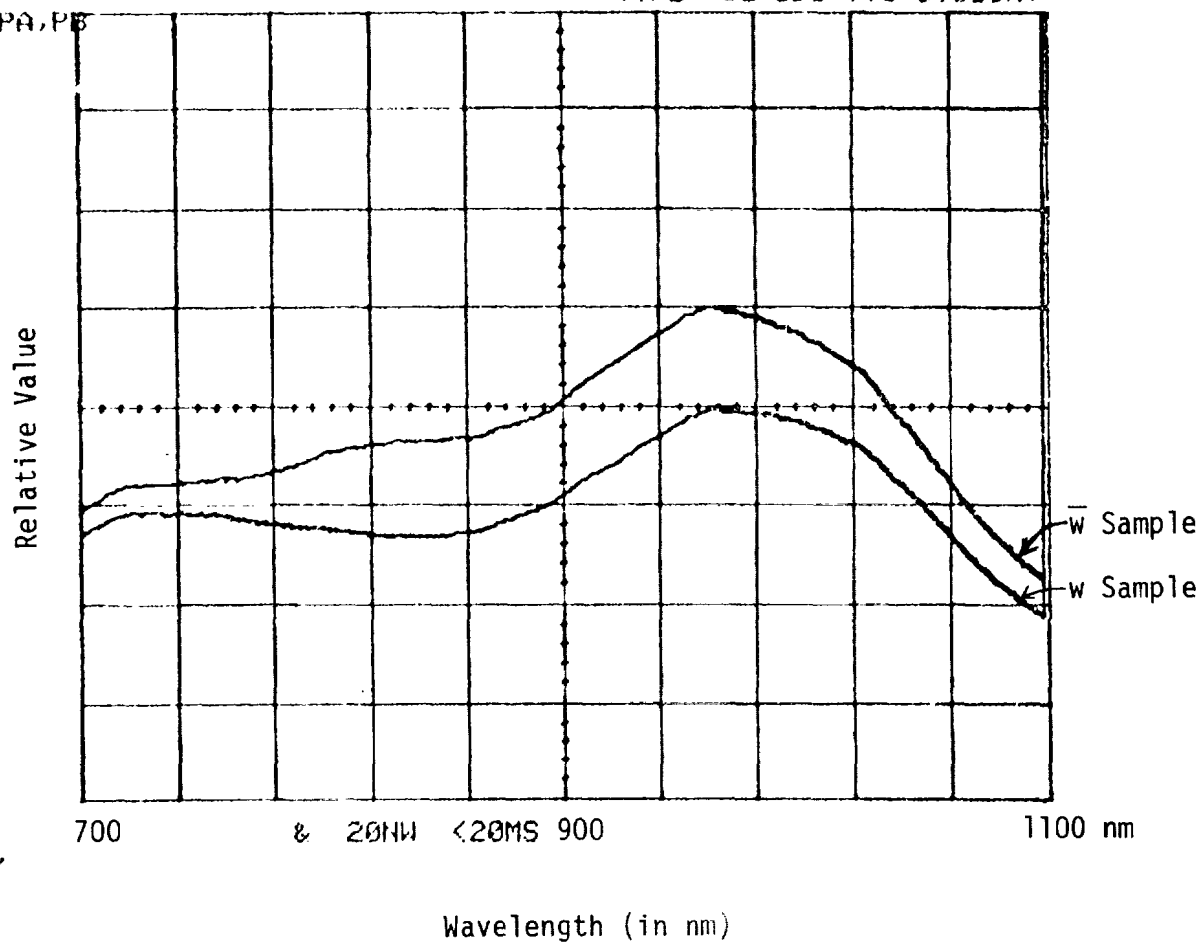


FIGURE 11. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE OG-590
(From 700-1100 nm)

LIS 19

19 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (700-1100NM)

READY

*REM

*GRA PA/PS

900NM 40NM

TYPE-- RG 610 (TO 0.57 UM)

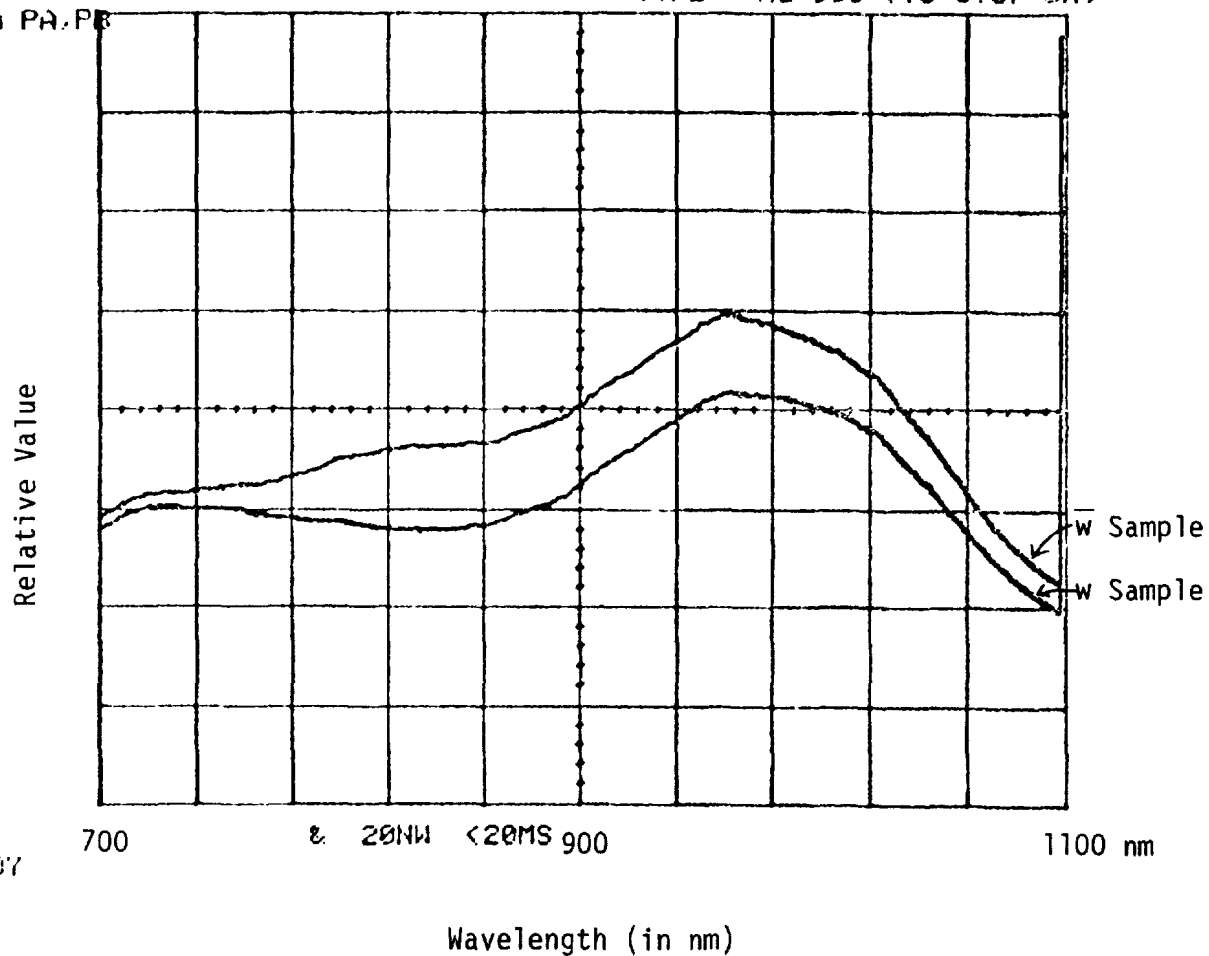


FIGURE 12. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE RG-610
(From 700-1100 nm)

LIS 19

19 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (700-1100NM)

READY

*REM

20PA PA:PB

900NM

40NM

TYPE-- BG-18 (0.69 TO 1.3 UM)

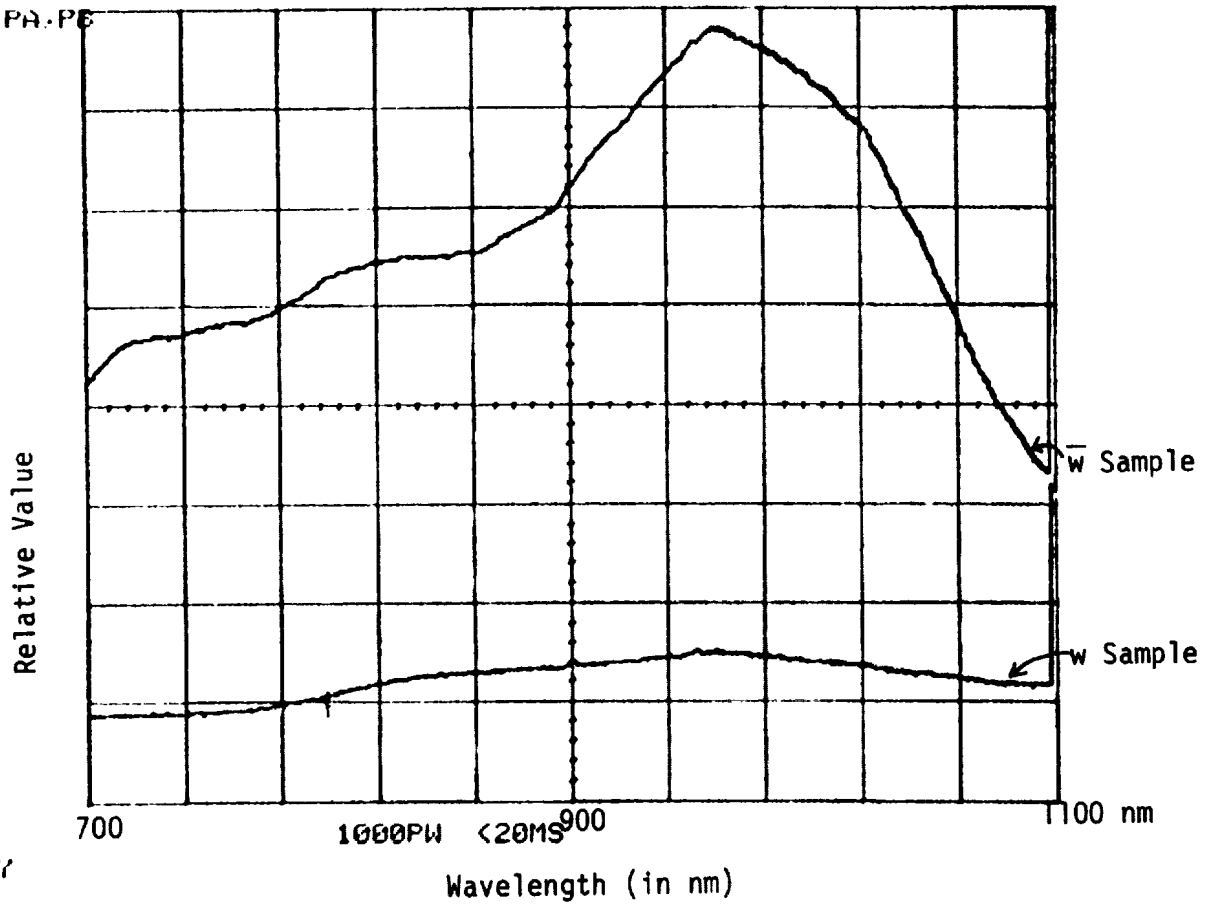


FIGURE 13. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE BG-18
(From 700-1100 nm)

