NATIONAL BUREAU OF STANDARDS REPORT

4554

COMPUTATION OF THE EFFECTIVE INTENSITY
OF
FLASHING LIGHTS

By

C. A. Douglas

NBS

U. S. DEPARTMENT OF COMMERCE
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by
C. A. Douglas

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Airborne Equipment Division
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and

Equipment Laboratory
Wright Air Development Center

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Computation of the Effective Intensity of Flashing Lights

Abstract

A mathematical analysis has been made of the effects on the effective intensity, I_e, computed from the Blondel and Rey relation

$$I_e = \frac{\int_{t_1}^{t_2} I dt}{a + t_2 - t_1}$$

produced by changes in the limits of the integral. The maximum value of I_e is obtained when the times t_1 and t_2 are the times when the instantaneous intensity, I, is equal to I_e. Methods which facilitate the computation of I_e, the checking of conformance to effective intensity specifications, and the computation of visual range of flashing lights are given.

1. INTRODUCTION

It is generally recognized that when a light signal consists of separate flashes, the instantaneous intensity during the flashes must be greater than the intensity of a steady light in order to obtain threshold visibility. Blondel and Rey[1] found that the threshold illuminance for an abrupt flash (a flash producing a relatively constant illuminance throughout its duration) is

$$E' = E(a + t)/t \qquad (1)$$

where E is the threshold illuminance for a steady light, t is the flash duration, and a is a constant. They found that a was equal to 0.21.

It is convenient to evaluate flashing lights in terms of their effective intensity, I_e, that is, the intensity of a fixed light which will produce the same visual effect as does the flashing light. Then

$$I_e = IE/E'$$

or

$$I_e = \frac{It}{a + t} \qquad (2)$$

Later Toulmin-Smith and Green[2] found that somewhat different effective intensities were obtained when the illuminance at the eye was above threshold. However, Hampton[3] showed that their experimental results could be adequately

expressed by equation 2 when a is a function of the illuminance at the eye.

The flash from most lights used in aviation service, airway beacons, anticollision lights, etc., is not abrupt. The instantaneous intensity often rises and falls gradually and may vary appreciably during the flash. If the flash duration is very short or if the times of rise and fall of intensity are short in comparison to the flash duration, only small uncertainties would be introduced in the determination of flash duration and by the use of the product of the peak intensity during the flash and the flash duration for It. However, in many cases significant errors would be introduced. Some modification of equation 2 is required.

Some of the specifications for these lights have evaluated their signals in terms of the candle-seconds in the flash, integrating over a period of not more than 0.5 second, that is

$$\text{candle-seconds} = \int_{t_1}^{t_2} I dt$$

where I is the instantaneous intensity and $t_2 - t_1$ does not exceed 0.5 second. This method of evaluation provides a measure of comparison between lights of roughly the same flash characteristics but is not suited to the comparison of lights of different flash characteristics nor to the computation of visual ranges.

When the specification for anticollision lights was being drafted, it was suggested that a modified form of equation 2 be used for the computation of effective intensity, so that*

$$I_e = \frac{\int_{t_1}^{t_2} I dt}{.2 + t_2 - t_1} \qquad (3)$$

The question of choice of limits was immediately raised. Rather than use an arbitrary set of limits, such as choosing for t_1 and t_2 the times when I was 10% of the peak of the flash, a choice of limits which would make I_e a maximum was suggested. This immediately poses the problem of developing a method, other than trial and error, of obtaining the maximum value of I_e. The development of such a method is the purpose of this paper.

2. FUNDAMENTAL THEOREMS

The method of obtaining the maximum value of I_e will be developed by means of one theorem and two corollaries. The proofs follow.

- - - - - - -

*Blondel and Rey suggested the use of this equation!

2.1 Theorem. <u>I_e is a maximum when the limits t_1 and t_2 are the times when $I = I_e$.</u>

Consider an intensity-time distribution curve of the type shown in figure 1, the only restrictions on the shape of the curve being that I is less than I_e in the intervals t_1'' to t_1 and t_2 to t_2'' and I is greater than I_e in the intervals t_1 to t_1' and t_1' and t_2' to t_2.

$$\text{Let} \qquad I_e = \frac{\int_{t_1}^{t_2} I\,dt}{a + t_2 - t_1} \tag{3a}$$

where the times t_1 and t_2 are the times when $I = I_e$.

Case I.

Consider the case where the integration is performed over the time interval t_1' to t_2' which lies within the interval t_1 to t_2.

Then the intensity I' at the times t_1' and t_2' is greater than I_e.

$$I' > I_e \tag{4}$$

$$\text{Let} \qquad I_e' = \frac{\int_{t_1'}^{t_2'} I\,dt}{a + t_2' - t_1'} \tag{5}$$

$$\text{Then} \int_{t_1}^{t_2} I\,dt = \int_{t_1}^{t_1'} I\,dt + \int_{t_1'}^{t_2'} I\,dt + \int_{t_2'}^{t_2} I\,dt \tag{6}$$

so that

$$I_e\,(a + t_2 - t_1) = \int_{t_1}^{t_1'} I\,dt + I_e'\,(a + t_2' - t_1') + \int_{t_2'}^{t_2} I\,dt \tag{7}$$

$$\text{But} \int_{t_1}^{t_1'} I\,dt > I_e\,(t_1' - t_1) \tag{8a}$$

$$\text{and} \int_{t_2'}^{t_2} I\,dt > I_e\,(t_2 - t_2') \tag{8b}$$

Substituting and combining terms we have

$$I_e\ (a + t_2' - t_1') > I_e'\ (a + t_2' - t_1')$$

Therefore $$I_e > I_e' \quad (9)$$

Case II.

Consider now the case where the integration is performed over the time interval t_1'' to t_2'' which includes the interval t_1 to t_2.

Then the intensity I'' at the times t_1'' and t_2'' is less than I_e.

$$I'' < I_e \quad (10)$$

Let $$I_e'' = \frac{\int_{t_1''}^{t_2''} I dt}{a + t_2'' - t_1''} \quad (11)$$

then, $$\int_{t_1''}^{t_2''} I dt = \int_{t_1''}^{t_1} I dt + \int_{t_1}^{t_2} I dt + \int_{t_2}^{t_2''} I dt \quad (12)$$

and $$I_e''\ (a + t_2'' - t_1'') = \int_{t_1''}^{t_1} I dt + I_e (a + t_2 - t_1) + \int_{t_2}^{t_2''} I dt \quad (13)$$

But $$\int_{t_1''}^{t_1} I dt < I_e\ (t_1 - t_1'') \quad (14a)$$

and $$\int_{t_2}^{t_2''} I dt < I_e\ (t_2'' - t_2) \quad (14b)$$

Substituting and combining terms we have

$$I_e > I_e'' \quad (15)$$

Thus I_e is greater than both I_e' and I_e''. Therefore, the maximum value which can be obtained from the Blondel-Rey relation, equation 3, is that obtained

when the intensity at the beginning and end of the interval of integration is equal to the effective intensity.

2.2 Corollary 1. <u>If the instantaneous intensity is integrated over a period of time, t_1' to t_2', shorter than t_1 to t_2, and I' is the instantaneous intensity at these times, a value I_e' is obtained for the effective intensity that is always less than I'.</u>

From equation 9 we have

$$I_e > I_e' \tag{9}$$

but

$$I' > I_e \tag{4}$$

Therefore

$$I' > I_e' \tag{16}$$

2.3 Corollary 2. <u>If the instantaneous intensity is integrated over a period of time t_1'' to t_2'' - longer than t_1 to t_2, and I" is the instantaneous intensity at the times t_1'' and t_2'', a value I_e'' is obtained for the effective intensity that is always greater than I".</u>

From equation 13 we have

$$I_e'' (a + t_2'' - t_1'') = \int_{t_1''}^{t_1} Idt + I_e(a + t_2 - t_1) + \int_{t_2}^{t_2''} Idt \tag{13}$$

But

$$\int_{t_1''}^{t_1} Idt > I''(t_1 - t_1'') \tag{17a}$$

and

$$\int_{t_2}^{t_2''} Idt > I''(t_2'' - t_2) \tag{17b}$$

Also

$$I_e(a + t_2 - t_1) > I_e'' (a + t_2 - t_1) \tag{18}$$

Substituting these into equation 13 and simplifying, we have

$$I_e'' > I'' \tag{19}$$

3. COMPUTATIONS OF EFFECTIVE INTENSITY

Guides for the computation of the effective intensity from an intensity-time distribution curve may be obtained from the theorem and corollaries.

3.1 Computation of I_e.

1. Make an estimate I' of the value of the effective intensity and solve equation 3 using the values of t corresponding to this intensity obtaining I_{e_1}.

2. Repeat step 1 above using as limits the values of t corresponding to the I_{e_1} obtained in step 1 obtaining I_{e_2}. Repeat as often as necessary to obtain the desired accuracy.

Note that when I_e is much less than the maximum instantaneous intensity (i.e., the flash is of short duration) the correct value of I_e will be obtained in a very few steps. When the flash is of relatively long duration, it may frequently be advantageous to make a new estimate of I_e after carrying out step 2 rather than using the limits corresponding to I_{e_2} in order to decrease the number of steps.

Note that if the estimated effective intensity is too high (I' in figure 1) the effective intensity, I_{e_1}, computed in step 1 will be below I_e (I" of figure 1) and thus I_e lies between I' and I_{e_1}. If the initial estimate is lower than I_e (I" of figure 1), I_e will be greater than both I" and I_{e_1} and a "straddle" is not obtained but I_e is approached continuously from the low side.

3.2 Determination of Conformance of a Flashing Light to Specification Requirements.

1. Compute I_{e_1} using the time limits corresponding to the specified effective intensity I_s. If I_{e_1} is greater than I_s, the unit obviously complies, for the conditions are those of figure 2a (corollary 2).

