Light Sources and Filters

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LIGHT SOURCES

The most common light source is the bulb containing a heated wire. This is called a thermal light source, and its radiant emission is governed by the Planck Black Body law. An ideal black body radiator is represented by an isothermal enclosure with a small hole from which radiation emerges. Although no such device can be perfectly realized, a heated wire approximates it well enough to qualify as a "gray" body, one whose radiant emission is nearly a constant fraction of the ideal black body emission at all wavelengths.

The characteristic of black body radiation is that the spectrum depends only on the temperature of the radiating body. A "family" of curves can be derived that describe the emission from the radiator as a function of wavlength, with the temperature of the body as the parameter. The accompanying figure shows such a family of curves. The scale is logarithmic both in wavelength and intensity, as a large range must be covered. It is seen that the position of the peak of the emission curve moves toward shorter wavelength with increasing temperature and at the same time the value of peak emission increases with temperature.

The sun represents very nearly an ideal black body radiator at a temperature of 5900 degrees Kelvin. Standard filament light bulbs, which universally use tungsten wire as the radiating element, operate at temperatures ranging from 2750 to 3050 degrees Kelvin. Recently developed quartz-halogen bulbs operate at somewhat higher temperature. The limiting temperature for any filament bulb is 3755 degrees, the melting point of tungsten.

As the temperature of the filament is raised there is a change in both intensity and color. The intensity increases and the color changes from red to yellow, then white and eventually blue-white. Most light sources, therefore, can be characterized by their color which is usually expressed in terms of a color temperature. The hotter the source the whiter its spectrum. This is illustrated on the "black body locus" of the standard CIE color curve.

It does not matter how the source temperature is produced, whether a higher wattage lamp is used or whether a higher voltage is applied to a lower rated bulb. The filament will emit the radiation that is characteristic of the temperature.

The sun's radiation is modified somewhat by elements in the atmospheres of both the sun and the earth. The Fraunhofer lines are absorptions taking place in the solar atmosphere by cooler atoms. These are narrow absorptions characteristic of the atomic spectra of most of the known elements. They are not visible to the naked eye. The earth's atmosphere, likewise, removes some of the energy from the incoming radiation but this takes place principally in the infrared and is due to water vapor, carbon dioxide, and other so-called "greenhouse gases." The total energy reaching the surface is approximately 1.4 kilowatts on each square meter of surface perpendicular to the sun's rays.

The most commonly used non-thermal light source is the fluorescent tube which contains mercury vapor as the active element. Ultraviolet radiation emitted by mercury is absorbed by materials coated inside the tube known as phosphors, which in turn emit visible wavelengths. The choice of phosphor(s) determines the color of the light emitted. Fluorescents are characterized by their apparent color as daylight (bluish), cool white, and warm white, in order of increasing red and declining blue content. Their radiant emission falls nearly along the black body locus of the CIE curve.

Other non-thermal sources are high pressure mercury, xenon, and sodium arc lamps which produce a brilliant light which however does not match a black body curve and therefore does not have an associated color temperature. The xenon arc produces the whitest light of any of these bulbs, as well as the most intense. It was the source initally used for photocoagulation before the advent of the laser.

FILTERS

The spectrum of light reaching the eye is modified by the interposition of filters between it and the light source. There are many different kinds of filters; in this paper we will limit the discussion to glass filters and interference filters.

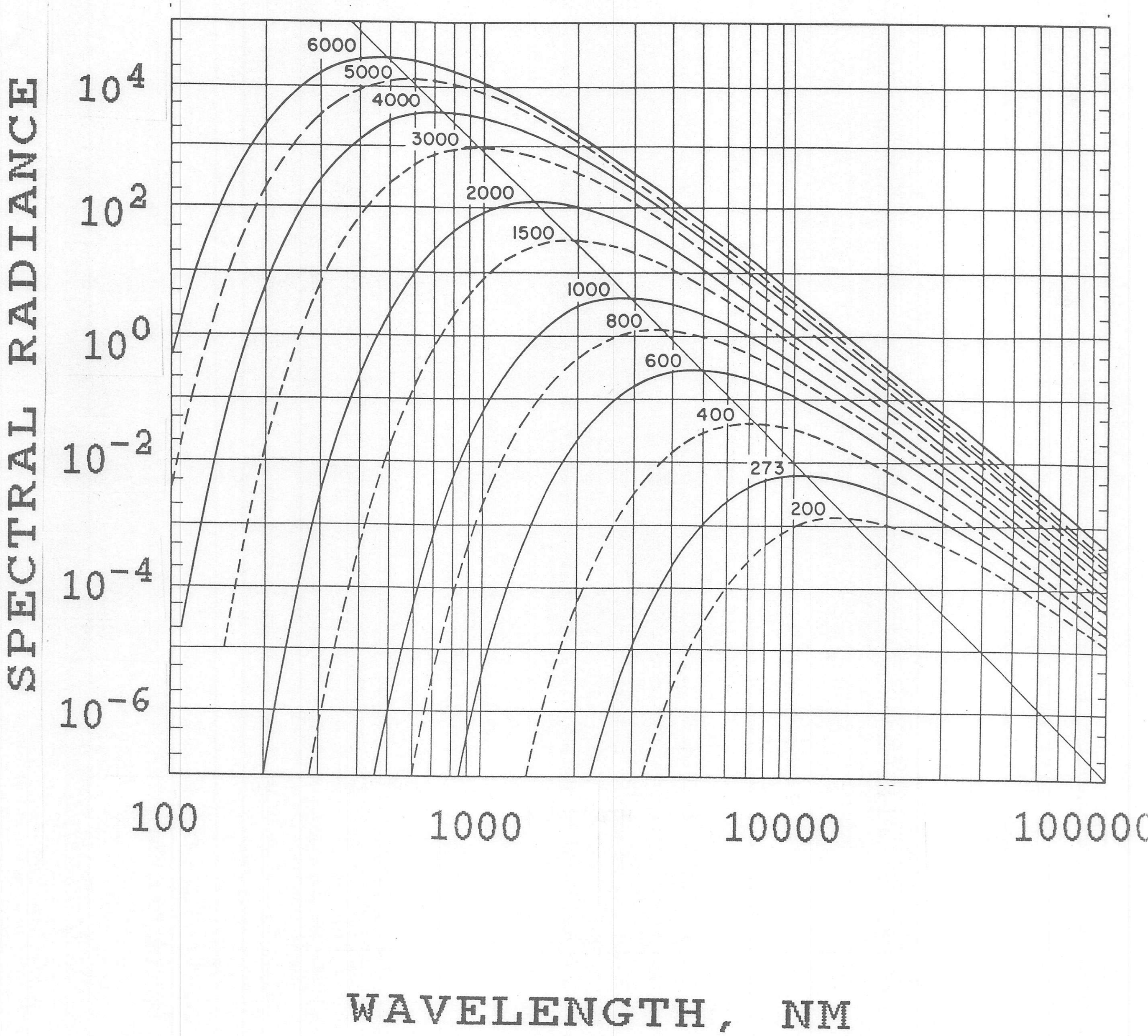
Glass filters are produced by adding a mineral to the glass melt in the manufacturing process. Each additive produces a characteristic color which can usually be somewhat modified in the manufacturing process. The modification involves using greater or lesser amount of mineral additive, and controlling the thickness of the resulting glass. There are only a relatively few useful minerals that can be used in glass because of the high temperature of the manufacturing process. All the glass filters produced in the United States are made by Kopp Glass in Pittsburgh and are listed in their catalog along with drawings of their transmission spectra. The actual glass is obtainable from one of their suppliers.

The action of the filter is characterized by its spectral transmittance which is the percent transmission as a function of wavelength. When two filters are used together, their effect is the product of the individual effects at each wavelength. The order of the filters in the light path is unimportant. When combined with a light source the filter produces a characteristic brightness and color. A tabulation of the transmittance of the filters used in the syntonic instruments is attached, along with the corresponding Kopp glass specification.

The glass filters typically produce a relatively broad spectrum of radiation. A narrow spectrum can be obtained with an interference filter that operates on the same principle as the familiar anti-reflection coating. A multilayer structure is produced that relies on the thickness of the individual layers to give very good transmission over a restricted band of wavelengths and essentially zero transmission elsewhere. The wavelength of the peak transmission can be controlled throughout the visible and near UV region.

Regardless of which filter is used, the radiant energy reaching the eye depends also on the source characteristics. An inspection of the family of curves for black bodies at different temperatures shows that in all cases the source produces significantly more red than blue light, so the subject will receive relatively more light through a red filter than a blue one of equal bandwidth. The perceived brightness depends also on the photopic sensitivity of the eye, which peaks at the green and drops rapidly in the red and blue.