LIS 19

19 REMARK SPECTRAL POWER DISTRIBUTION OF LASER EYEWEAR (700-1100NM)

READY

REM

4000 PA, PE

900NM

40NM

TYPE--KG-3 (0.9 TO 12 UM)

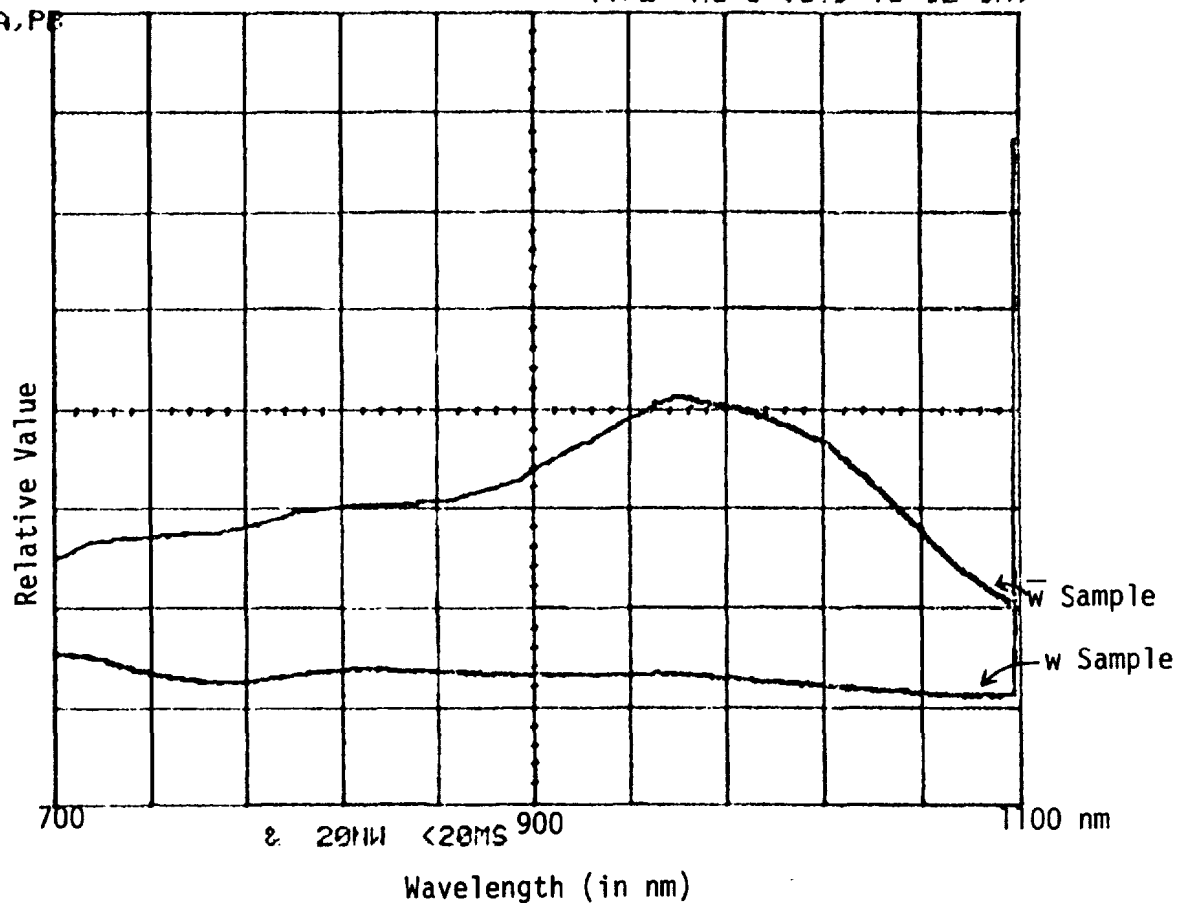


FIGURE 14. SPECTRAL POWER DISTRIBUTION CURVE OF SAMPLE KG-3
(From 700-1100 nm)

LIS 15

15 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 400 TO 800NM

READY

*REM

100M PD

100M 40NM

TYPE GG-9(TO 0.42UM)