2. If I_{e_1} is equal to I_s, the unit just complies, for then $I_e = I_s = I_{e_1}$ (theorem).

3. If I_{e_1} is less than I_s, the unit fails for then the conditions are those of figure 2b (corollary 1).

Note that the degree by which the unit exceeds or fails to meet the specification requirements is not given by the single computation of section 3.2. The method outlined in section 3.1 must be used for this purpose.

3.3 Visual Range Computations.

If the visual range of the light, under specified conditions of transmittance and threshold, is desired, compute the effective intensity by using

the method outlined in section 3.1 and compute the visual range by using Allard's Law.

If the problem is only the determination of whether the light can be seen at a given distance under specified conditions of transmittance and threshold, use Allard's law to compute the fixed intensity required to make the source visible at this distance. Then, by using the method outlined in section 3.2, determine if the effective intensity of the unit exceeds this intensity.

3.4 Application to Complex Intensity-Time Curves

Not all units have smooth intensity-time distribution curves similar to the curve shown in figure 1. Consider an intensity-time distribution curve of the type shown in figure 3 where I_b is the average intensity in the time interval t_b to t_y. (The time interval t_c - t_z is sufficiently short so that the momentary decrease in intensity is not visible.) If I_e is less than I_a or is greater than I_z, then the restrictions on the shape of the curve stated in theorem 1 are met and there is no problem in the determination of I_e.

Consider the case where I_e lies between I_a and I_z. It may be easily shown by means of equations 8 and 14 that as the shape of other parts of the intensity-time distribution curve change, the lower limits of time to be used to obtain the maximum value of equation 3 will lie between t_a and t_b or between t_y and t_z and will never lie between t_b and t_y. If I_e is equal to I_b, then either t_b or t_y can be used as the lower limit.

3.5 Application to Groups of Short Flashes

In general a signal from a flashing light consists of regularly spaced single flashes of light and the interval between flashes is so great that each flash has little influence on the effective intensity of the adjoining flashes.

However, there are lights that produce a number of very short flashes in rapid succession. An example of a light of this type is a unit using a number of condenser-discharge lamps to produce a single flash.

Consider a flash with an intensity-time distribution similar to that of figure 4. If the threshold intensity required to make a steady light visible is much less than I_e (I_{T_1}), the flash will be seen as a continuous flash with two peaks. However, if the threshold intensity is about equal to I_e (I_{T_2}), two separate flashes will be seen. The maximum distance at which the light can be seen will be determined by the effective intensity of a single flash computed over the time interval t_1 to t_2.

There appear to be no published data reporting studies of the effects of groups of flashes where the interval between flashes is short. Behavior

of the eye under somewhat similar conditions suggests that if in a group of flashes the periods during which the instantaneous intensity of the light is below the effective intensity of the flash are of the order of 0.01 second or less, the eye will perceive this group as a single flash. The effective intensity of the group should then be computed by equation 18 choosing as times t_1 and t_2 the first and the last times the instantaneous intensity is I_e (see figure 5).

$$I_e = \frac{\int_{t_1}^{t_a} Idt + \int_{t_b}^{t_c} Idt + \int_{t_d}^{t_e} Idt + \int_{t_f}^{t_2} Idt}{a + t_2 - t_1} \tag{18}$$

Note that I_e is the effective intensity of the group and not that of a single flash.

If the periods during which the effective intensity is less than I_e are of the order of 0.1 second or more, it is believed that the individual flashes will be seen. Therefore, the effective intensity should then be computed on the basis of a single flash.

When the dark period is between 0.01 and 0.1 second, the effective intensity will lie between that of a single flash and that of the group. The behavior during the transition is not known.

4. DISCUSSION

As noted above, concern has frequently been expressed about the choice of the limits for the integral of the Blondel-Rey relation when computing the visual range of a flashing light. Consider the situation shown in figure 6 where I_T is the intensity required for a steady-burning light to be seen at threshold, when the observation distance and the atmospheric transmittance are those under which the flashing light is observed. It seems illogical to extend the limits of the integral beyond t_1 or t_2 so that intensities which are below threshold, even for a steady-burning light, are included, or to exclude intensities which are above threshold for steady-burning lights. Using this reasoning Blondel and Rey suggested that the limits of the integral of equation 3 be the times, t_1 and t_2, when the instantaneous intensity is equal to the effective intensity. As shown above these are also the limits which make the integral a maximum. Therefore, the use of these limits in evaluating the performance of a lighting unit appears to be a logical choice.

The use of the maximum value of I_e as the effective intensity of a flashing light is probably not valid except when the light is at or near threshold. When the light is well above threshold, not only will the value of a in equation 3a be decreased, thus tending to increase the value of I_e, but also the limits of the integral should probably be extended to include the entire portion of the flash which is above threshold, thereby tending to decrease the value of I_e. In many cases this latter effect will be predominant. This is consistent with the decrease in effective intensity of airway beacons with increase in illuminance at the eye found by Neeland, Laufer, and Schaub[4].

This analysis should be considered only as a mathematical treatment of equation 3. The analysis neither proves nor disproves the validity of this equation in determining the effective intensity of flashing lights nor the validity of the principle of choosing the limits of integration so that the effective intensity is a maximum.

References

1. A. Blondel and J. Rey, Journal de Physique 1, 530 and 643 (1911)

2. A. K. Toulmin-Smith and H. N. Green, Illuminating Engineering (London) 26, 304 (1933)

3. W. M. Hampton, Illuminating Engineering (London) 27, 40 (1934)

4. G. K. Neeland, M. K. Laufer, and W. R. Schaub, Journal Optical Society of America, 28, 280 (1938)

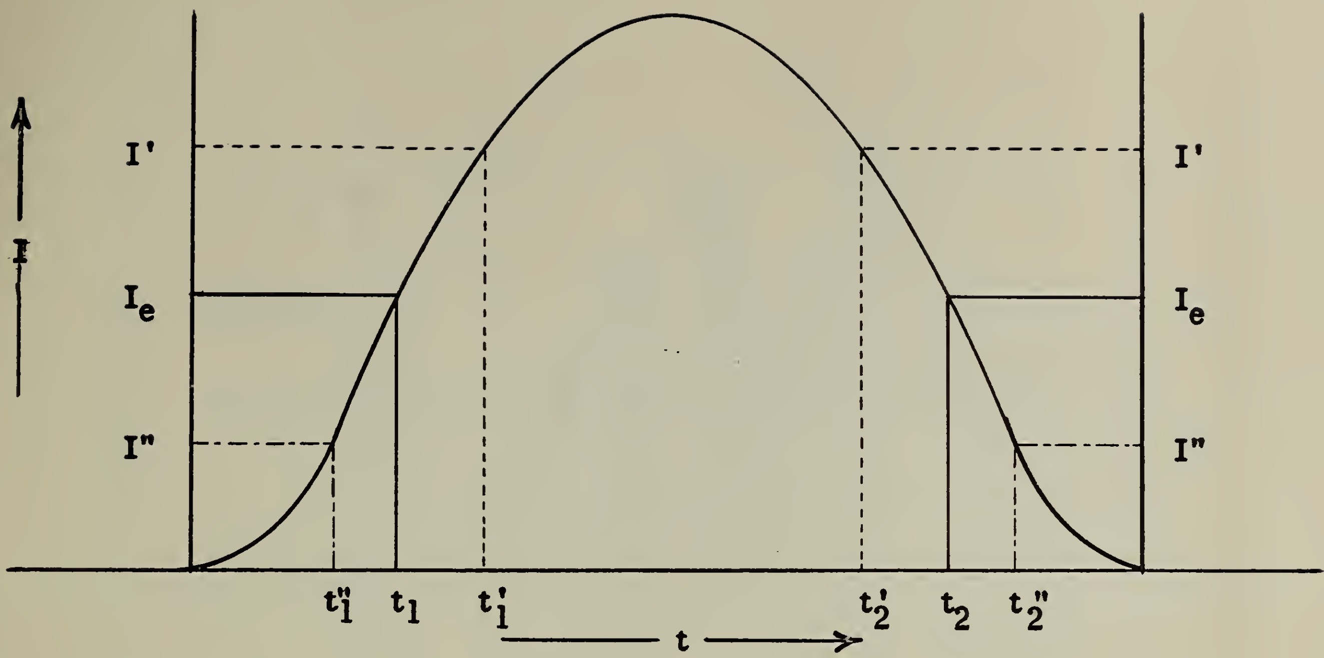
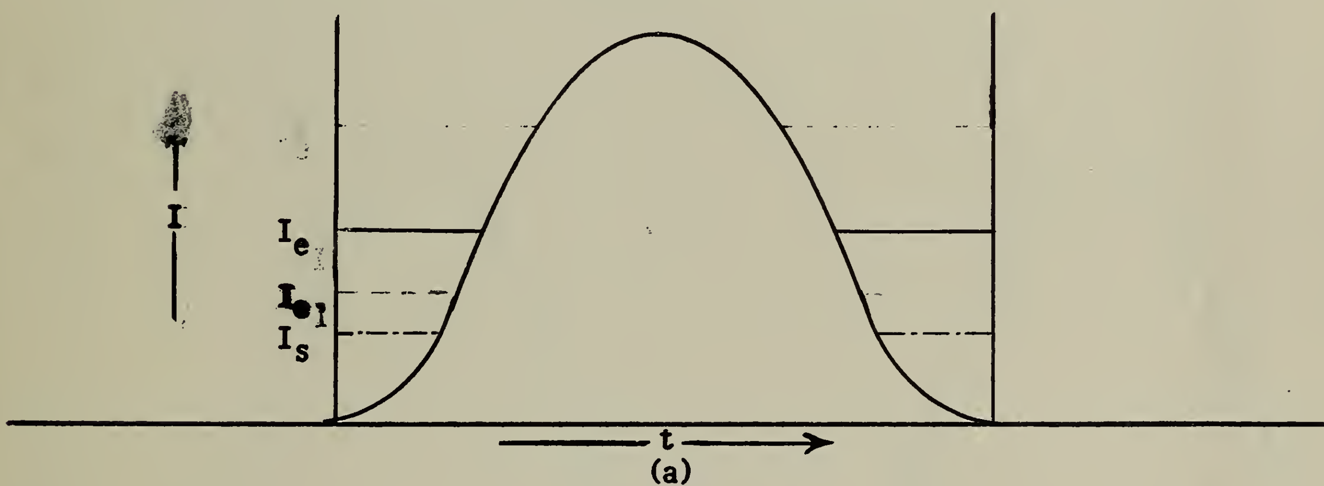