RADIANT EMISSION of a BLACK BODY

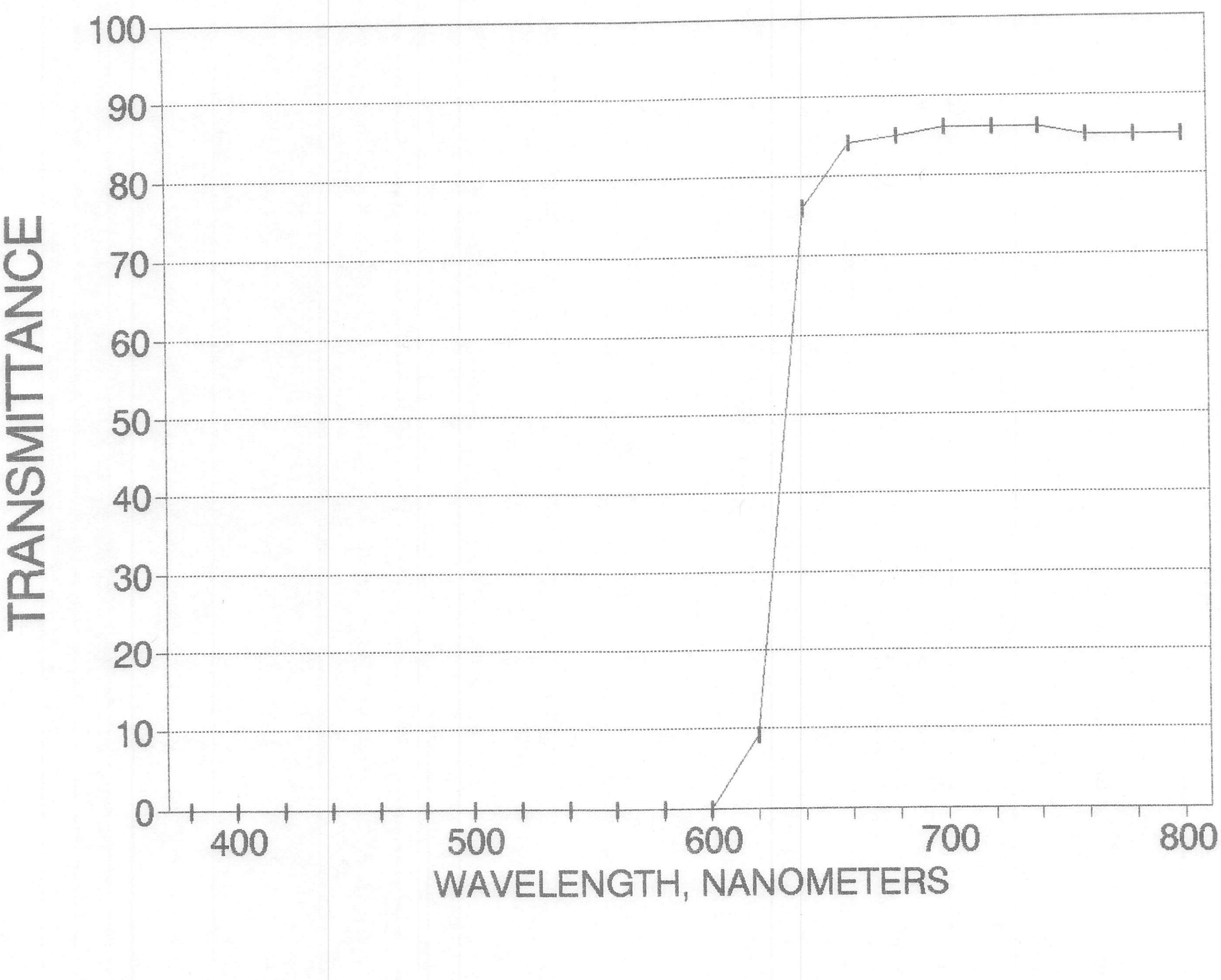


TRANSMITTANCE SPECTRA OF SYNTONIC FILTERS

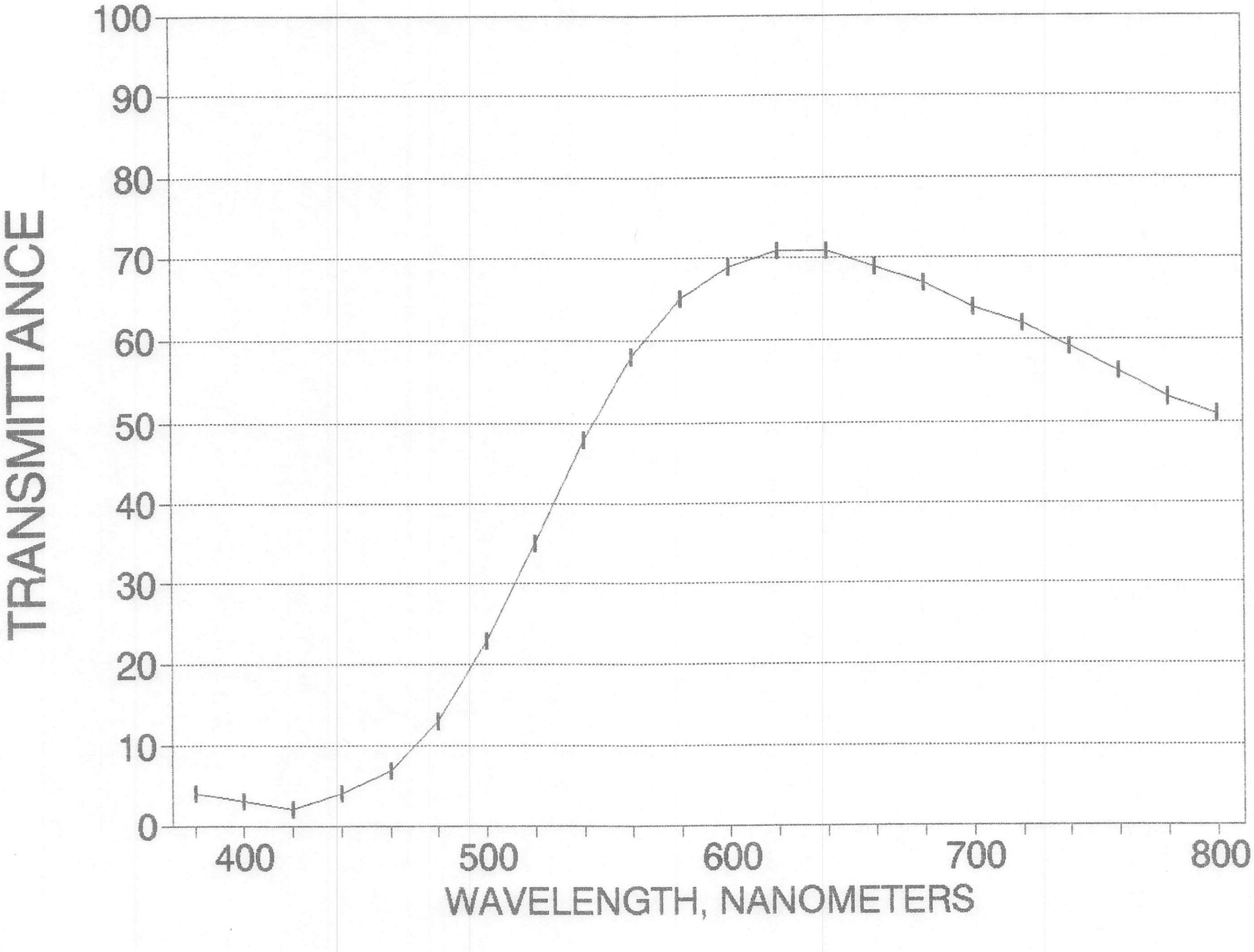
Wavelength nm	ALPHA	DELTA	THETA	OMEGA	UPSIL	MU	LAMBDA	PI	D	N	S
380	0	4	0	83	43	0	29	76	80	62	0
400	0	3	0	79	64	0	51	83	82	62	0
420	0	2	0	66	71	0	62	84	81	35	0
440	0	4	0	47	70	0	63	83	79	11	0
460	0	7	0	25	63	1	57	81	76	3	0
480	0	13	0	5	43	5	35	73	66	1	0
500	0	23	0	0	19	16	13	69	49	0	10
520	0	35	26	0	5	27	3	41	31	0	57
540	0	48	76	0	2	25	1	24	19	0	75
560	0	58	82	0	1	14	1	10	26	1	79
580	0	65	85	0	1	5	0	4	16	1	80
600	0	69	86	0	0	1	0	1	10	2	81
620	9	71	87	0	0	0	0	0	10	4	81
640	76	71	88	0	0	0	0	0	9	5	81
660	84	69	88	0	0	0	0	0	13	7	81
680	85	67	88	0	0	0	0	1	34	10	81
700	86	64	88	12	0	0	0	1	69	13	81
720	86	62	88	59	0	0	0	9	82	16	81
740	86	59	87	82	0	0	0	41	84	20	81
760	85	56	87	88	0	0	0	78	84	26	81
780	85	54	87	88	0	0	0	88	84	32	81
800	85	51	87	88	0	0	0	89	84	39	81
Kopp Glass	2404	3307	3486	5850	5031	4010	5433	5031	5572	5070	3780
Page no.	24	26	24	16	18	22	18	18	32	32	26
CS Number	2-59	3-77	3-69	7-59	5-61	4-64	5-59	5-56	1-61	7-62	3-80