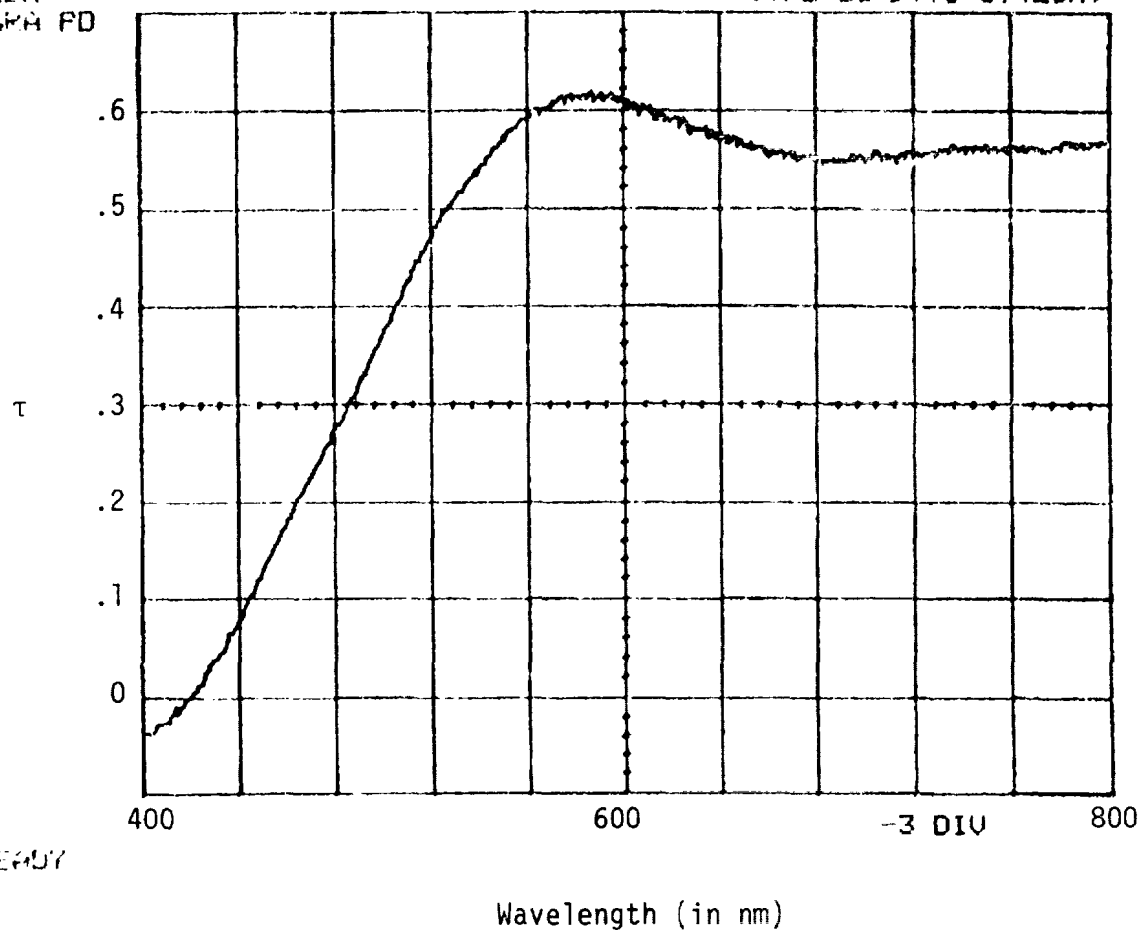


FIGURE 15. SPECTRAL TRANSMITTANCE OF GG-9 FROM 400 TO 800 nm

LIS 17

17 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 700 TO 1100NM

READY

*REM

3URA PC

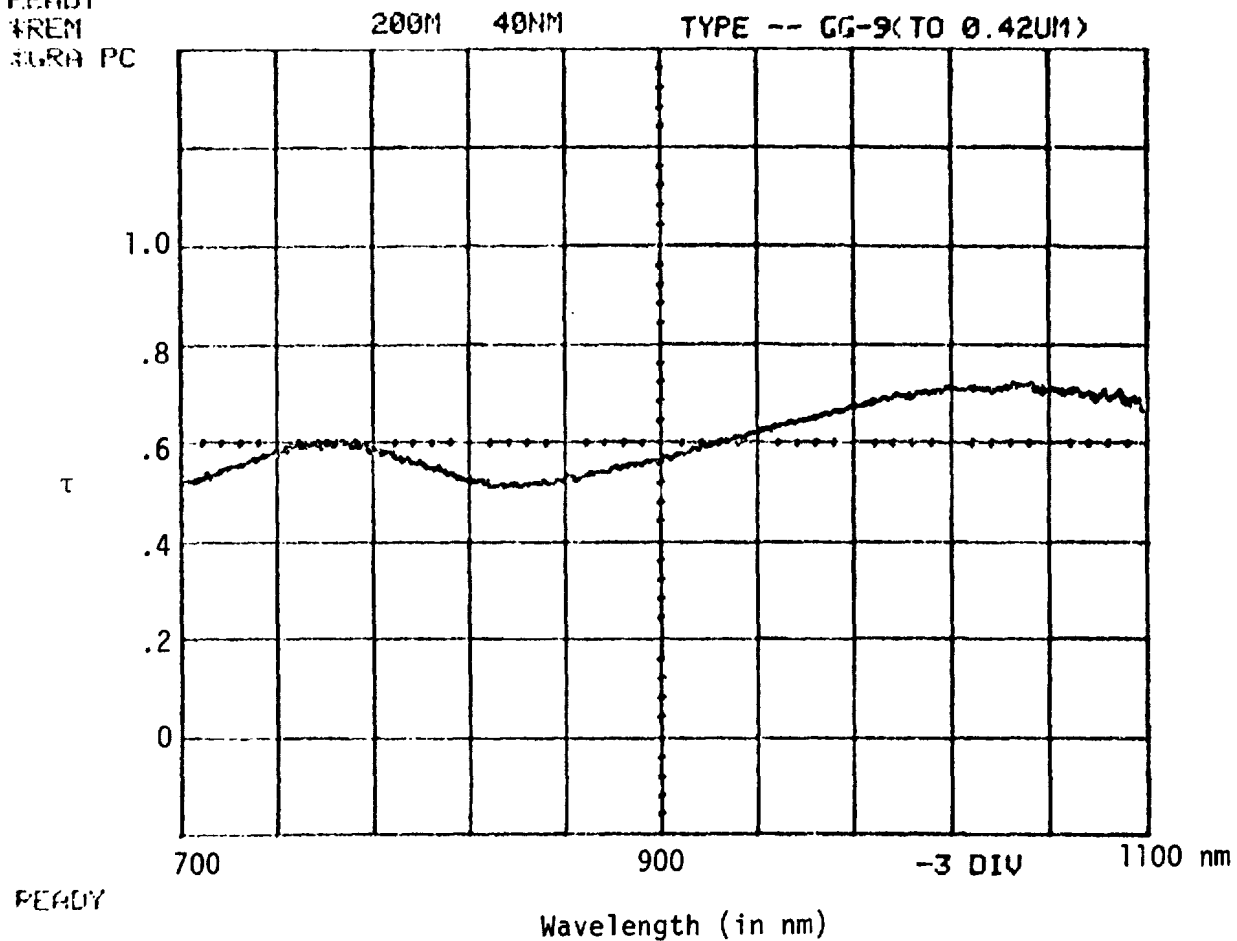


FIGURE 16. SPECTRAL TRANSMITTANCE OF GG-9 from 700 to 1100 nm

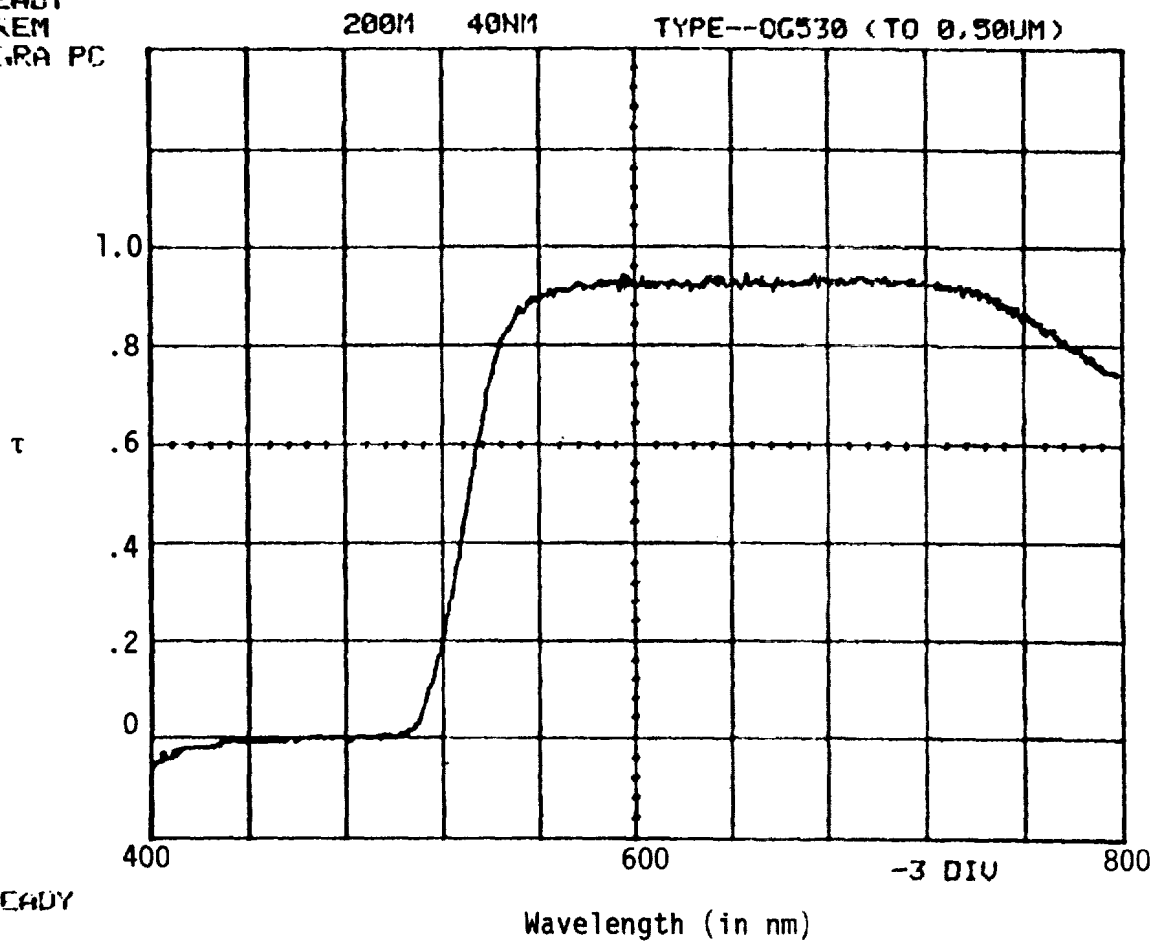
LIS 15

15 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 400 TO 800NM

READY

REM

RA PC



READY

FIGURE 17. SPECTRAL TRANSMITTANCE OF OG-530 FROM 400 TO 800 nm

LIS 17

17 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 700 TO 1100NM

PEADY

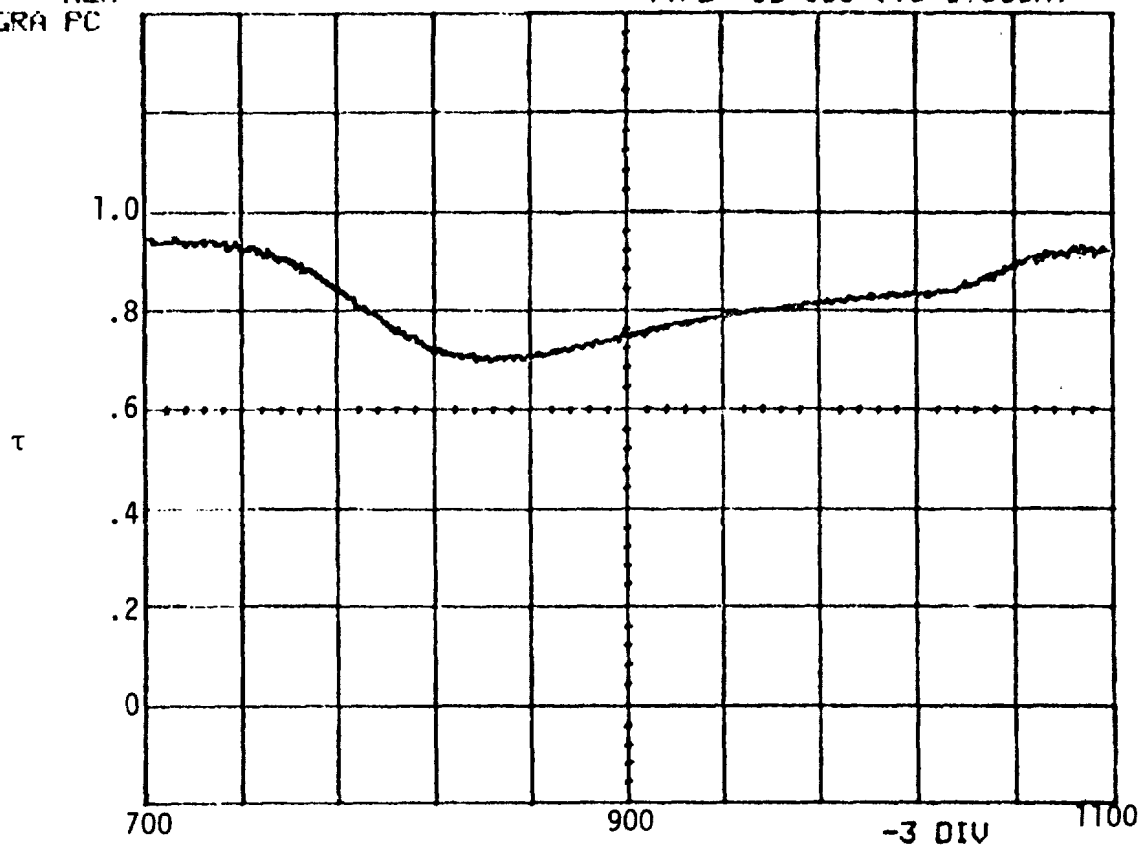
* REM

1GRA PC

200M

40NM

TYPE--OG 530 (TO 0.50UM)



PEADY

Wavelength (in nm)