Figure 1



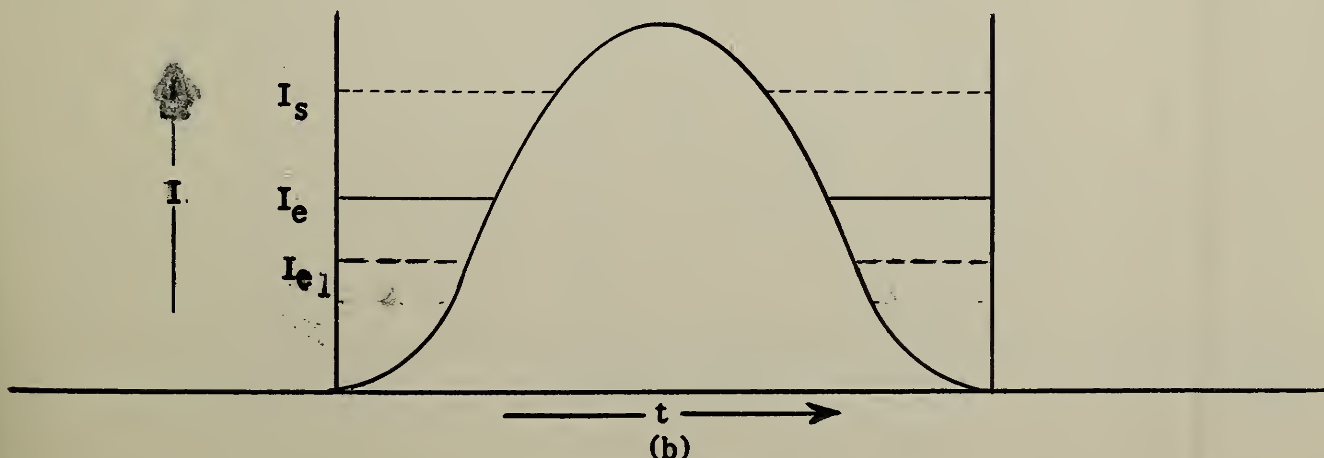


Figure 2

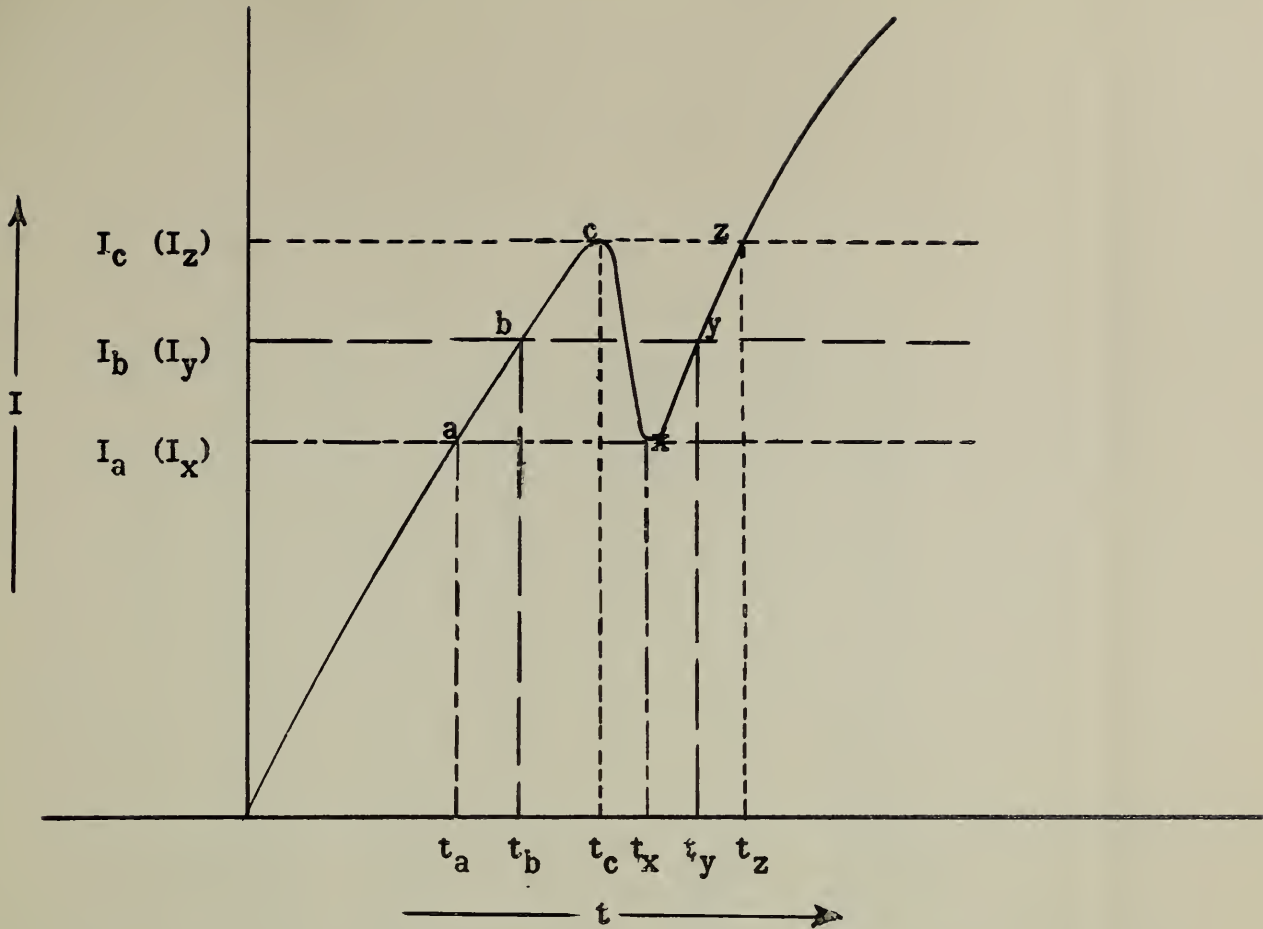


Figure 3

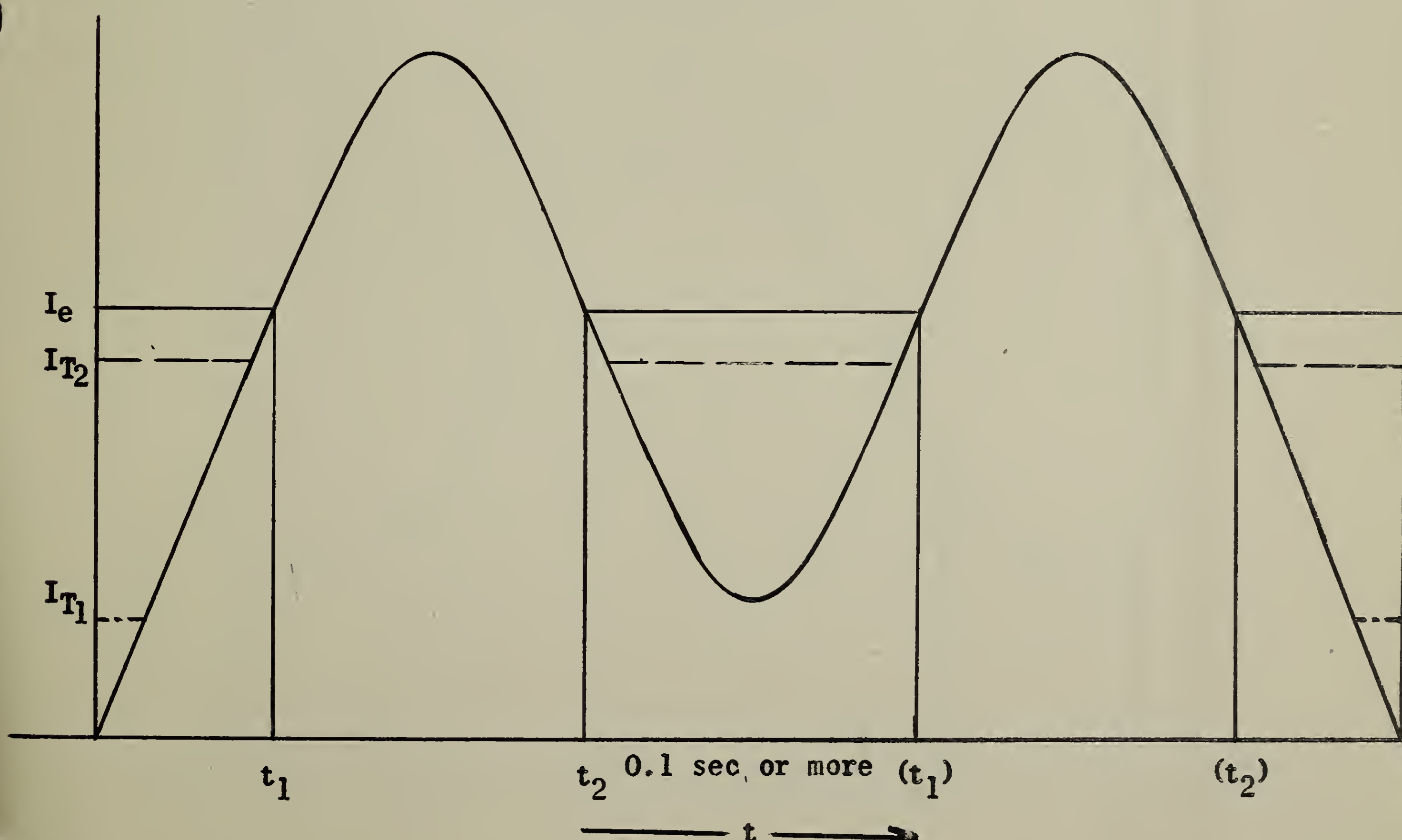


Figure 4

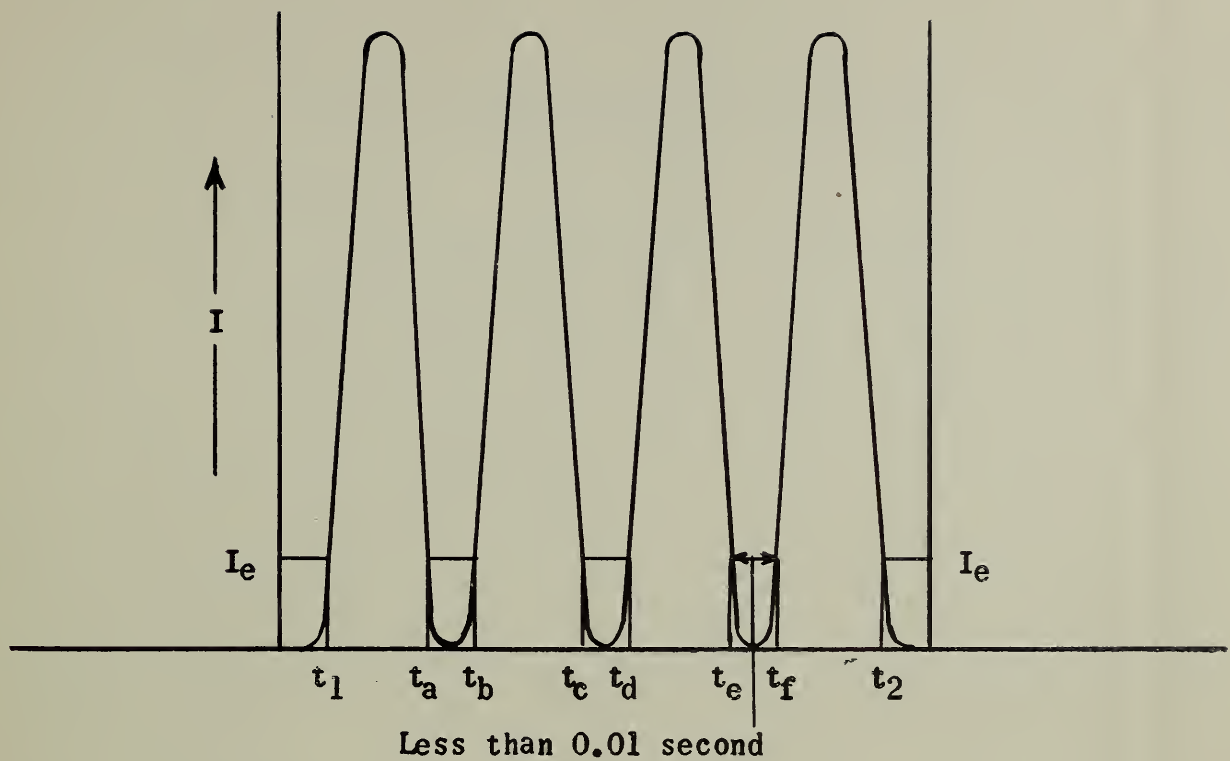


Figure 5

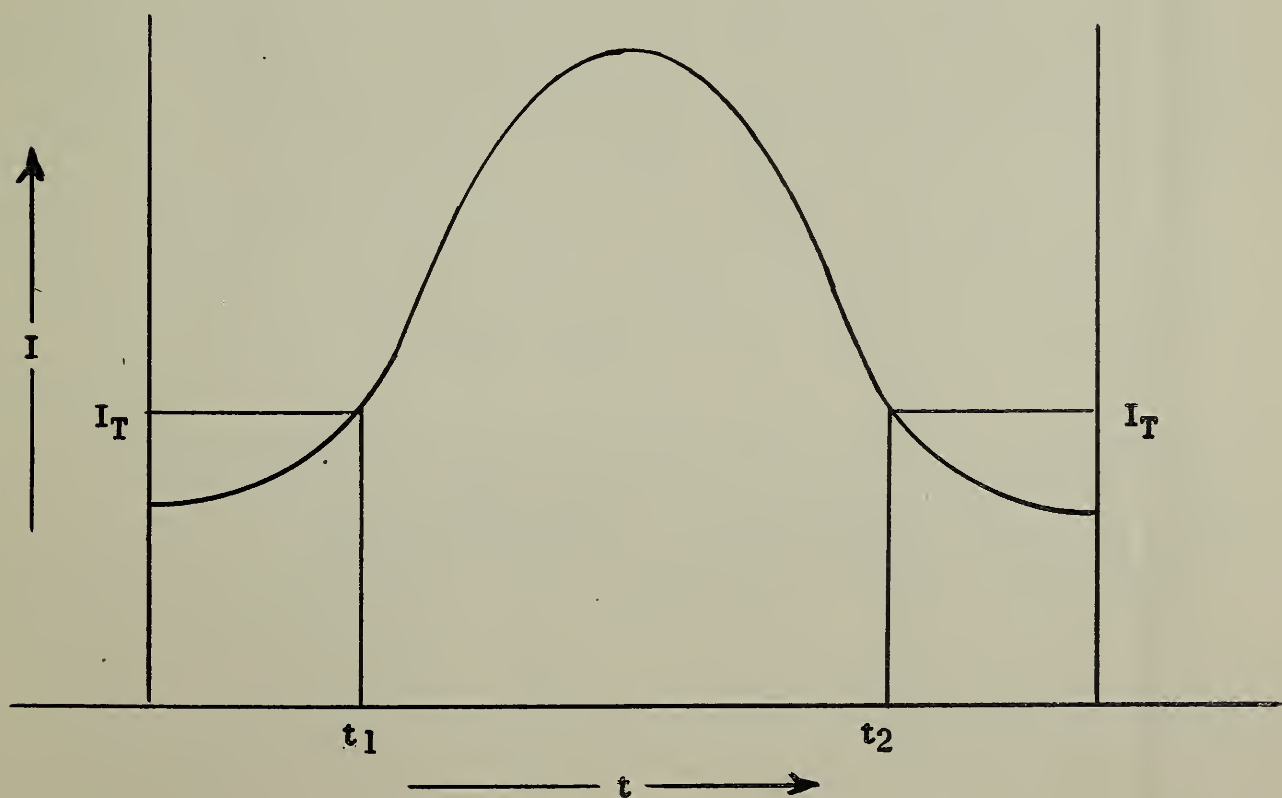


Figure 6

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT | **NBS REPORT**

0201-20-2325 October, 1956 4544

SPECTRAL TRANSMISSIVE AND COLORIMETRIC PROPERTIES OF SEVERAL AERIAL AND HAND CAMERA LENSES AND FILTERS

By

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To

U. S. Department of the Air Force
Aerial Reconnaissance Laboratory
Wright Air Development Center
Wright-Patterson Air Force Base, Ohio

Contract No. AF 33(616) 52-21
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NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

PREFACE

This is one of a series of NBS reports of spectrophotometric and colorimetric work done under NBS Project No. 0201 - 20 - 2325 entitled Color Reconnaissance Studies, financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio; Air Force Contract No. AF 33(616) 52-21. It is coordinated with Air Force Contract No. AF 33(616) - 262 under Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, who requested the NBS to perform this test of hand camera lenses and photographic filters. The work on the aerial camera lenses and filters was performed at the request of Captain Robert J. Fisher, Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Harry J. Keegan
Project Leader

SPECTRAL TRANSMISSIVE AND COLORIMETRIC PROPERTIES OF SEVERAL AERIAL AND HAND CAMERA LENSES AND FILTERS

Harry J. Keegan, John C. Schleter, Wiley A. Hall, Jr., and Gladys M. Haas*

Abstract