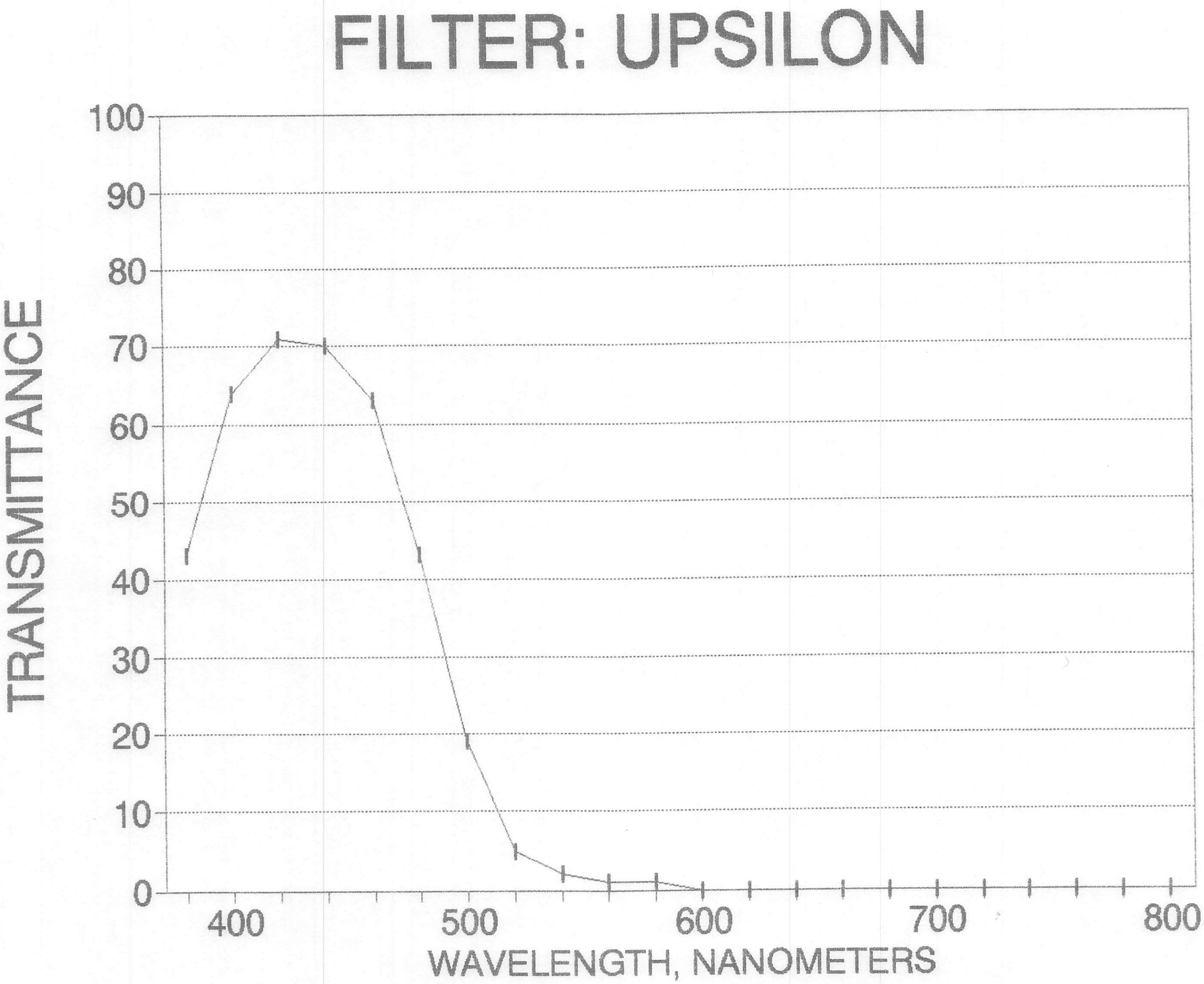
Avail from Mooney Precision Glass (203) 749-2275