FIGURE 18. SPECTRAL TRANSMITTANCE OF OG-530 FROM 700 TO 1100 nm

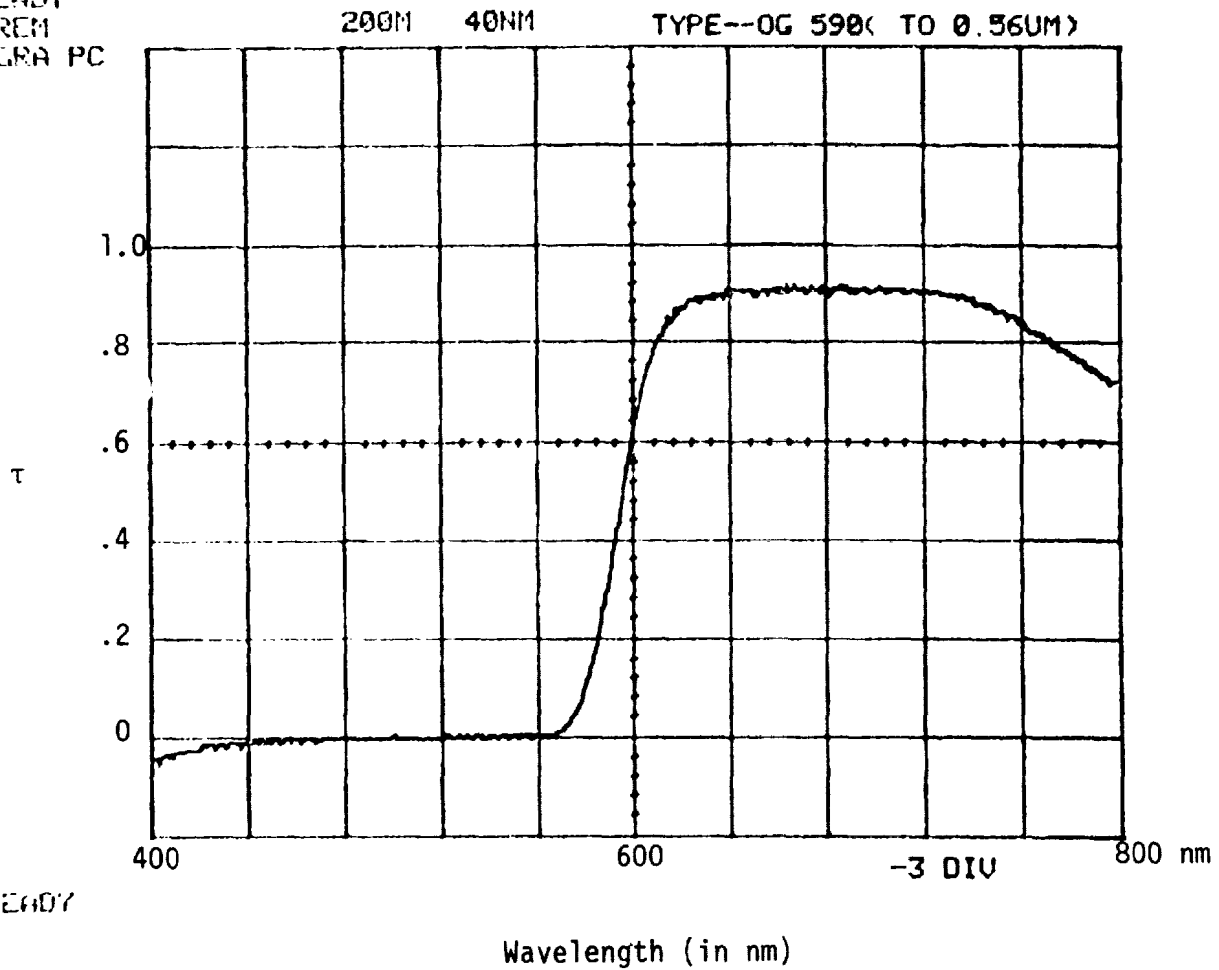
LIS 15

15 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 400 TO 800NM

READY

*REM

*GRA PC



READY

FIGURE 19. SPECTRAL TRANSMITTANCE OF OG-590 FROM 400 TO 800 nm

LIS 17

17 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 700 TO 1100NM

READY

*REM

4GRA PC

200M 40NM

TYPE-- OG 590 (TO 0.56UM)

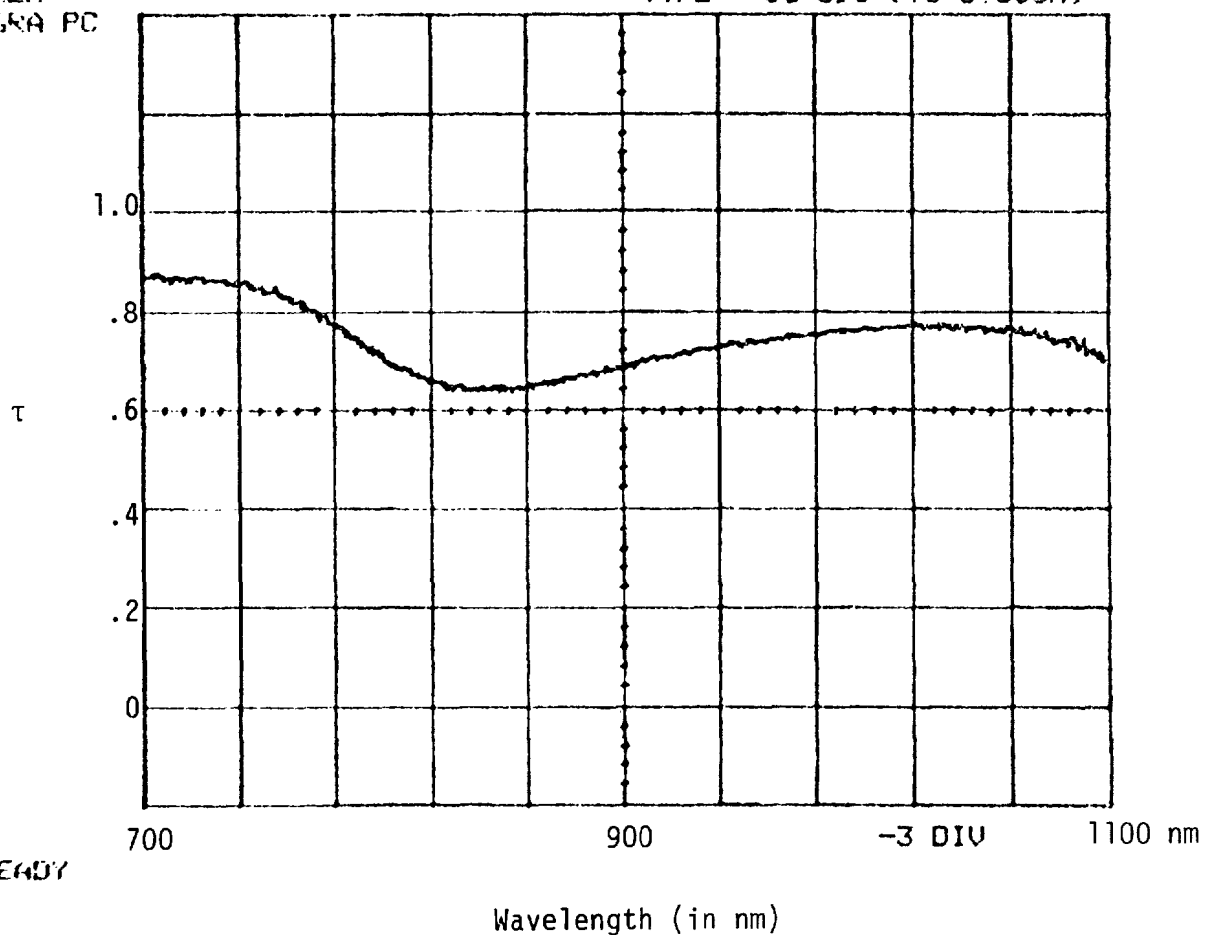


FIGURE 20. SPECTRAL TRANSMITTANCE OF OG-590 FROM 700 TO 1100 nm

LIS 15

15 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 400 TO 800NM

READY

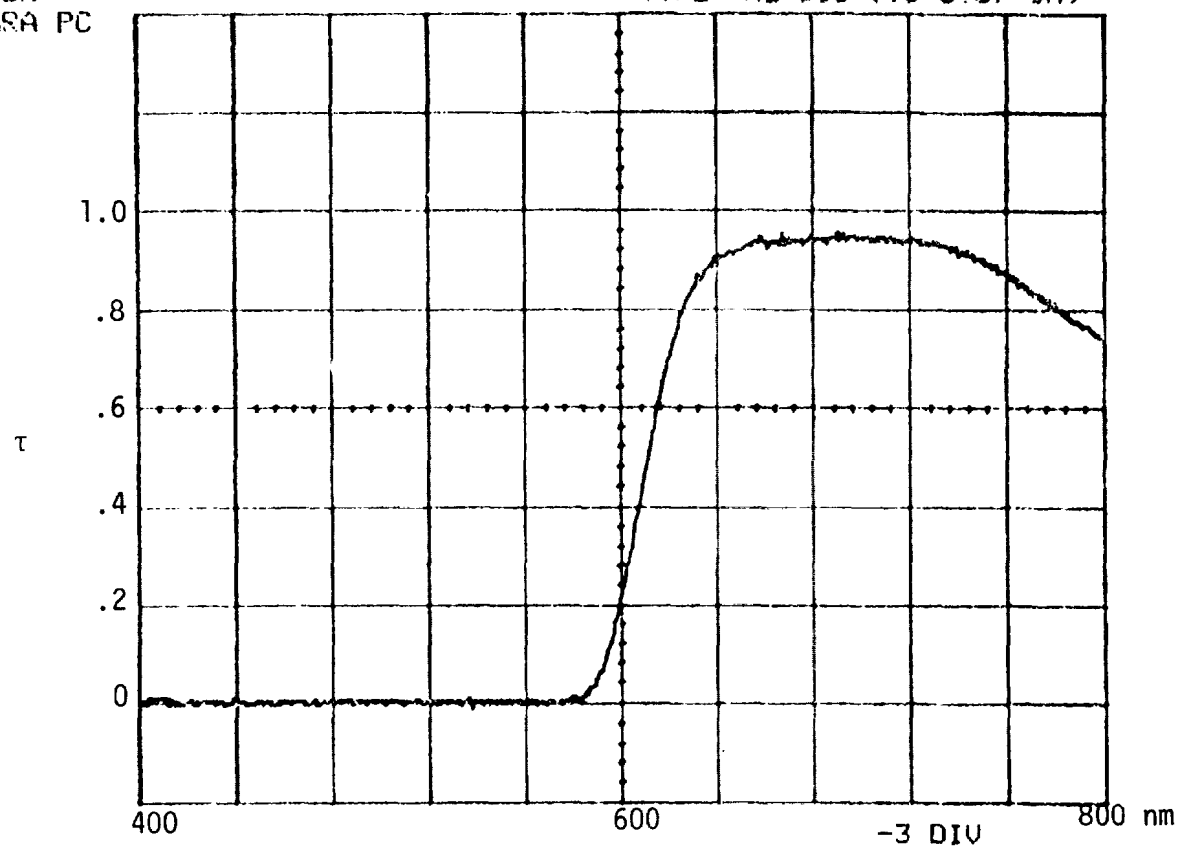
*REM

YGRA PC

200M

40NM

TYPE--RG 610 (TO 0.57 UM)



READY

Wavelength (in nm)