Measurements of spectral transmittance have been made for the visible and near infrared spectral region 400 to 1080 millimicrons on a General Electric recording spectrophotometer at the National Bureau of Standards for three components of two aerial-camera lenses, five hand-camera lenses, one yellow anti-vignetting aerial camera filter, ten color temperature correcting hand camera filters, and thirteen selective absorbing hand-camera filters. This report contains copies of the spectrophotometric curves of these photographic lenses and filters, tables and graphs of spectral transmittance and the colorimetric properties of the lenses and filters, and a comparative study of the conventional photographic color temperature correcting filters commercially recommended to be used for exposure of color film when the light source differs from that for which the film was manufactured.

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*Miss Haas is at present employed at the Mare Island Naval Shipyard, San Francisco, California.

Contents

I. Introduction

The overall objective of this Air Force investigation is stated as follows: "To develop by visible, near infrared, and near ultraviolet spectrophotometry, methods for the detection of objects from color reconnaissance; to study the colors, tonal contrast, and color separation necessary in aerial photography to yield maximum information; to determine the wavelength region at which the film manufacturer should strive to obtain maximum sensitivity to yield clear separation of an object from its adjacent area rather than to yield true color fidelity; to determine the characteristics required in a sensitized material for the rapid and accurate extraction of this information".

The present report is concerned with the spectral characteristics in the visible and near infrared regions of the spectrum of photographic lenses and filters.