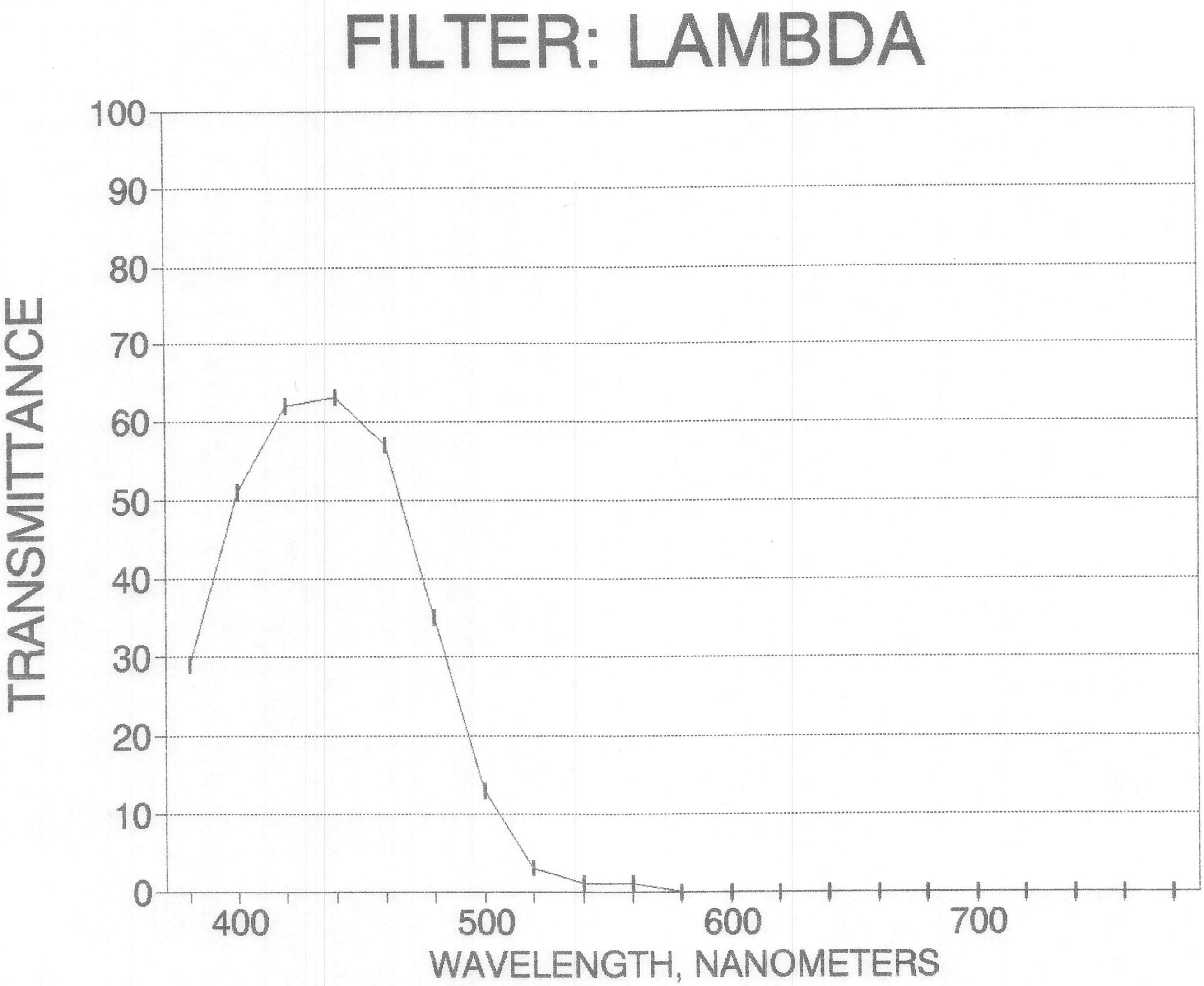
FILTER: ALPHA

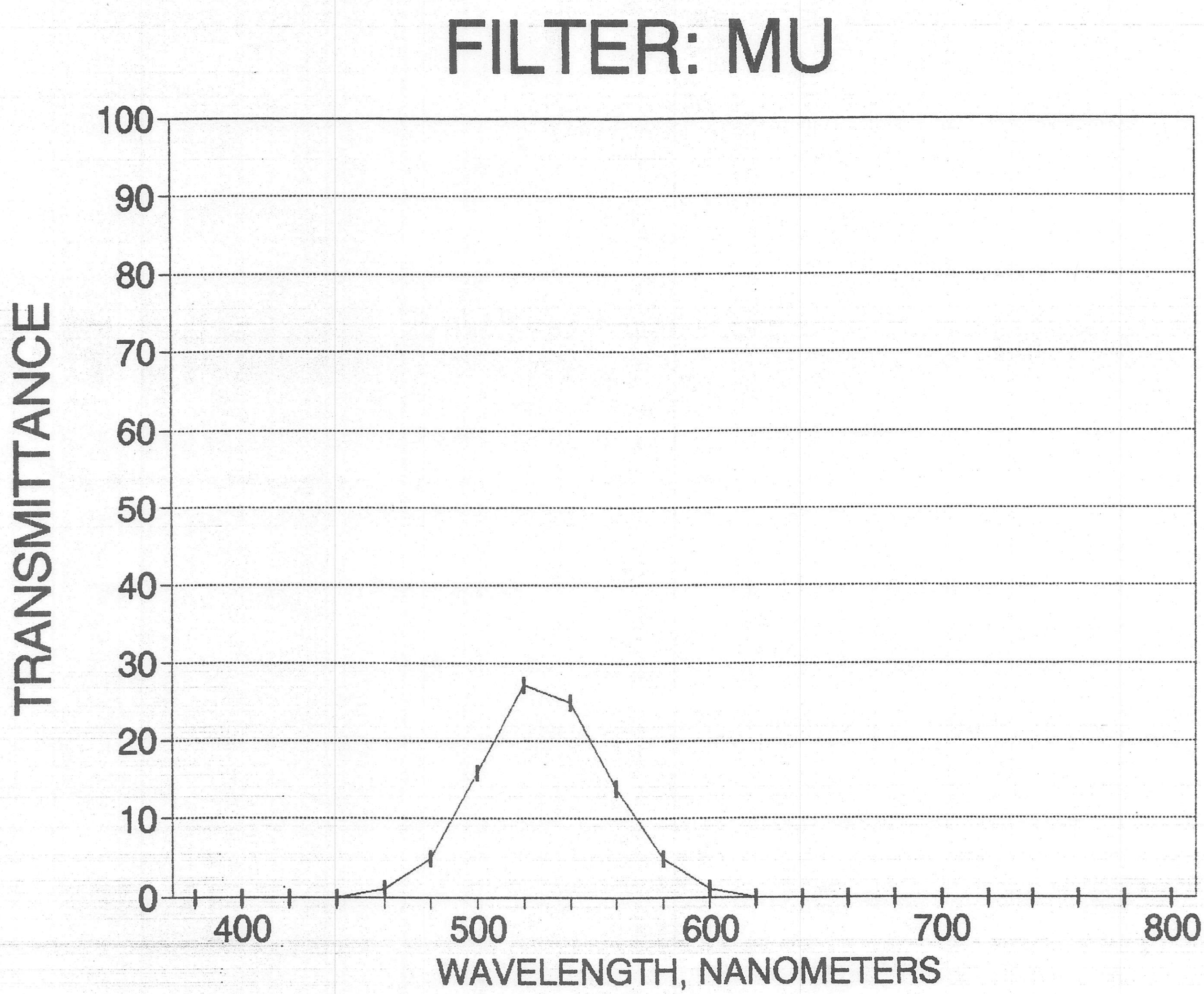


FILTER: DELTA

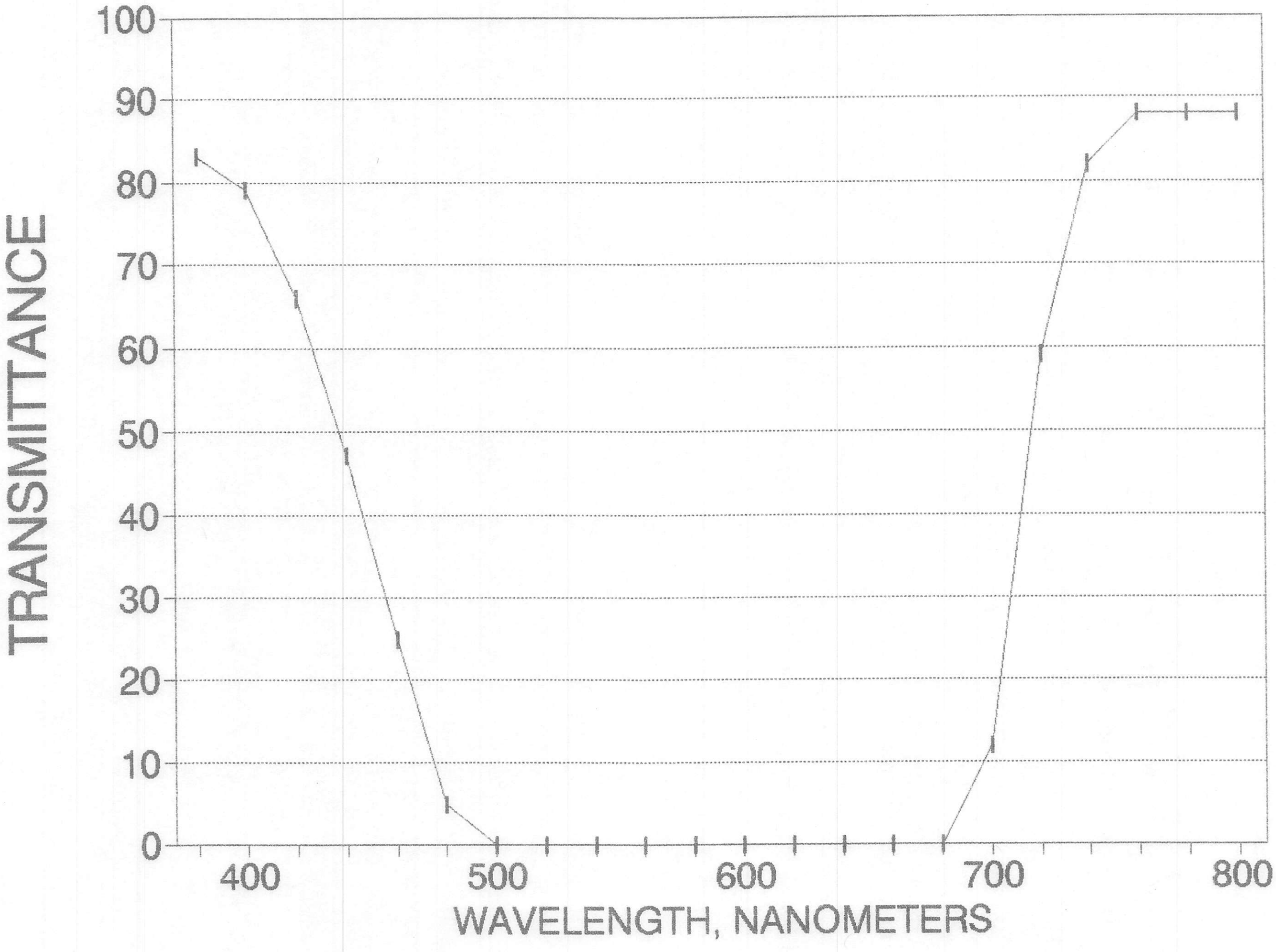



FILTER: UPSILON
TRANSMITTANCE
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
800
WAVELENGTH, NANOMETERS