FIGURE 21. SPECTRAL TRANSMITTANCE OF RG-610 FROM 400 TO 800 nm

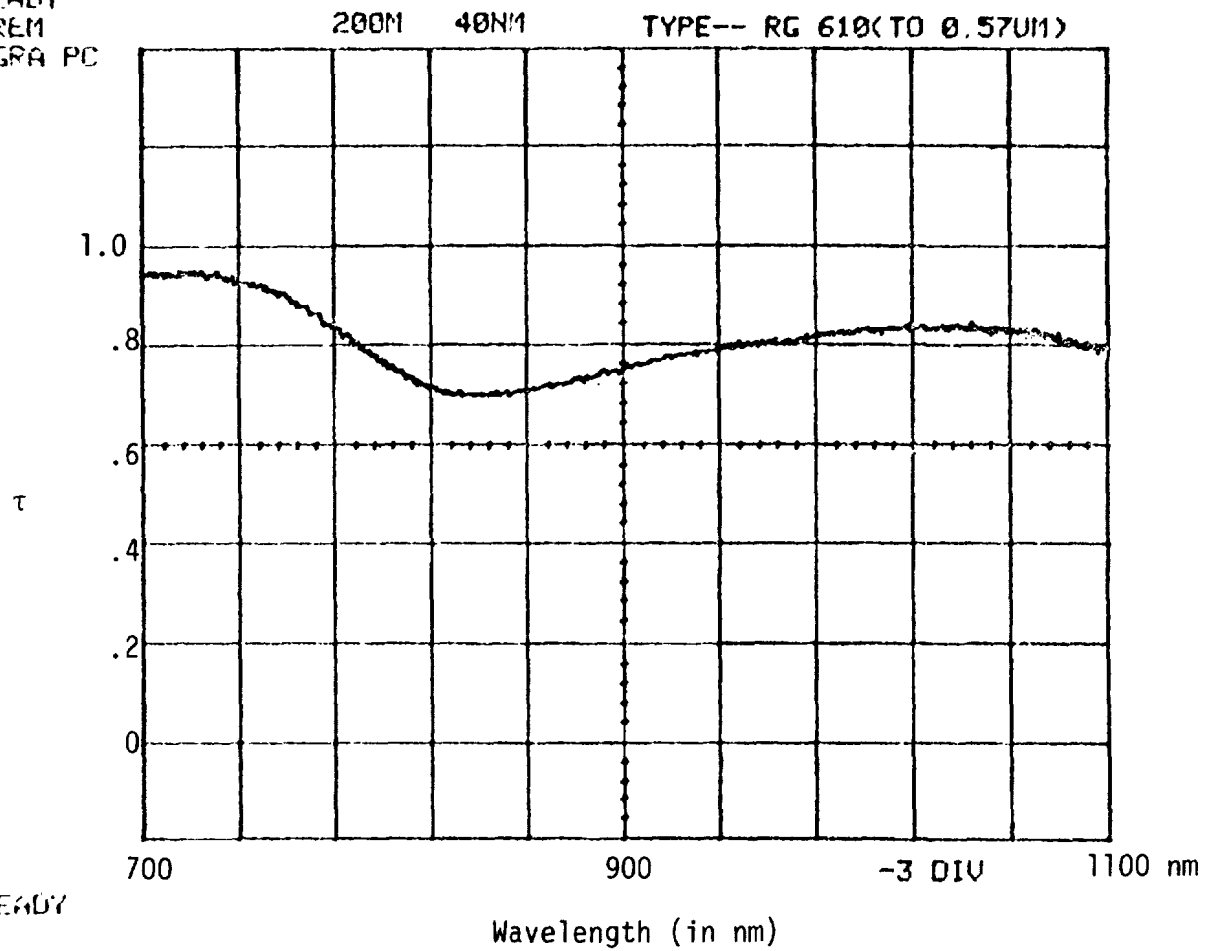
LIS 17

17 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 700 TO 1100NM

READY

*REM

%GRA PC



READY

FIGURE 22. SPECTRAL TRANSMITTANCE OF RG-610 FROM 700 TO 1100 nm

LIS 15

15 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 400 TO 800NM

READY

#REM

16FA PC

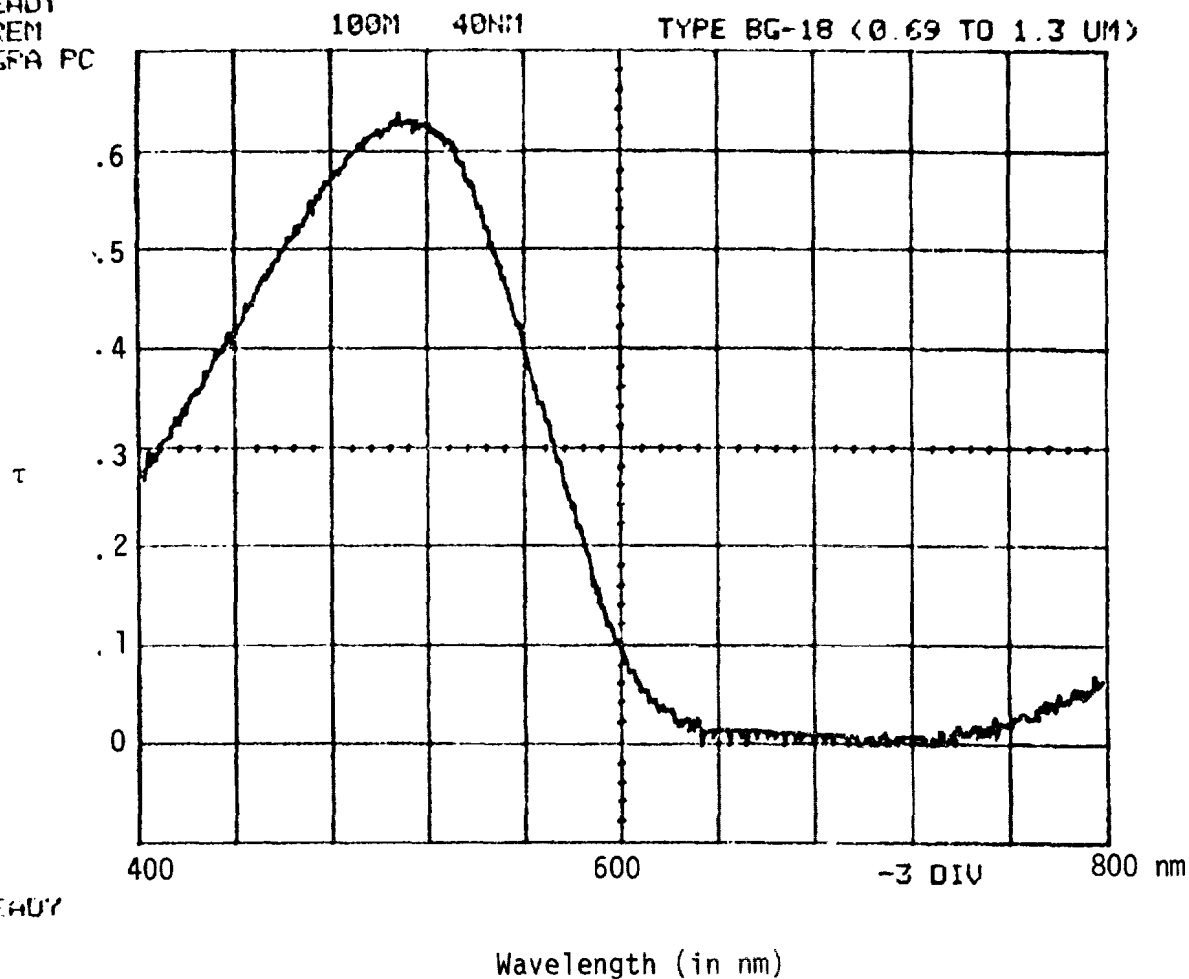


FIGURE 23. SPECTRAL TRANSMITTANCE OF BG-18 FROM 400 to 800 nm

LIS 17

17 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 700 TO 1100NM

PEADY

4REM

ALPHA PC

20M 40NM

TYPE-- BG-18 (0.69 TO 1.3UM)