To fulfill the requests for these studies, listed in Appendix C, measurements of spectral transmittance of these camera lenses and filters were made from 400 to 1080 millimicrons; chromaticity coordinates and daylight transmittances were computed for the spectral data 400 to 750 millimicrons; Munsell renotations and ISCC-NBS color designations were derived from these computations, as were also the ideal Lovibond-Scofield designations. These data are illustrated in tables and in graphs.

The method of measurements and the computational methods are those outlined in the original project proposal, and used in previous reports of this project [1, 2, 3, 4, 5].*

It is believed that this type of information will assist in the selection of a suitable camera with proper lens and filtering system to produce the desired photograph needed for this project, and that this information is a necessary step towards attaining the overall objective of this investigation.

II. Material

The aerial-camera lenses and filters were furnished by Captain Robert J. Fisher, Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. He and Sergeant S. G. Ujhely brought the cameras to the National Bureau of Standards on March 16, 1954. They were present during the two days that the measurements were made and assisted in demounting the lens elements from the cameras so that they could be fitted into place in the light beam of the General Electric recording spectrophotometer. They also reassembled the cameras and returned them to the Wright-Patterson Air Force Base.

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*Figures in brackets indicate references in the bibliography of this report, page 112.

Although three aerial cameras with lenses were brought to the National Bureau of Standards, measurements were made on the lenses of only two of them, the front and rear cells of a lens of 12" focal length and the rear cell of a 6" lens. These optical parts were placed in the General Electric recording spectrophotometer so that the illuminating beam was incident perpendicularly on the front surface of the lens cell and passed approximately through the center of the cell. The front cell of the 6" lens and the front and rear cells of a 24" lens with their mounts were so large that a rearrangement of the parts of the spectrophotometer (greater separation between sample beam and comparison beam) would have had to be carried out to accommodate them; so measurement of them was not attempted.

A description of these three lens-shutter aerial camera assemblies follows:

1) 6 inch (152.8 mm) f/6.3 Metrogon wide angle lens, Serial Number UF-6016, manufactured by the Bausch and Lomb Optical Company, Rochester, N. Y., for use with a "between-the-lens" shutter. The lens-shutter assembly is for use in a K-17 aerial camera. A glass antivignetting "minus blue" filter (for use with black and white film only) is a standard item in this assembly. Neither the lens elements nor the filter were coated with a reflection-reducing film.

2) 12 inch f/4.5 lens coated with a reflection-reducing film, Serial Number LF-8123, manufactured by the Bausch and Lomb Optical Company, Rochester, N. Y., for use with a "between-the-lens" shutter. This lens is not a standard lens but is used primarily for photographic tests at the Wright Air Development Center.

3) 24 inch (610 mm) f/6.0 Aero Tessar lens, Serial Number VF-2060, manufactured by the Bausch and Lomb Optical Company, Rochester, N. Y., for use with a K-18 aerial camera for a 9 by 18 inch negative.

The serial numbers given are for the lenses only; the serial numbers of the shutters are not recorded in this report. The telegram requesting these measurements, together with the reply, is included in Appendix C of this report.

The hand camera lenses and filters were furnished by Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, with requests for measurements dated April 20, 1953, July 13, 1953, and February 25, 1954. These three requests are included in Appendix C of this report. All of Dr. O'Neill's cameras and filters were returned to him after the measurements had been completed.

Also included in this report are the measurements made on two Leitz hand-camera lenses belonging to one of the authors (JCS).

Additional technical information on the Ansco and Kodak Wratten filters, studied in this report, are available from the manufacturer [6, 7, 8].

The assigned object numbers and descriptive designations for the identification of the material studied in this report are listed in Table I.

Table I

Assigned Object Numbers and Descriptive Designations for the Identification of the Aerial and Hand Camera Lenses and Filters.

A. Aerial Camera Lenses and Filters

Object No.	Sample Designation
(1)	Rear Cell, Bausch & Lomb Metrogon Lens, 6", f/6.3, Serial No. UF-6016.
(2)*	Assembled, Bausch & Lomb Metrogon Lens System, 6", f/6.3, Serial No. UF-6016.
(3)	Front Cell, Bausch & Lomb Coated Lens, 12", f/4.5, Serial No. LF-8123.
(4)	Rear Cell, Bausch & Lomb Coated Lens, 12", f/4.5, Serial No. LF-8123.
(5)*	Assembled Coated Lens System, Bausch & Lomb, 12", f/4.5, Serial No. LF-8123.
(6)	Yellow Glass Filter for use with Bausch & Lomb Metrogon Lens, Filter Only.
(7)	Yellow Glass Filter for use with Bausch & Lomb Metrogon Lens, Filter and Anti-vignetting Neutral Density Spot.

* Computed from spectral transmittance data of lens cells.

B. Hand Camera Lenses and Filters

Object No.	Sample Designation
(8)	Ansco Xenon Lens, 50 mm focal length, f/2, Serial No. 2563656.
(9)	Kodak Ektar Lens, 80 mm focal length, f/2.8, Serial No. ET814L.
(10)	Leitz Elmar Lens, 90 mm focal length, f/4, Serial No. 720367.
(11)	Leitz Summitar Lens, 50 mm focal length, f/2, Serial No. 603453.
(12)	Ansco Portrait Lens, No. 30, Plus 1, Size 6.
(13)	Ansco No. 10 Conversion Filter, Size 5 (sample a).
(14)	Ansco No. 11 Conversion Filter, Size 5 (sample a).
(15)	Ansco No. 10 Conversion Filter, Size 6 (sample a).
(16)	Ansco No. 11 Conversion Filter, Size 6 (sample a).

Table I (Continued)

B. Hand Camera Lenses and Filters (Continued)

Object No.	Sample Designation
(17)	Ansco No. 10 Conversion Filter, Size 5 (sample b).
(18)	Ansco No. 11 Conversion Filter, Size 5 (sample b).
(19)	Ansco No. 10 Conversion Filter, Size 6 (sample b).
(20)	Ansco No. 11 Conversion Filter, Size 6 (sample b).
(21)	Kodak Wratten Filter 80A, Series VI.
(22)	Kodak Wratten Filter 85, Series VI.
(23)	Ansco Ultraviolet-Absorbing Filter UV-15, Size 5.
(24)	Ansco Ultraviolet-Absorbing Filter UV-16, Size 5.
(25)	Ansco Ultraviolet-Absorbing Filter UV-17, Size 5.
(26)	Ansco Ultraviolet-Absorbing Filter UV-15, Size 6.
(27)	Ansco Ultraviolet-Absorbing Filter UV-16, Size 6.
(28)	Ansco Ultraviolet-Absorbing Filter UV-17, Size 6.
(29)	Ansco Ultraviolet-Absorbing Filter UV-16, Size 7.
(30)	Ansco Ultraviolet-Absorbing Filter UV-17, Size 7.
(31)	Kodak Wratten Filter A, Series VII.
(32)	Kodak Wratten Filter B, Series VII.
(33)	Kodak Wratten Filter C5, Series VII.
(34)	Kodak Wratten Filter N, Series VII.
(35)	Kodak Wratten Filter Aero 2, Series VII.

III. Spectrophotometric Measurements

Measurements of spectral transmittance were made on the NBS General Electric recording spectrophotometer [9, 10] for the visible and near infrared spectral range 400 to 1080 millimicrons. Slits of approximately 10 millimicrons of spectral width were used for the measurements in the visible spectrum, 400 to 750 millimicrons, and 20 millimicrons of spectral width for the near infrared spectrum, 730 to 1080 millimicrons. All recordings were made with calibration curves (didymium, zero, and 100% curves) for making wavelength and photometric scale corrections [11, 12]. Each of the sixteen curve sheets was read and corrected at each ten millimicron interval between 400 and 1080 millimicrons.

IV. Spectrophotometric Results

Ozalid prints of the 24 original recordings for the visible (400 to 750 millimicrons) and the near infrared (730 to 1080 millimicrons) spectral ranges obtained on the NBS General Electric recording spectrophotometer are included in Appendix A of this report. Tables of reduced and corrected data read from these 35 spectrophotometric curves are tabulated in Appendix B.

These corrected spectral transmittance data are shown in Figures 1 to 3 for the aerial camera lenses and filters and in Figures 10 to 22 for the hand camera lenses and filters.

The spectral transmittance data of the aerial camera lens system, computed from spectrophotometric data of the lens cells, are tabulated in Appendix B Figures 1 and 2 show respectively the spectral transmittance of the "B&L Metrogon 6" f/6.3" lens system, assuming the front and rear lens cells to be duplicates, and the "B&L 12" f/4.5" lens system.

Copies of the spectrophotometric curves of the aerial camera lenses and filter were given to Captain Fisher on March 17, 1954. Copies of the spectrophotometric curves of some of the hand camera lenses and filters were given to Dr. O'Neill on September 16, 1953 for incorporation in his report to the Wright Air Development Center dated September 30, 1953 [13].

V. Colorimetric Computations

The spectral transmittances in the visible spectrum, 380 to 770 millimicrons, of the 35 lenses and filters were integrated into the International Commission on Illumination (C.I.E.) standard observer and coordinate system [14] for Source C, representative of average daylight. These colorimetric computations yielded the chromaticity coordinates and daylight transmittances listed in Tables II and V of this report. Also listed are the dominant wavelength and excitation purity [15] of the materials studied.

VI. Munsell Renotations and ISCC-NBS Color Designations

From the above determined C.I.E. chromaticity coordinates and daylight

transmittances of the 35 lenses and filters, the Munsell renotations were obtained from graphs of conversion from the C.I.E. system to the Munsell renotation system [16]. These Munsell renotations were then converted into terms of ISCC-NBS color designations [17].