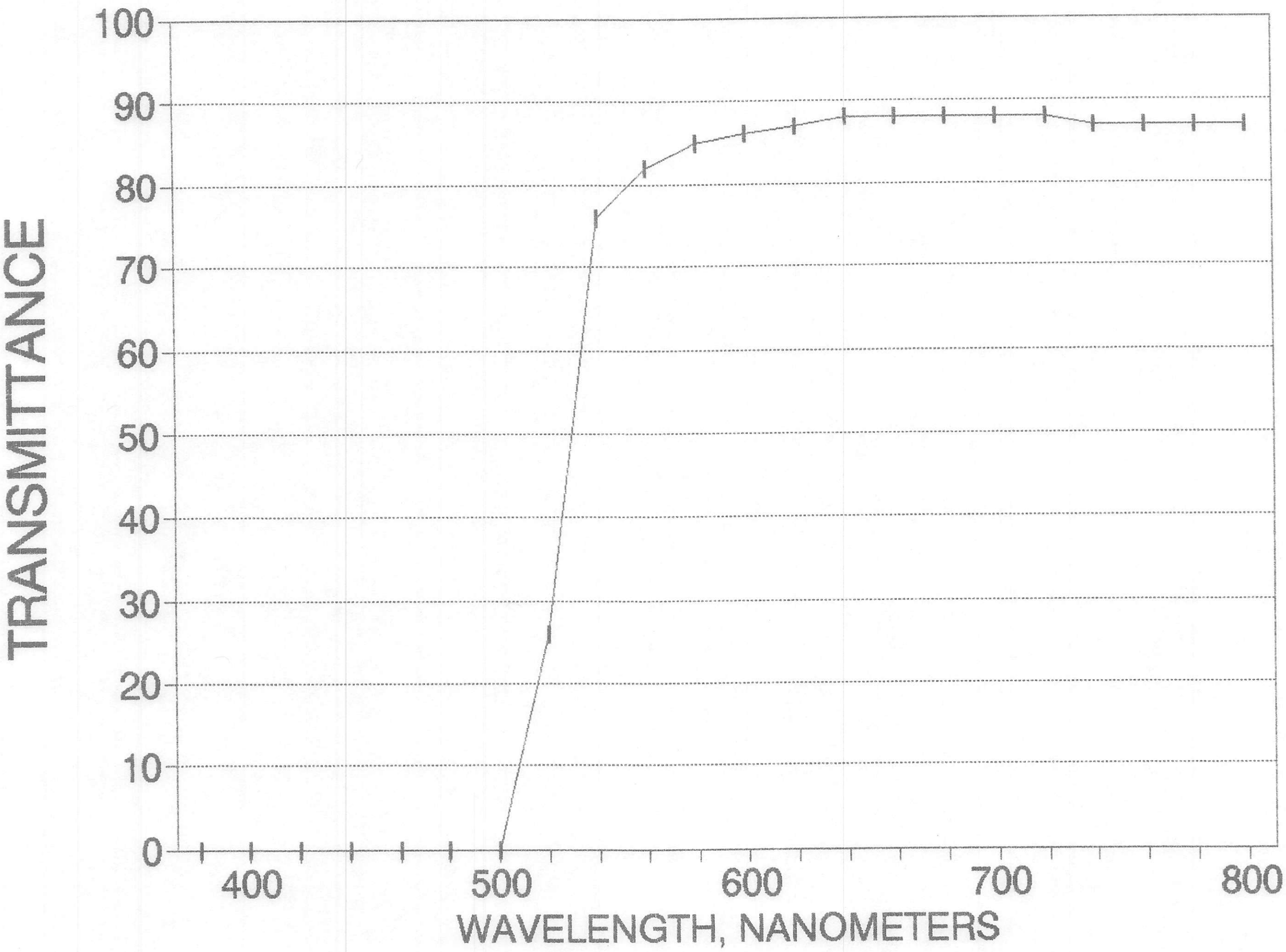

FILTER: LAMBDA
TRANSMITTANCE
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
WAVELENGTH, NANOMETERS


FILTER: MU
100
90
80
70
60
50
40
30
20
10
0
TRANSMITTANCE
400
500
600
700
800
WAVELENGTH, NANOMETERS

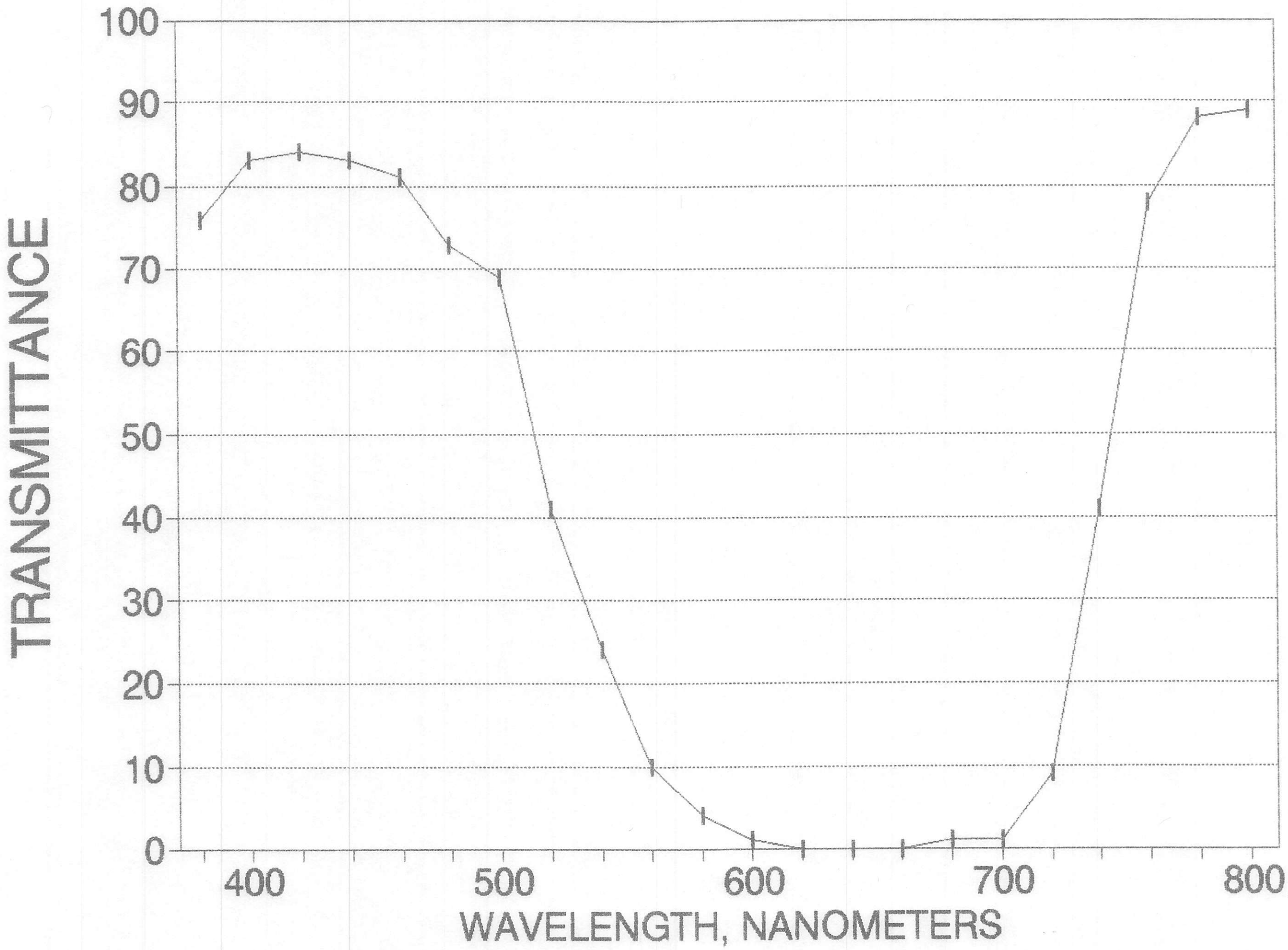