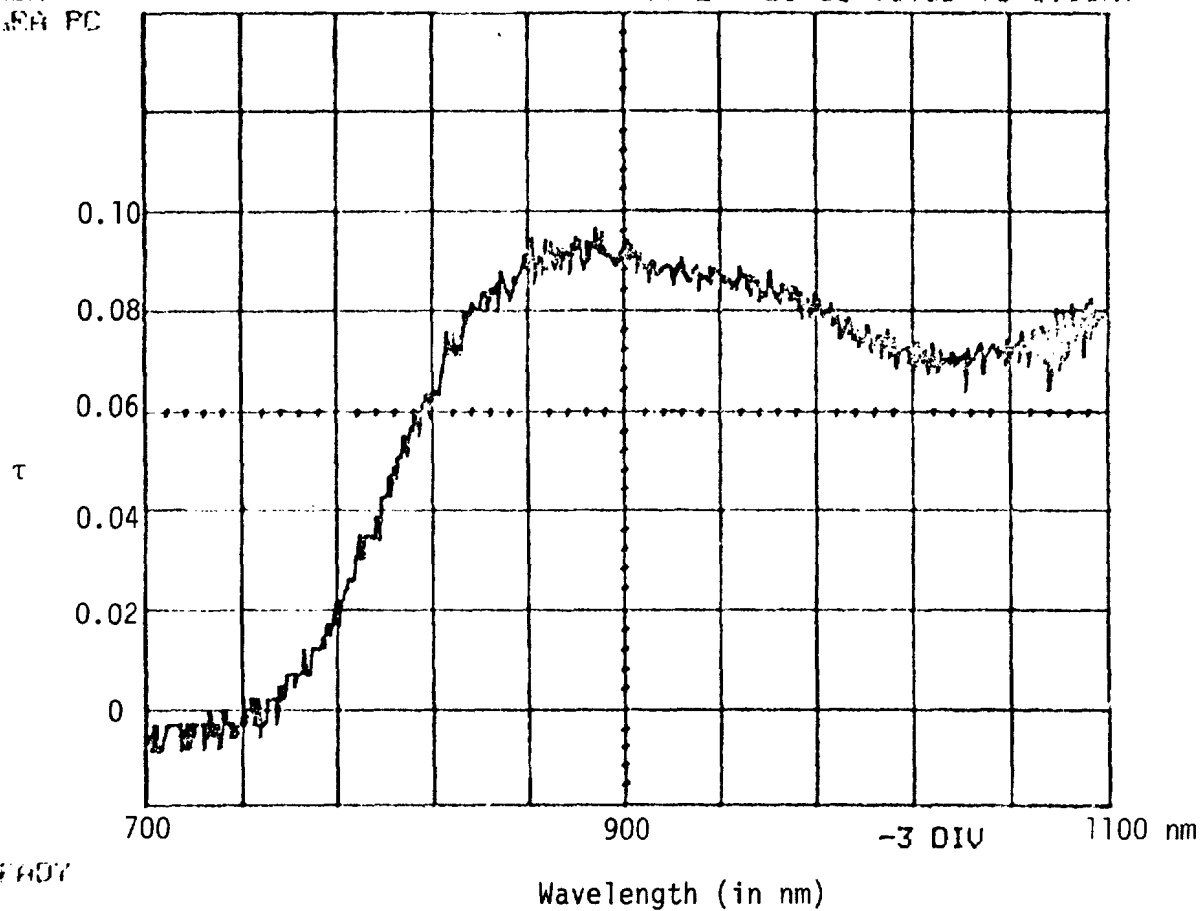


FIGURE 24. SPECTRAL TRANSMITTANCE OF BG-18 FROM 700 TO 1100 nm

LIS 15

15 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 400 TO 800NM

READY

*REM

-GRA PC

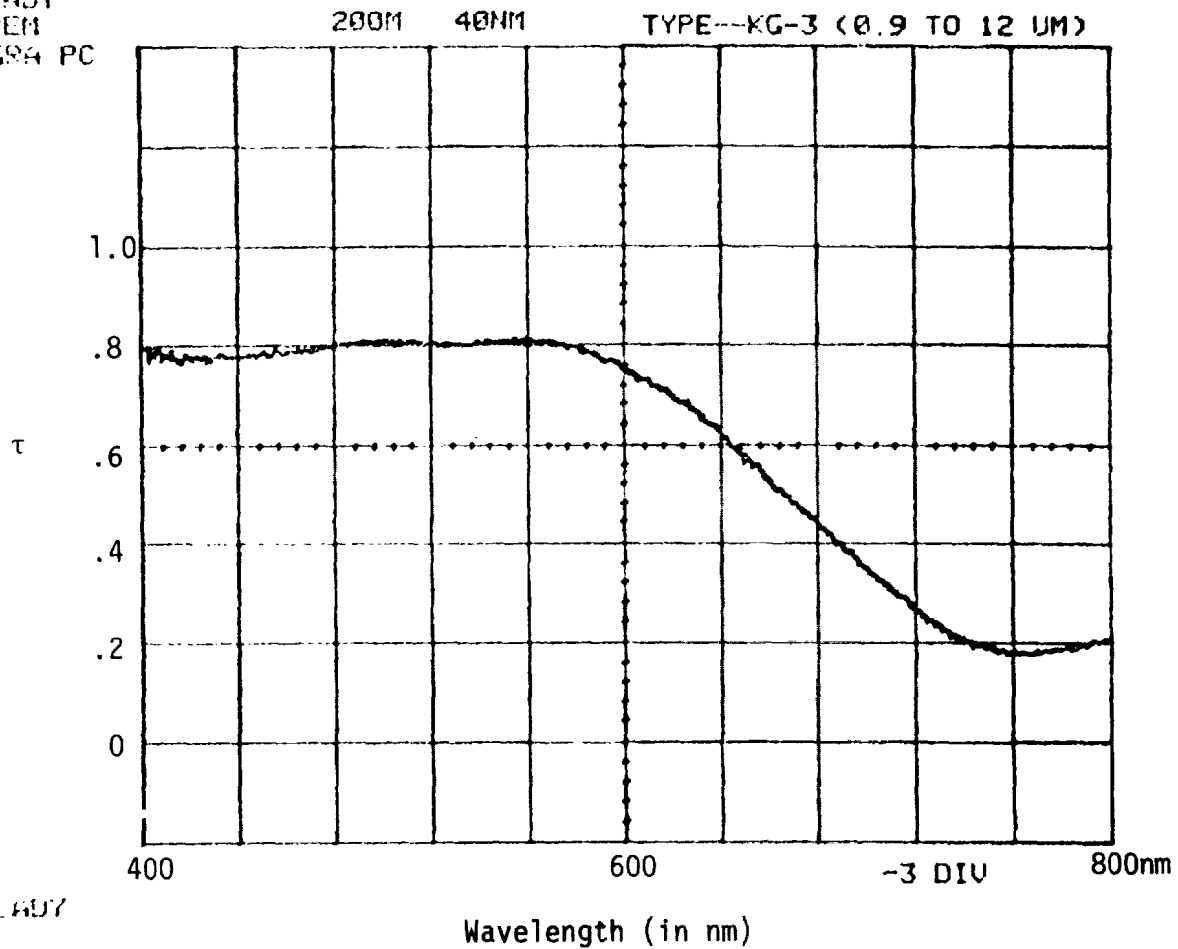


FIGURE 25. SPECTRAL TRANSMITTANCE OF KG-3 FROM 400 TO 800 nm

LIS 17

17 REMARK SPECTRAL TRANSMITTANCE OF LASER EYEWEAR FROM 700 TO 1100NM

READY

*REM

*GRA PC

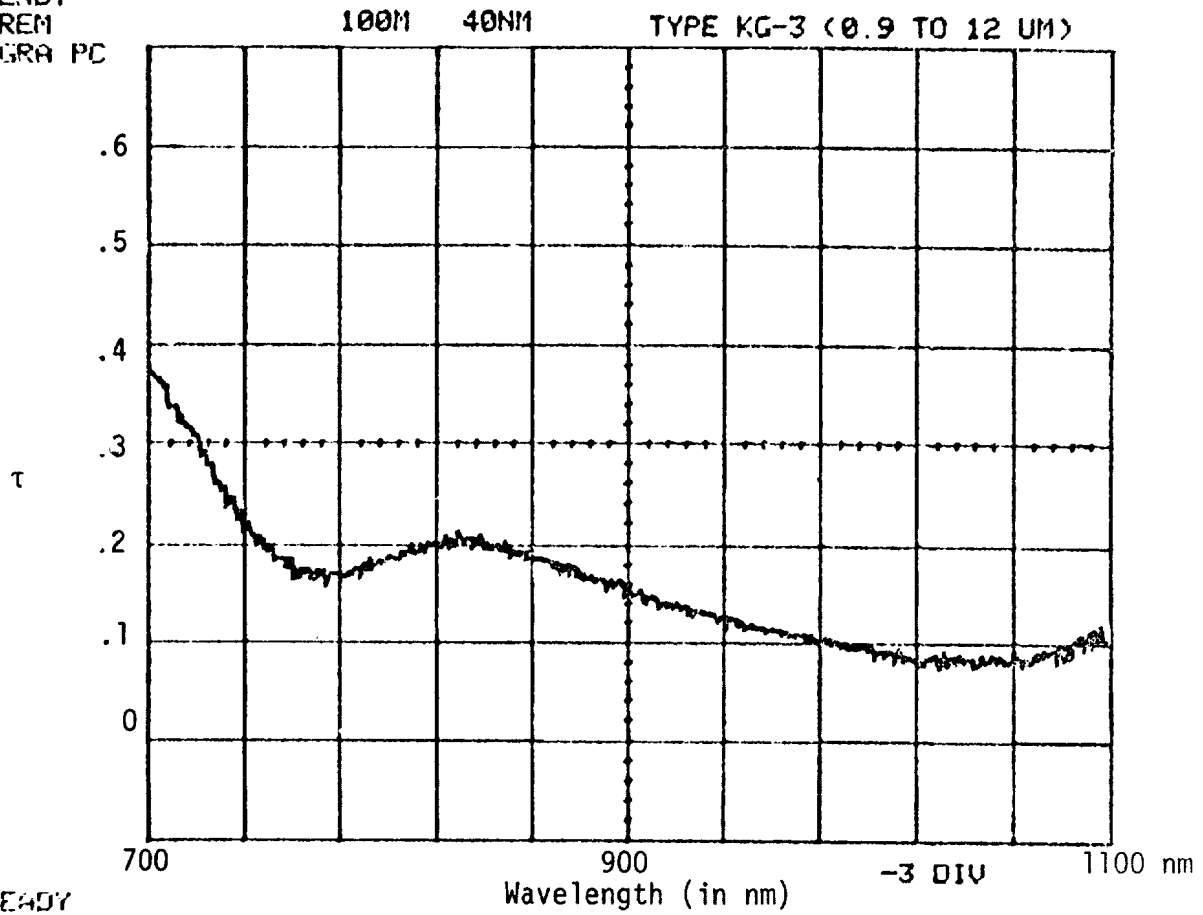