VII. Lovibond Notations

In order that a comparison may be made between the transparent lenses and filters of this test and a standardized system of transparent media of the same approximate material, conversions were made from the C.I.E. chromaticity coordinates x and z of the camera lenses and filters to the Lovibond designations by means of the large scale graphs engraved on aluminum, for Source C, of the "ideal" Lovibond system as derived by Scofield [18], and sold by the Tintometer Ltd., Salisbury, England [19]. A similar C.I.E. graph, for Source C, for the NBS standard set of the Lovibond glasses, is also available in this country [20]. This and other information on the Lovibond Color System has been published by Judd [21]. The schematic illustrations, Figures 8, 9, and 35 to 41, are intended to show the relationship between the aerial and hand camera lenses and filters in terms of the "ideal" Lovibond system [22].

VIII. Aerial Camera Lenses and Filters

The following nine illustrations and three tables of data contain the spectrophotometric and colorimetric specifications of seven components, either measured or computed, for two of the three aerial-camera lens systems and filter that Captain Robert J. Fisher and Sergeant S. G. Ujhely brought to the National Bureau of Standards for measurement from the Aerial Reconnaissance Laboratory, Wright-Patterson Air Force Base, Ohio.

As mentioned in Section II, Material, above, it was not feasible to measure directly the spectral transmittance of the front lens cell of the 6" lens or of either of the assembled 6" or 12" lens systems. It is known, however, that the 6" lens is symmetrical; that is, the front and rear lens cells are essentially duplicates of each other; so a close approximation to the spectral transmittance of the assembled 6" lens system was found by squaring at each wavelength the value of the spectral transmittance obtained for the rear lens cell. Similarly a close approximation to the spectral transmittance of the assembled 12" lens system was obtained by the product at each wavelength of the values of spectral transmittance found for the front and rear lens cells.

Figures 1 to 3 show the visible and near-infrared spectral transmittance of seven components of these two aerial-camera lens systems and filter, plotted from the tables of data listed in Appendix B. These data were read or computed from the original recordings of spectral transmittance taken from the General Electric recording spectrophotometer and corrected for wavelength and photometric scale errors. Ozalid copies of these recordings are shown in Appendix A.

Figures 4 and 5 show the chromaticity coordinates of these seven components of the two aerial-camera lens systems and filter computed from the visible portion of the spectral transmittance data (400 to 750 millimicrons) of these components and converted into terms of the International Commission on Illumination (C.I.E.) standard observer and coordinate system for Source C. The chromaticity coordinates, daylight transmittance, dominant wavelength, and excitation purity of these materials are listed in Table II.

Figures 6 and 7 show the Munsell renotations of these seven components of the two aerial camera lens systems and filter schematically illustrated. These data were obtained graphically by means of the C.I.E. chromaticity coordinates and daylight transmittance and are listed in Table III together with the ISCC-NBS color designations, derived from the Munsell renotations of these components.

Figures 8 and 9 show the "ideal" Lovibond units of red, yellow, and blue glasses for each of the seven components of the two aerial camera lens systems and filter. These data were obtained graphically by means of the C.I.E. chromaticity coordinates and are listed in Table IV together with the computed daylight transmittance which serves as the ordinate for the upper portions of the diagrams on Figures 8 and 9.

Figure 1. Visible and near infrared spectral transmittance of components of a Metrogon lens, B & L 6" f/6.3, from an aerial camera:

(1) Rear lens cell.

(2) Assembled lens system (assuming that the front lens cell has the same spectral transmittance as the rear lens cell).

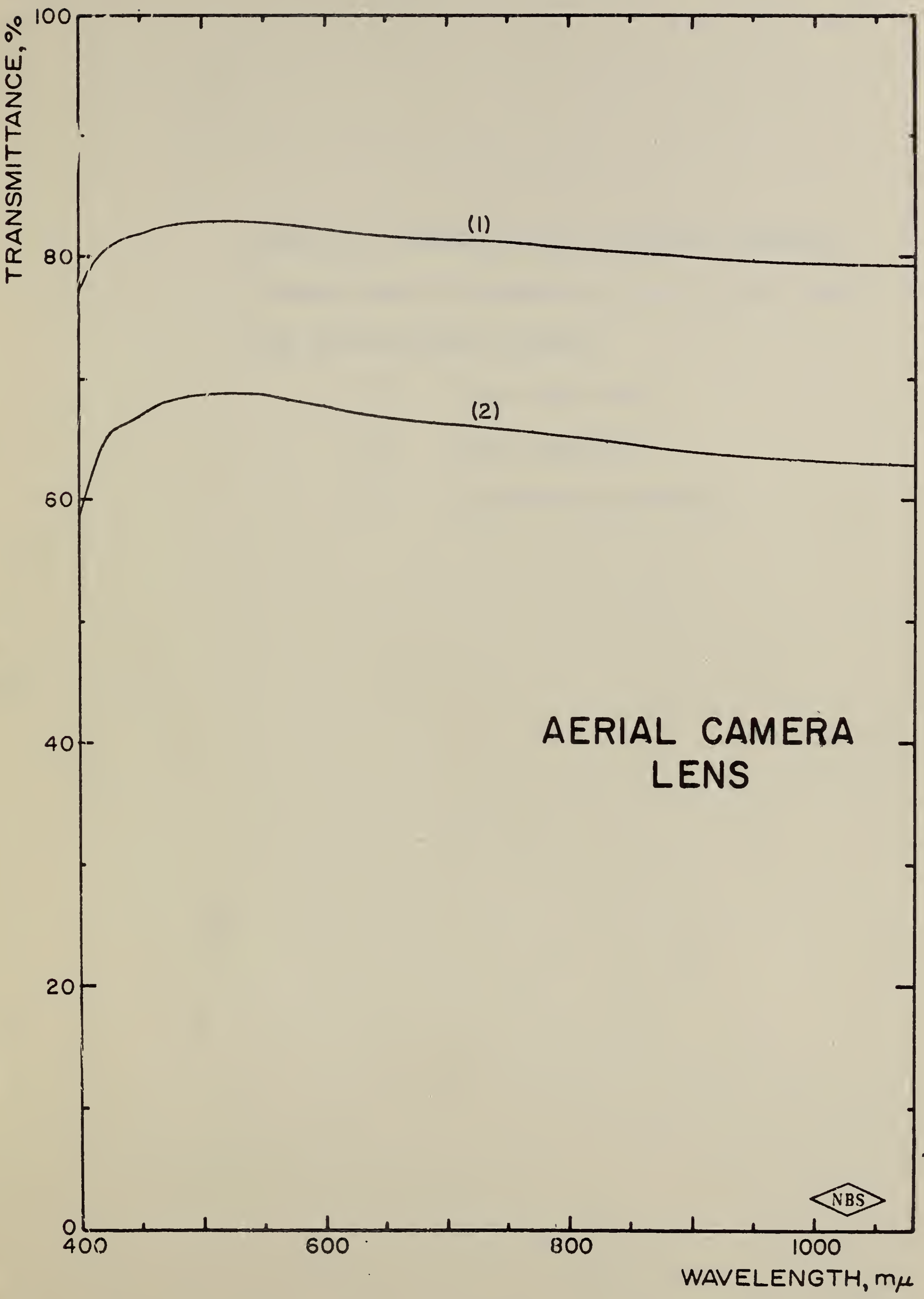

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(1)
(2)
AERIAL CAMERA LENS
NBS

FIGURE 1

Figure 2. Visible and near infrared spectral transmittance of components of a B & L 12" f/4.5 lens from an aerial camera:

(3) Front lens cell.

(4) Rear lens cell.

(5) Assembled lens system.