FILTER: OMEGA



FILTER: THETA

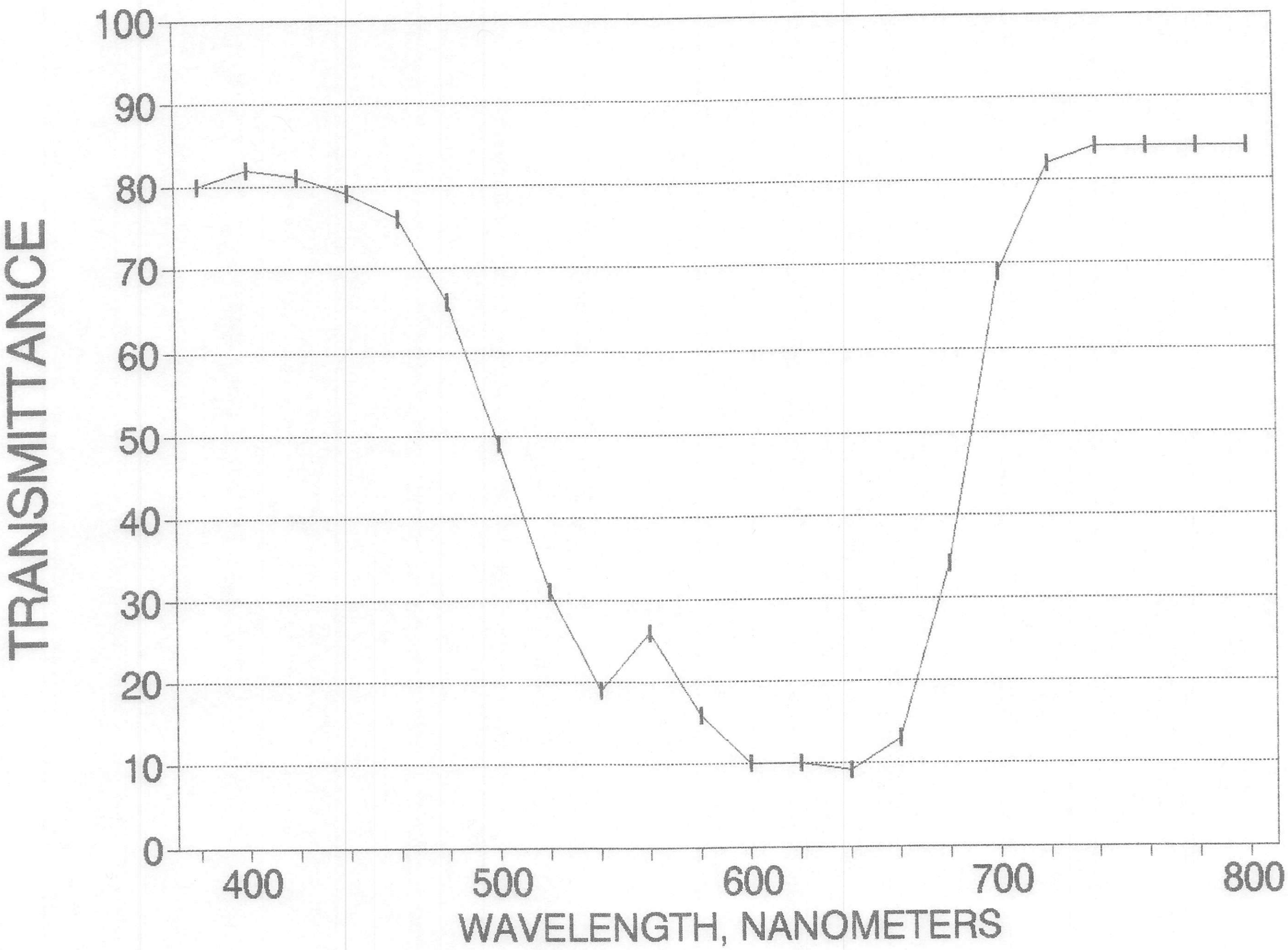


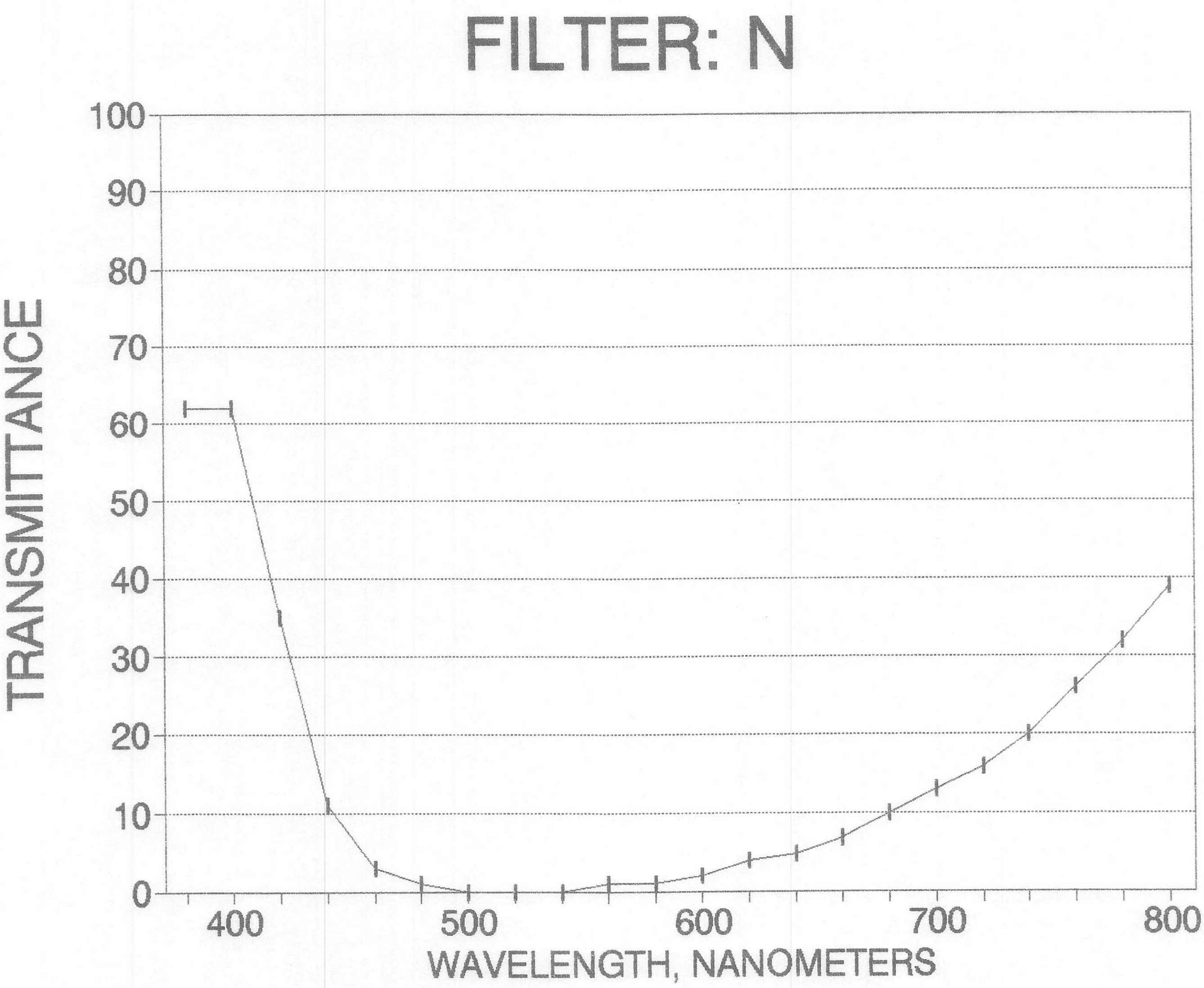
FILTER: PI



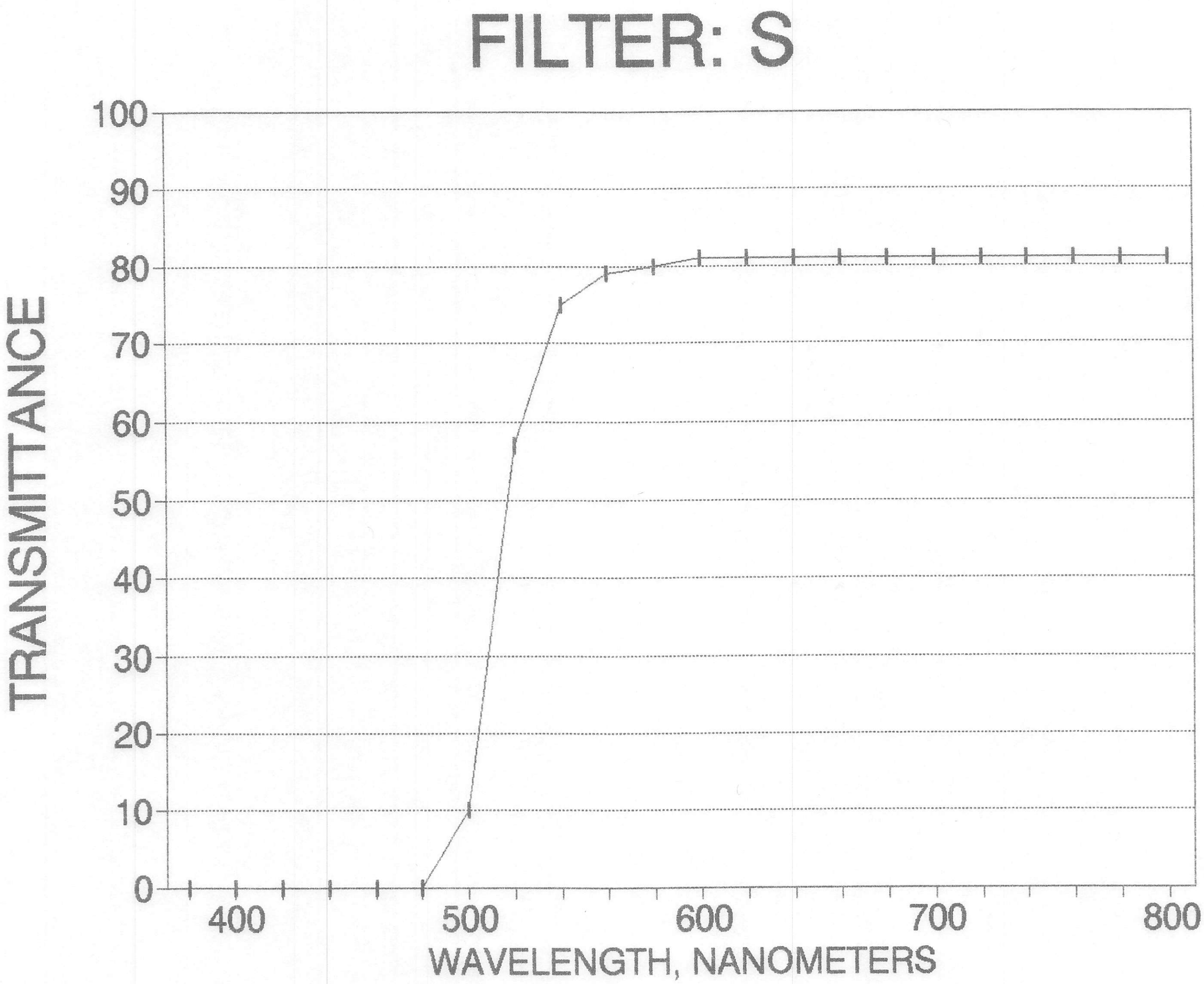
100
90
80
70
60
50
40
30
20
10
0
TRANSMITTANCE
400
500
600
700
800
WAVELENGTH, NANOMETERS