FIGURE 26. SPECTRAL TRANSMITTANCE OF KG-3 FROM 700 TO 1100 nm

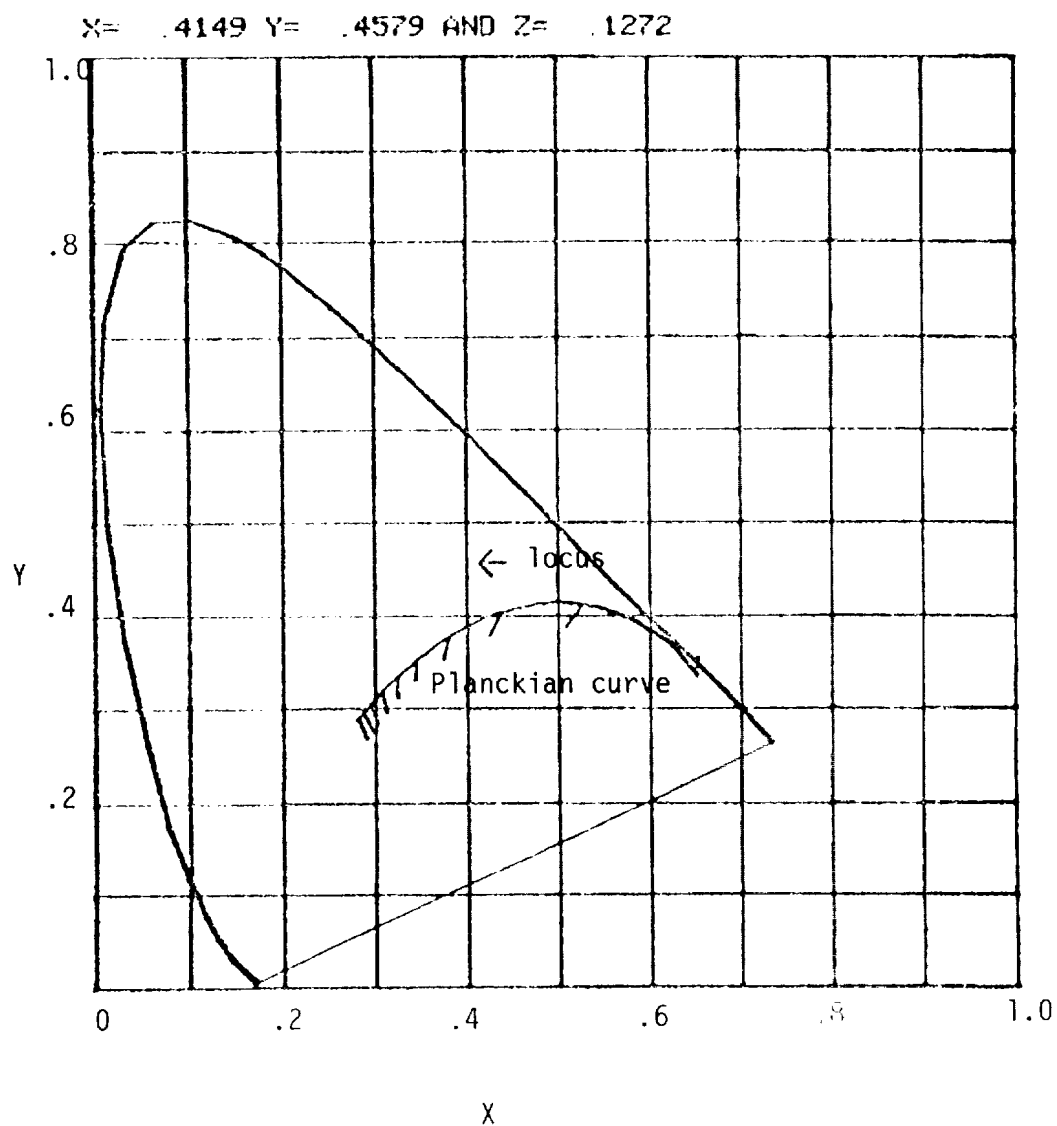


FIGURE 27. CIE CHROMATICITY DIAGRAM AND COORDINATE VALUES OF GG-9

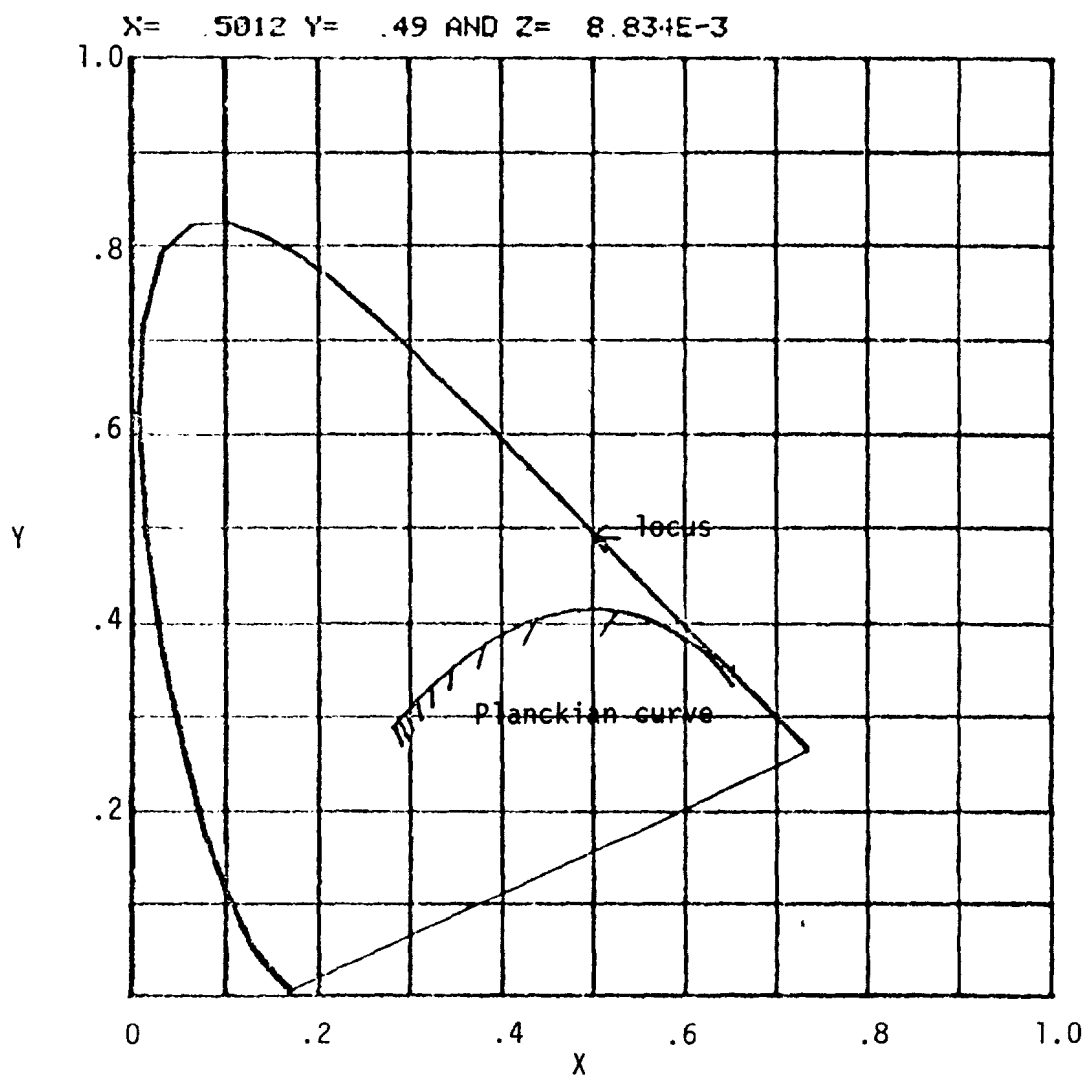


FIGURE 28. CIE CHROMATICITY DIAGRAM AND COORDINATE VALUES OF OG-530

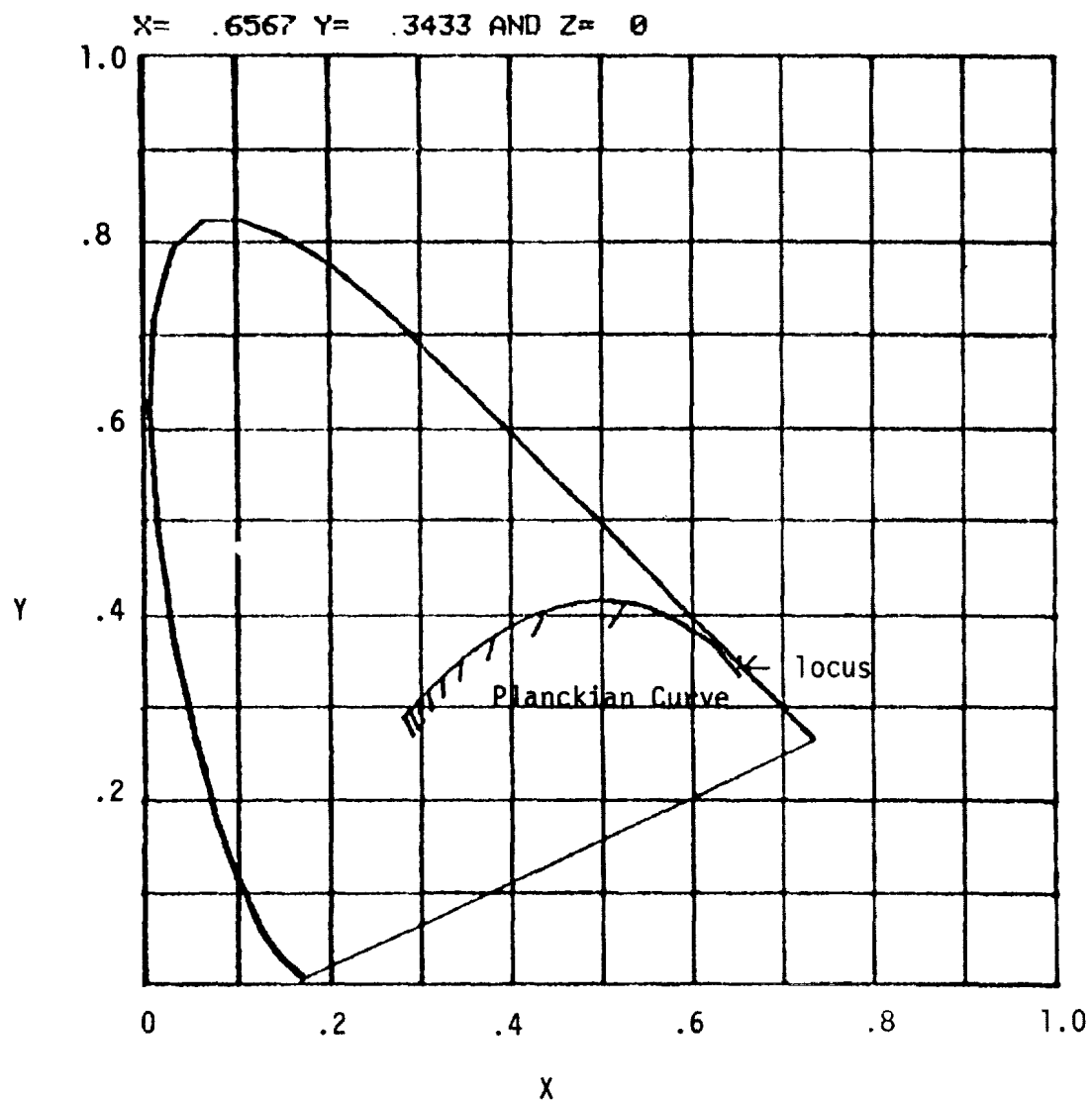


FIGURE 29. CIE CHROMATICITY DIAGRAM AND COORDINATE VALUES OF OG-590

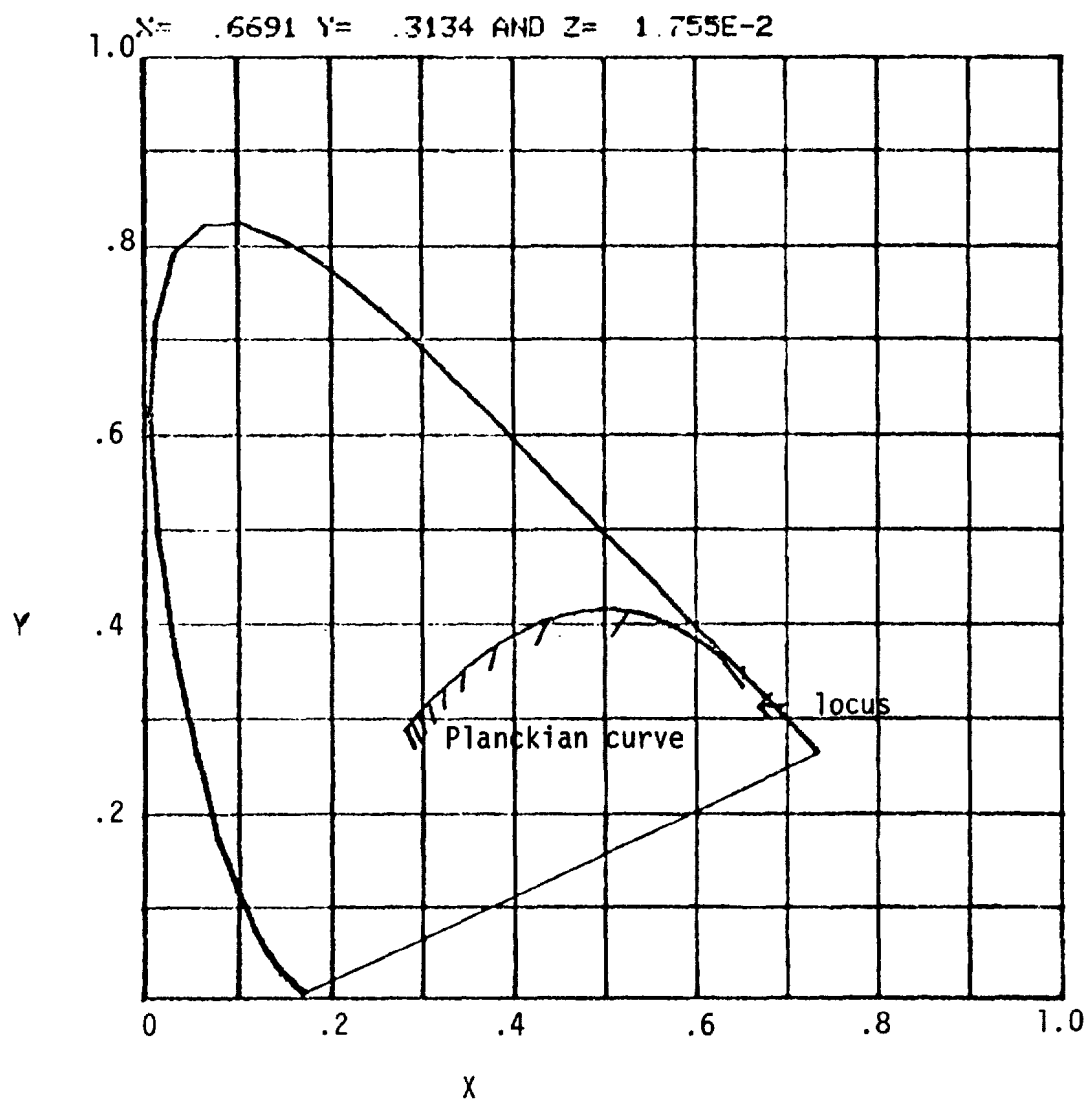


FIGURE 30. CIE CHROMATICITY DIAGRAM AND COORDINATE VALUES OF RG-610