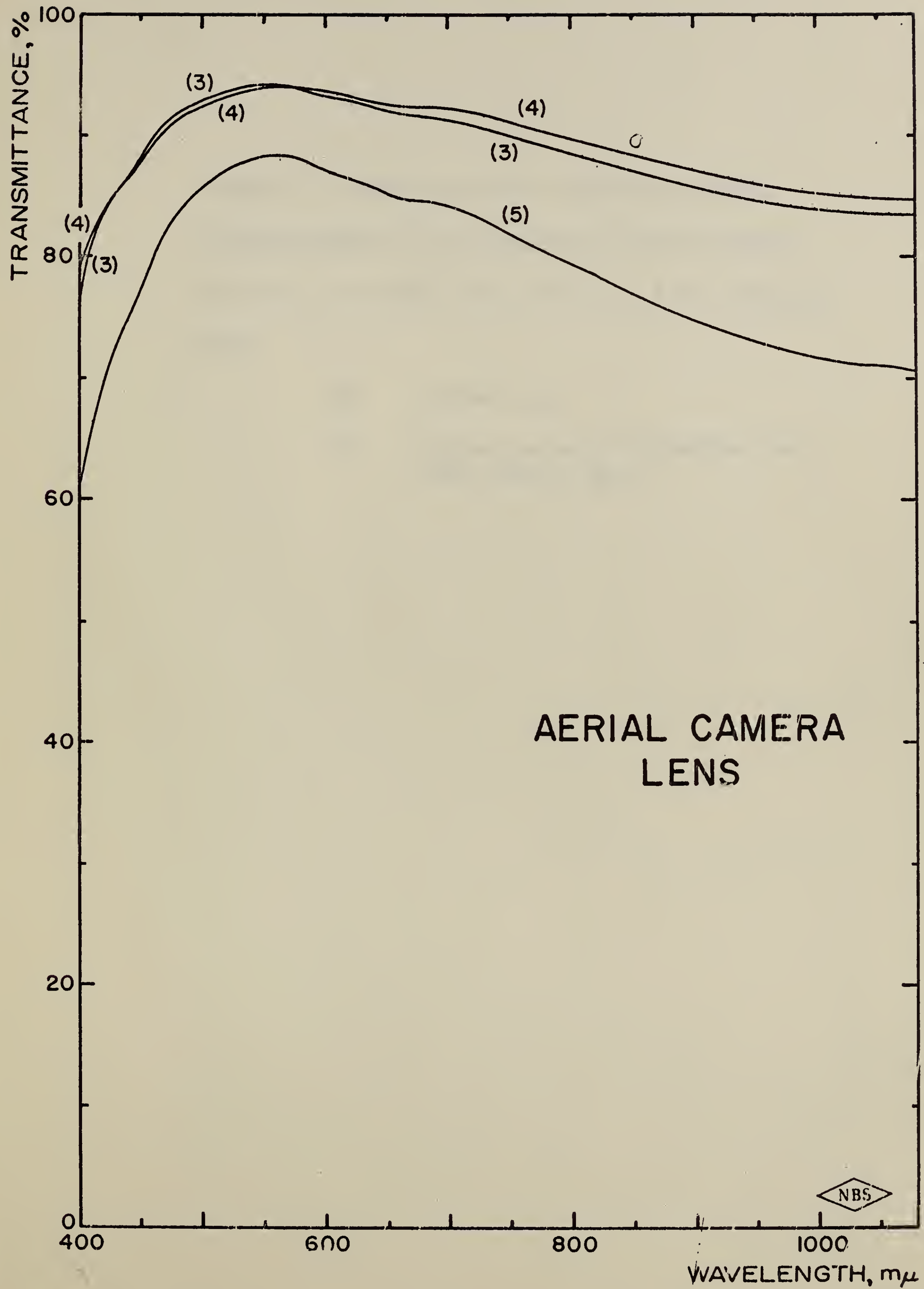

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(3)
(4)
(5)
AERIAL CAMERA LENS
NBS

FIGURE 2

Figure 3. Visible and near infrared spectral transmittance of a yellow-glass filter (approximately 1 cm thick) for use with a B & L Metrogon lens:

(6) Filter only.

(7) Filter and anti-vignetting neutral density spot.

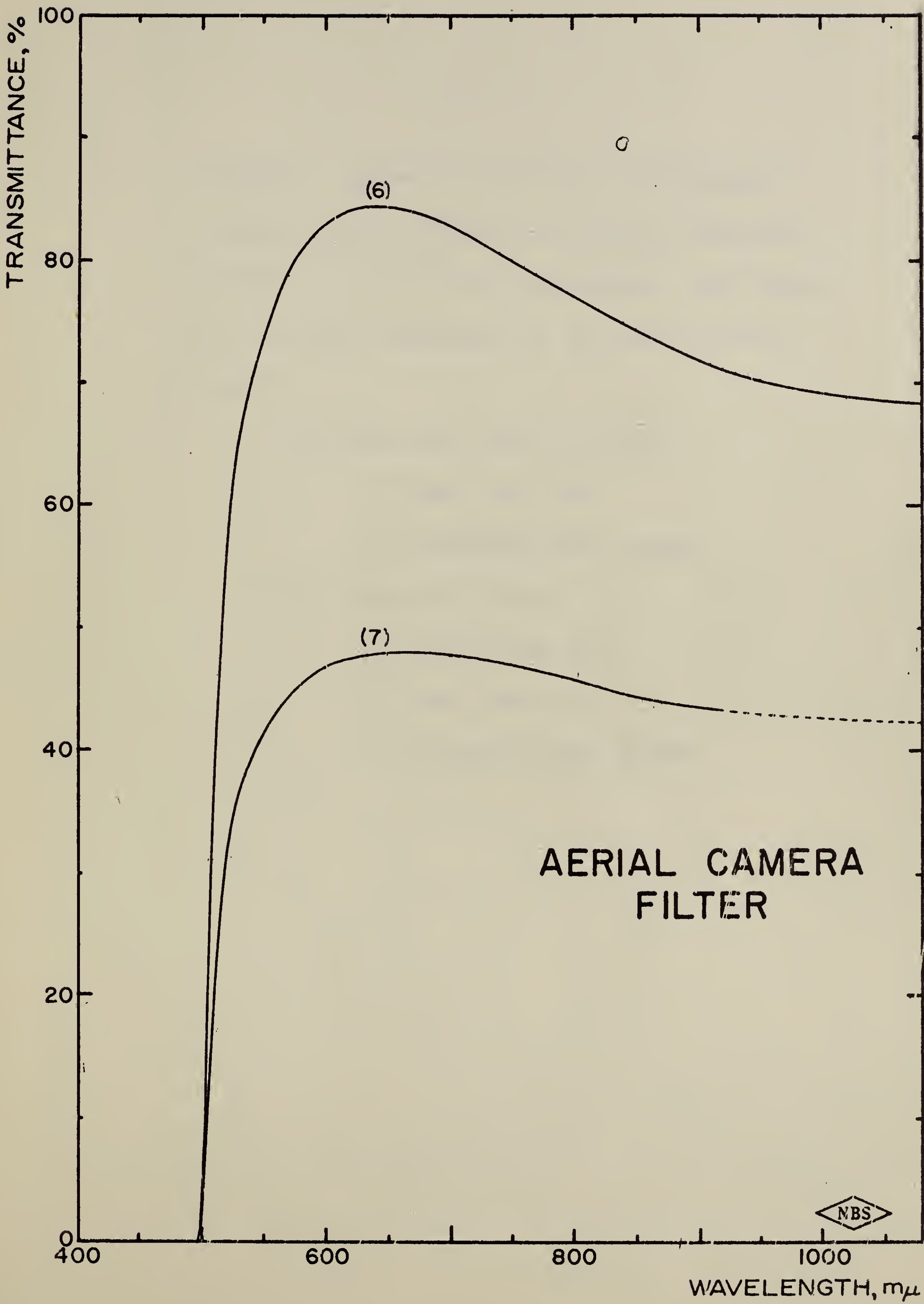

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(6)
(7)
AERIAL CAMERA
FILTER
NBS

FIGURE 3

Figure 4. Segment of the C.I.E. chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of several components of two aerial-camera lenses:

B & L Metrogon lens, 6", f/6.3

(1) Rear lens cell

(2) Assembled lens system

B & L lens, 12", f/4.5

(3) Front lens cell

(4) Rear lens cell

(5) Assembled lens system

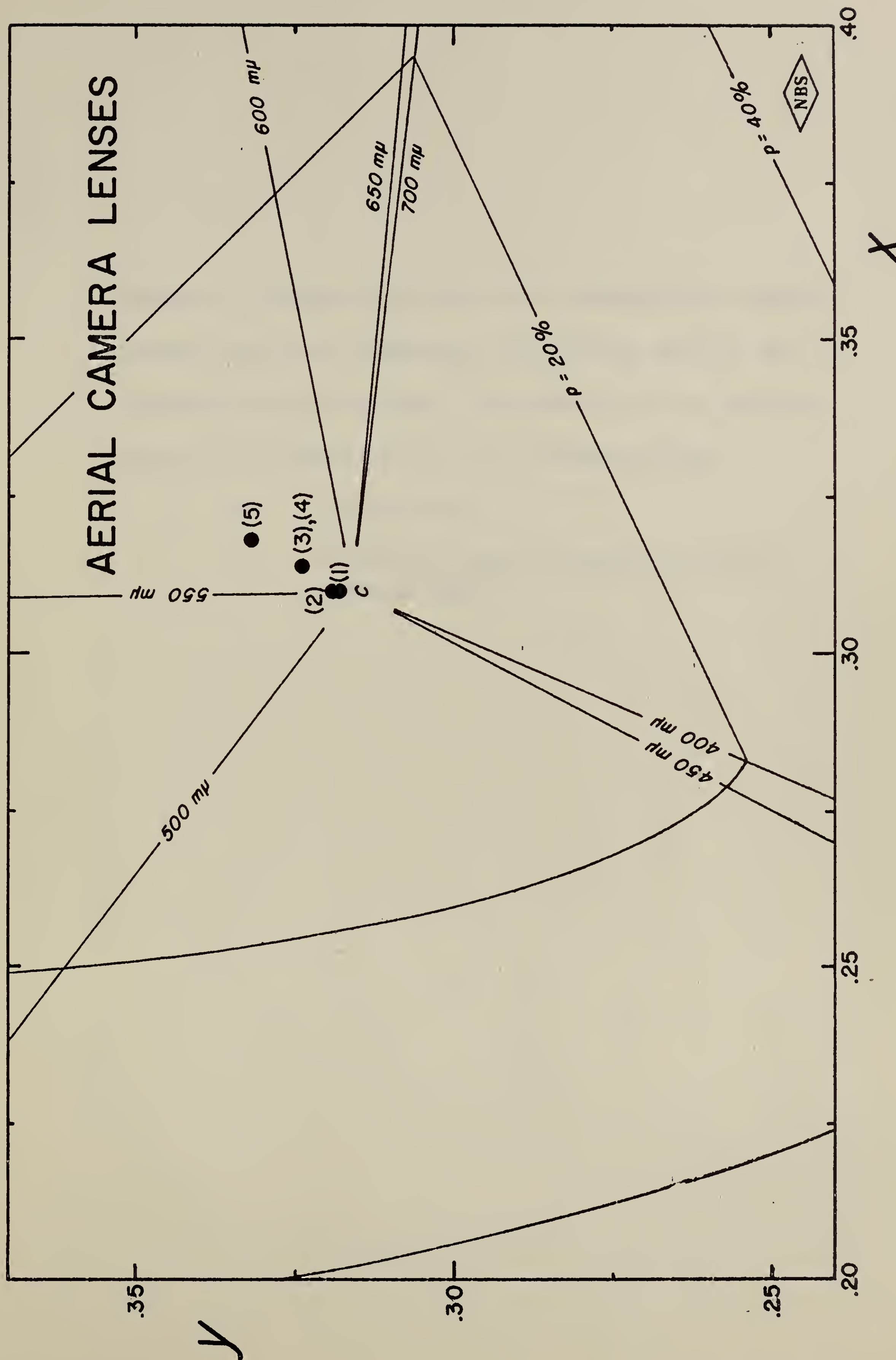

AERIAL CAMERA LENSES
600 mμ
650 mμ
700 mμ
550 mμ
500 mμ
450 mμ
400 mμ
ρ = 20%
ρ = 40%
(5)
(3),(4)
(2)
(1)
C
NBS
.20
.25
.30
.35
.40
X
.25
.30
.35
Y