FILTER: D

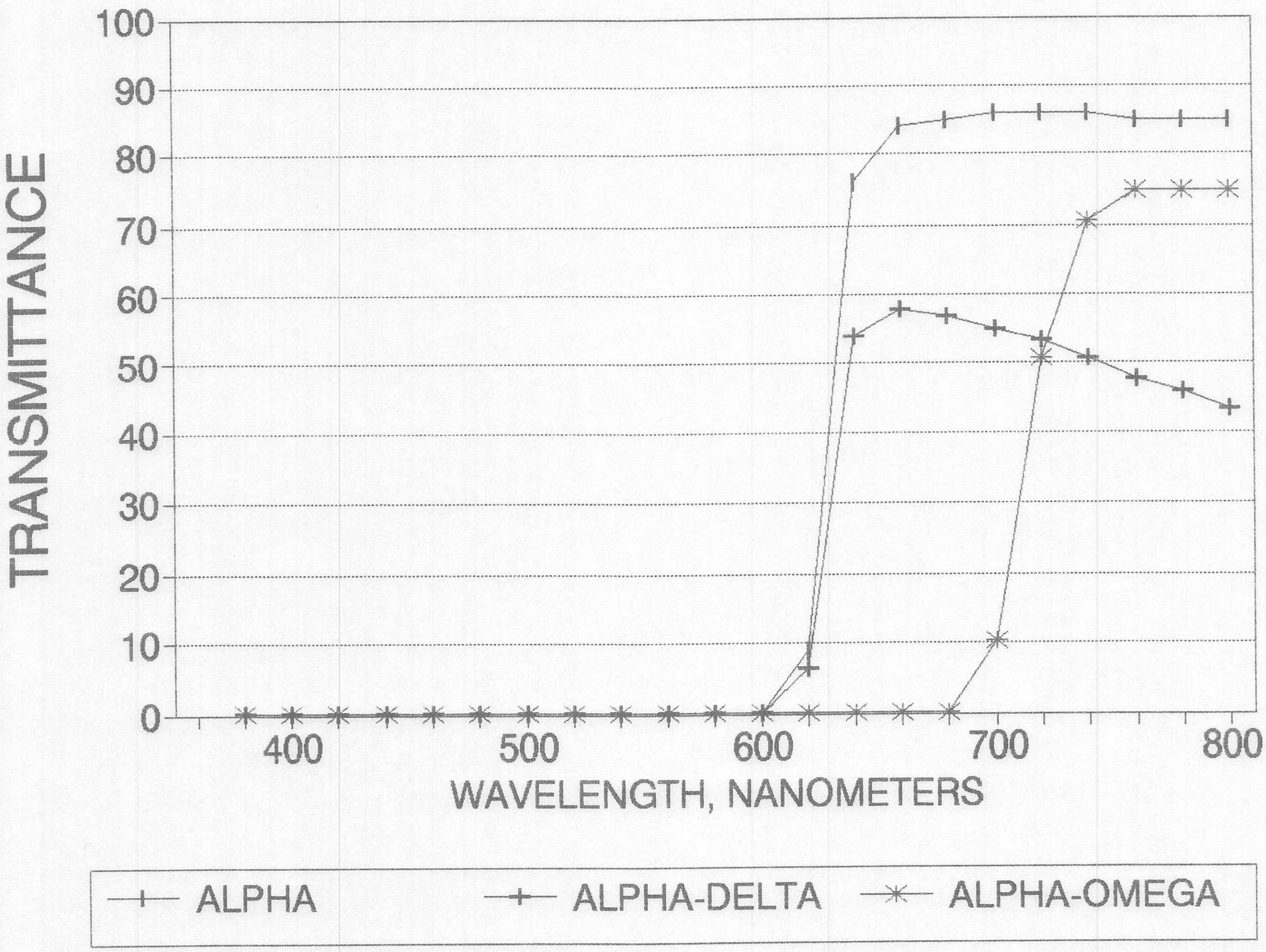

TRANSMITTANCE
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
800
WAVELENGTH, NANOMETERS