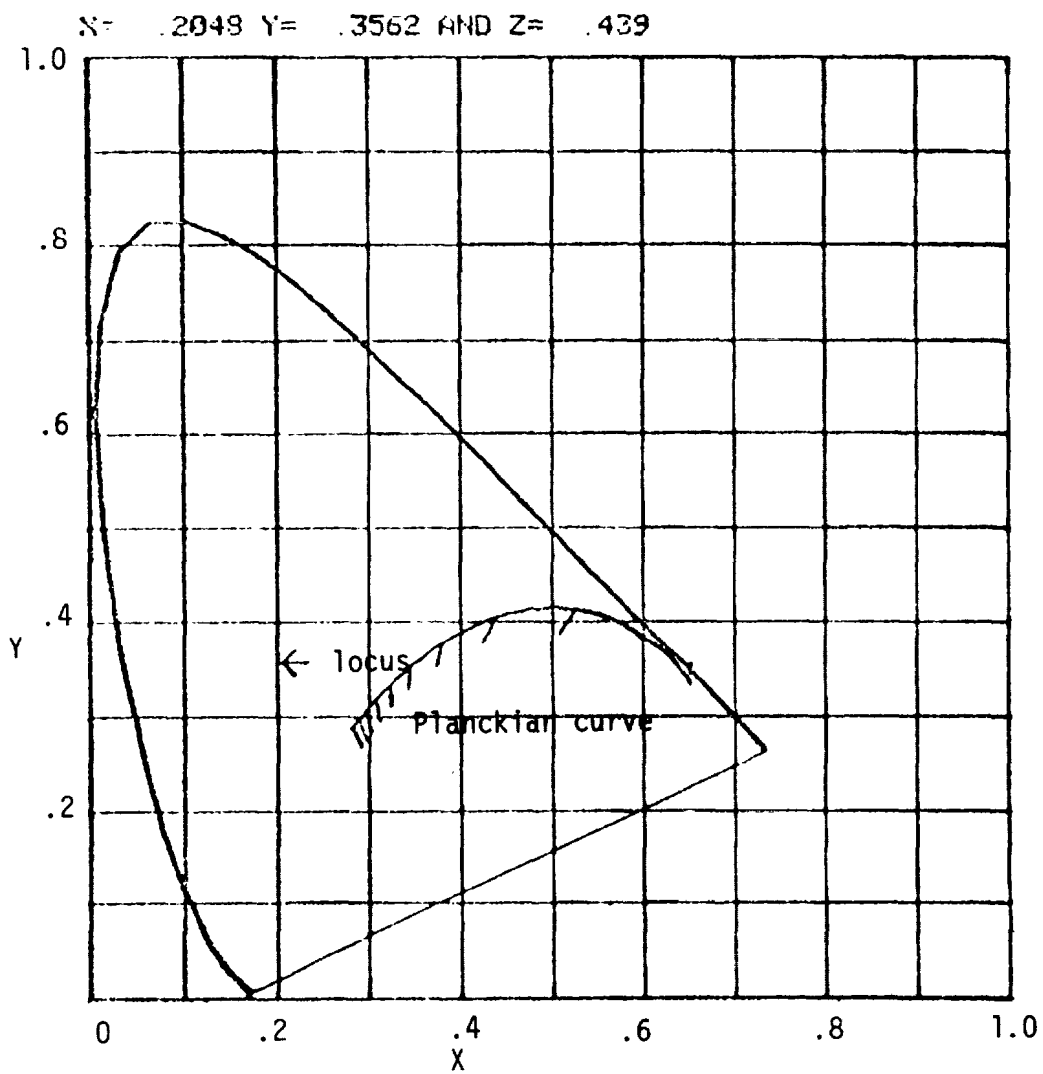


FIGURE 31. CIE CHROMATICITY DIAGRAM AND COORDINATE VALUES OF BG-18

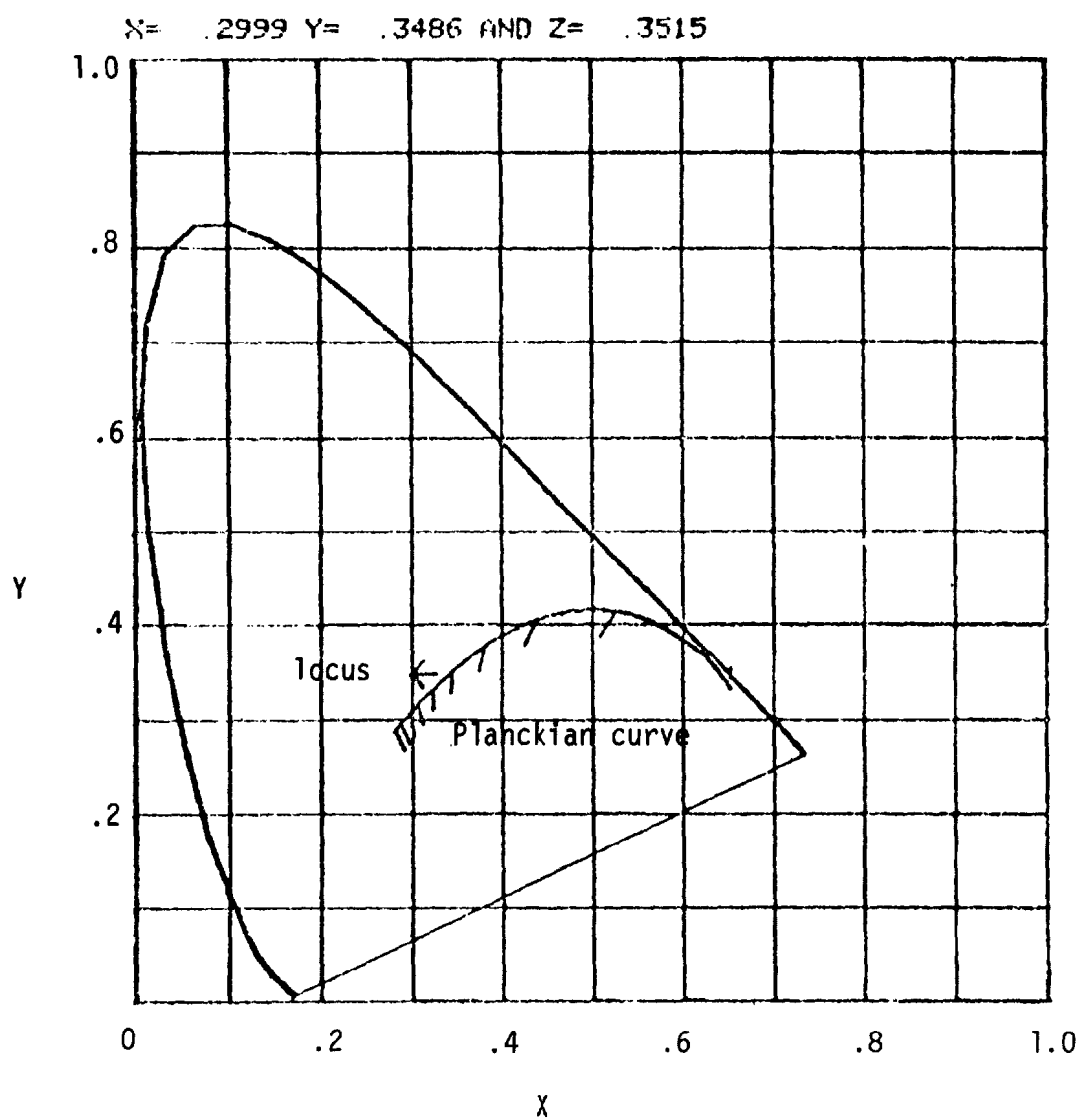


FIGURE 32. CIE CHROMATICITY DIAGRAM AND COORDINATE VALUES OF KG-3

TABLE 1

Chromaticity Values	X	Y	Z
Sample			
1. GG-9	0.4149	0.4579	0.1272
2. OG-530	0.5012	0.4900	0.0088
3. OG-590	0.6567	0.3433	0
4. RG-610	0.6691	0.3134	0.0175
5. BG-18	0.2048	0.3562	0.4390
6. KG-3	0.2999	0.3486	0.3515

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