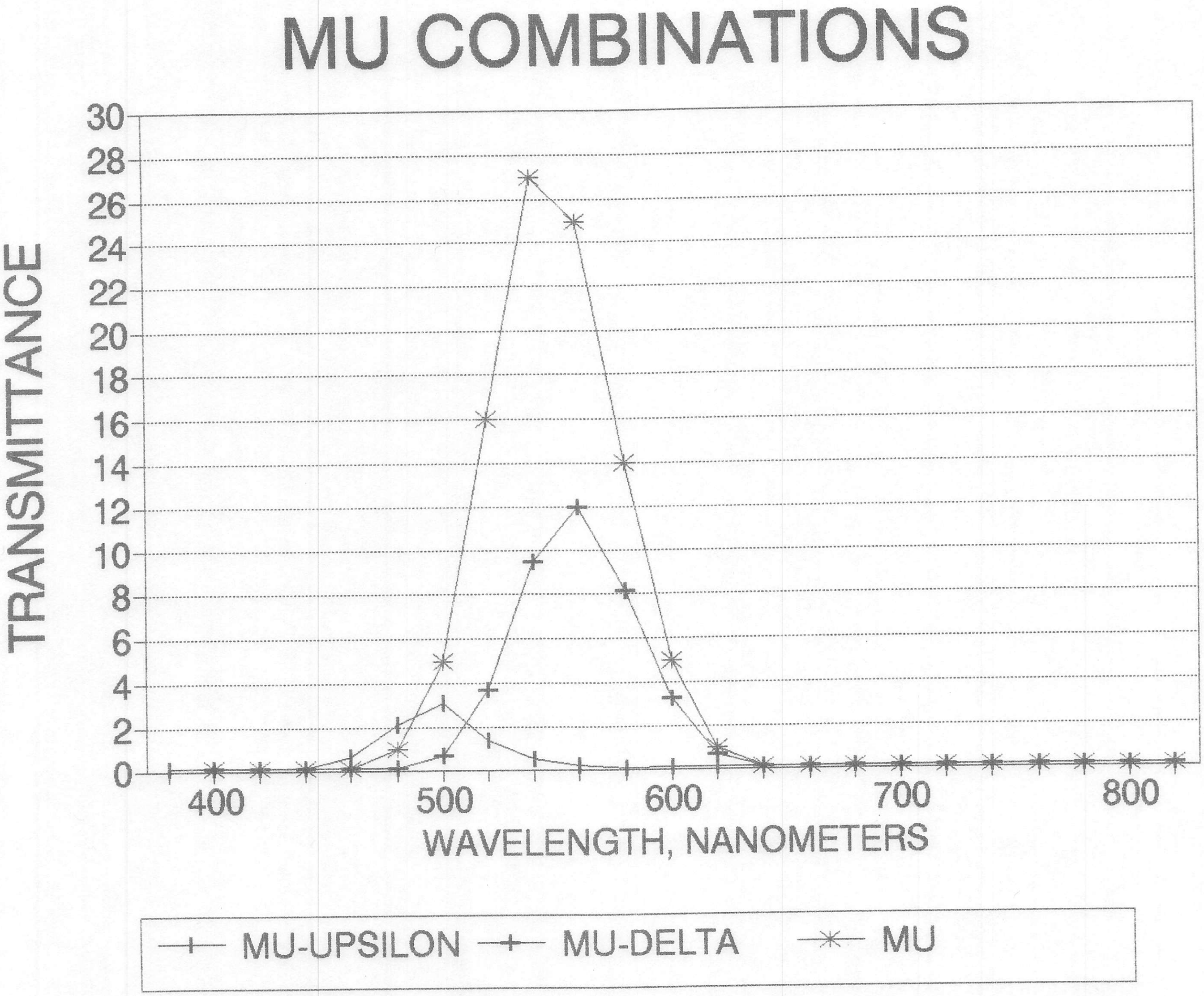


FILTER: N
TRANSMITTANCE
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
800
WAVELENGTH, NANOMETERS

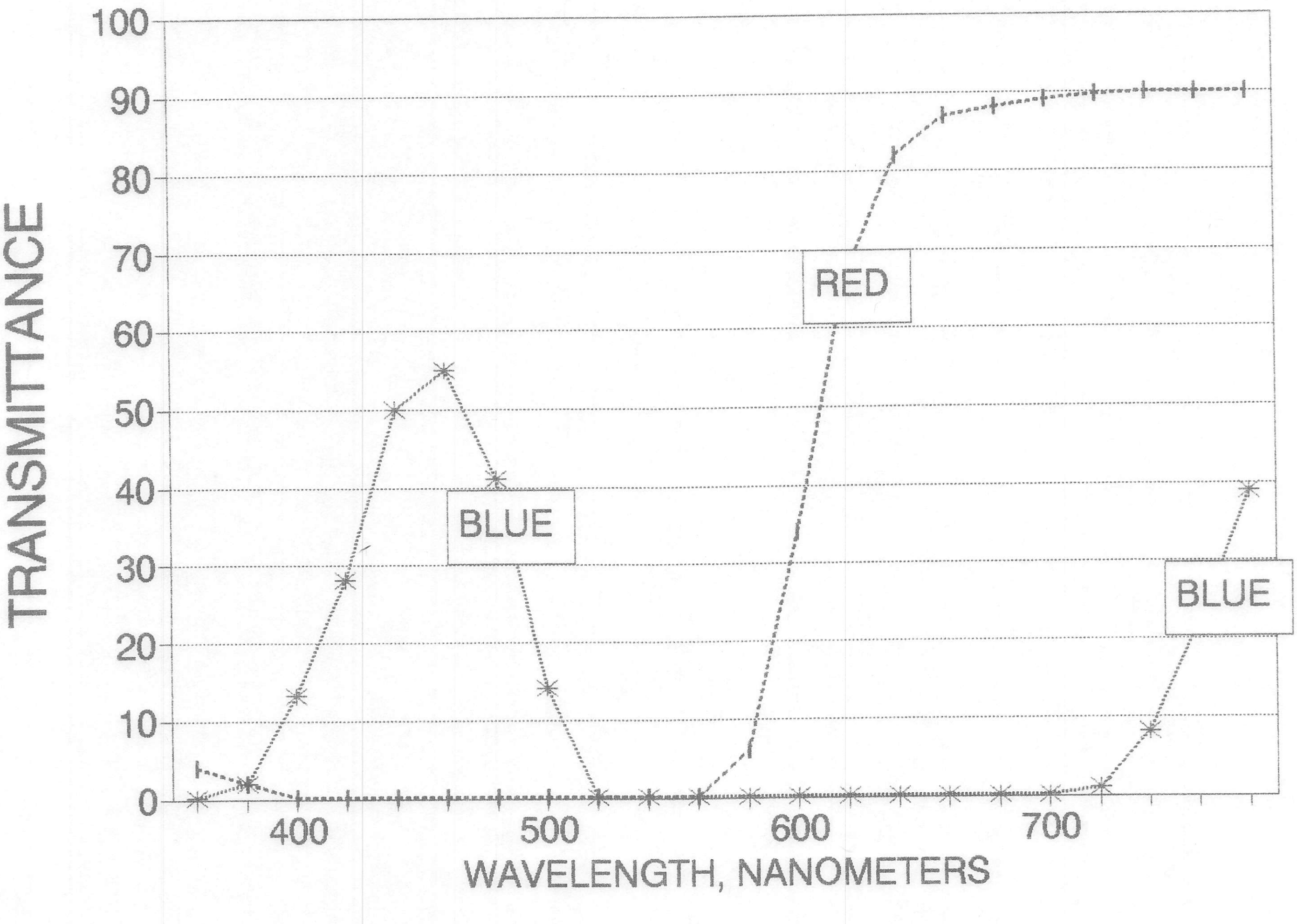

FILTER: S
TRANSMITTANCE
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
800
WAVELENGTH, NANOMETERS

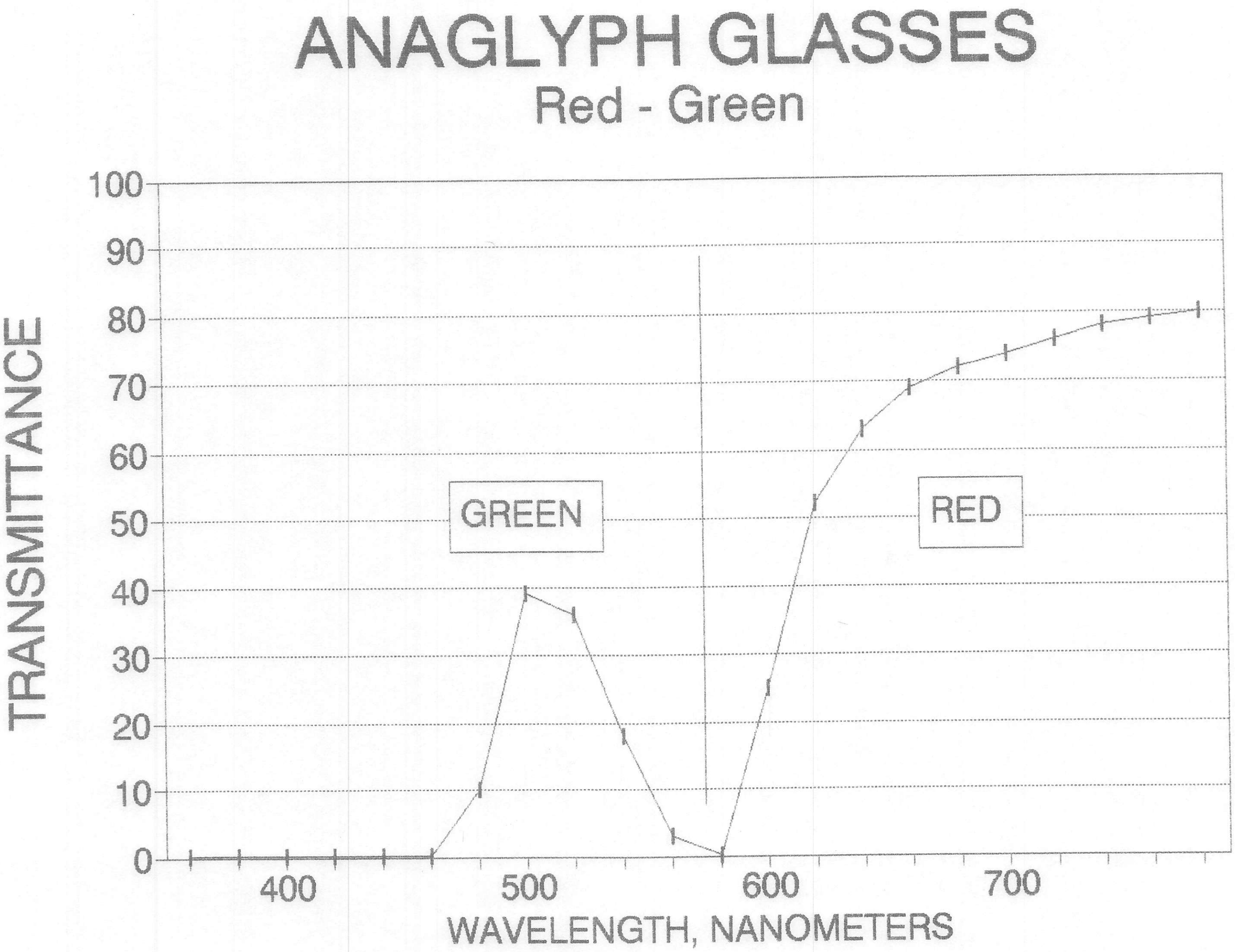
ALPHA COMBINATIONS




MU COMBINATIONS
TRANSMITTANCE
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
400
500
600
700
800
WAVELENGTH, NANOMETERS
MU-UPSILON
MU-DELTA
MU

NASCENTIZATION GLASSES




ANAGLYPH GLASSES
Red - Green
TRANSMITTANCE
100
90
80
70
60
50
40
30
20
10
0
GREEN
RED
400
500
600
700
WAVELENGTH, NANOMETERS