FIGURE 4

Figure 5. Segment of the C.I.E. chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates, for Source C, of a yellow-glass filter used with a B & L Metrogon Lens:

(6) Filter only

(7) Filter and anti-vignetting neutral density spot

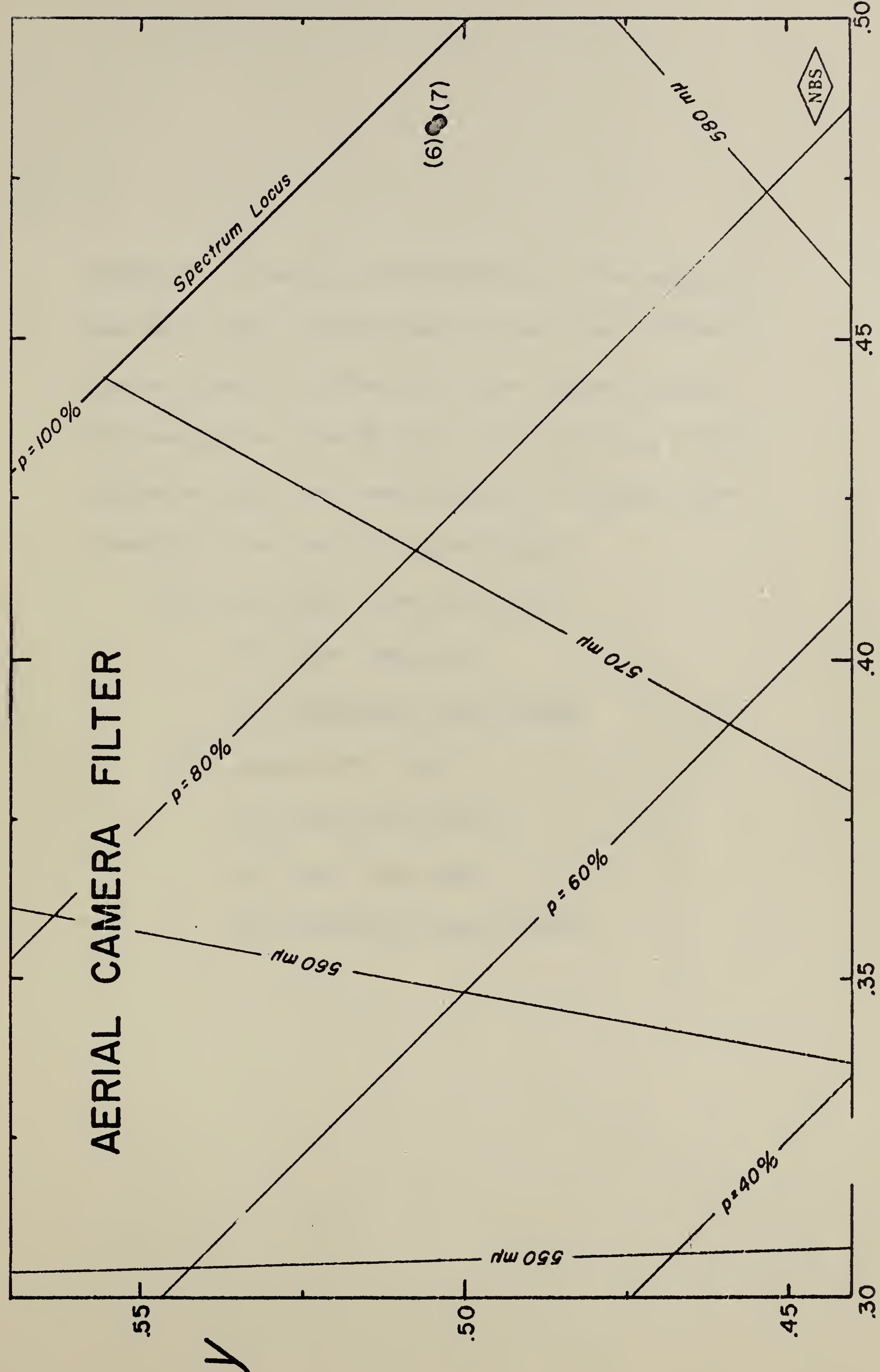

AERIAL CAMERA FILTER
Spectrum Locus
p=100%
p=80%
p=60%
p=40%
550 mμ
560 mμ
570 mμ
580 mμ
(6)
(7)
NBS
x
y
.30
.35
.40
.45
.50
.55
.50
.45

FIGURE 5

Figure 6. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against the Munsell Hue and Chroma points projected from the lower diagram of several components of two aerial-camera lenses:

B & L Metrogon lens, 6", f/6.3

(1) Rear lens cell

(2) Assembled lens system

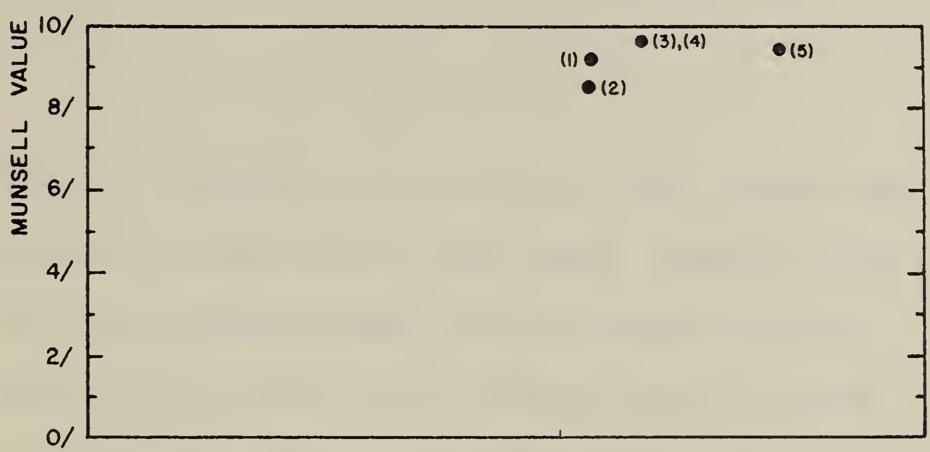
B & L lens, 12", f/4.5

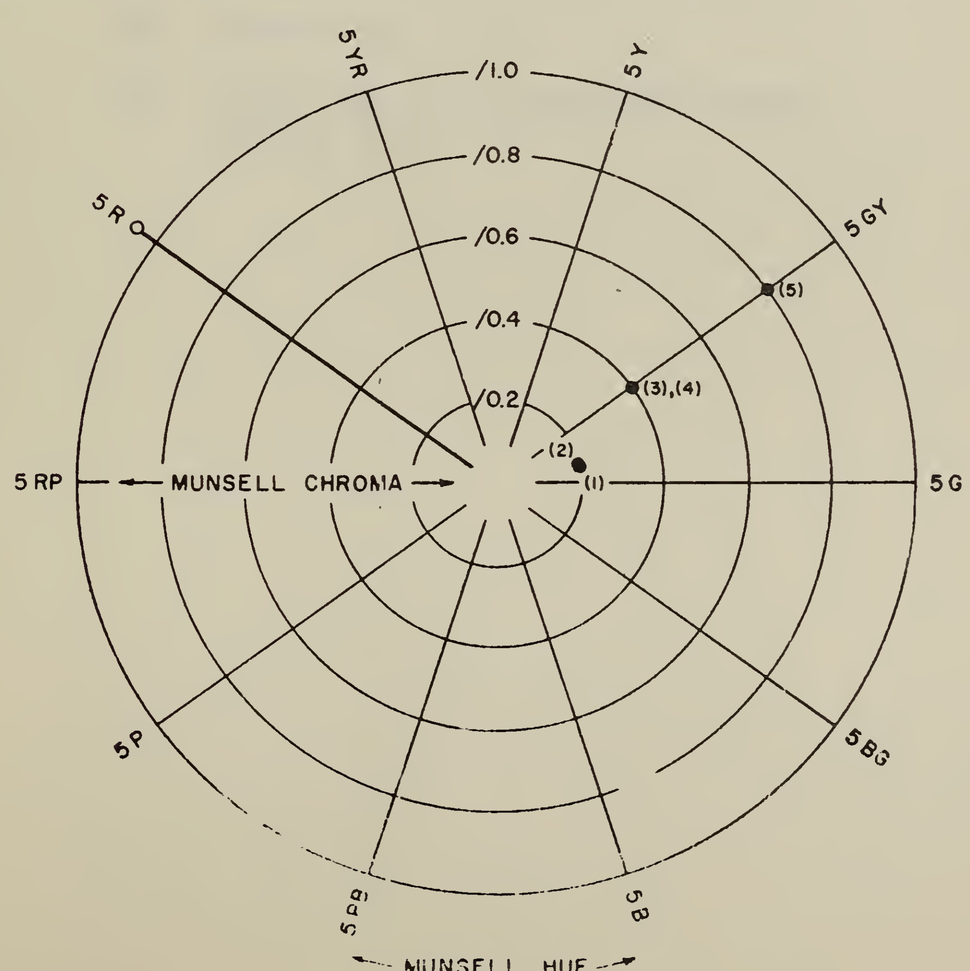
(3) Front lens cell

(4) Rear lens cell

(5) Assembled lens system

AERIAL CAMERA LENSES





NBS

FIGURE 6

Figure 7. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against the Munsell Hue and Chroma points projected from the lower diagram of a yellow-glass filter used with a B & L Metrogon lens:

(6) Filter only

(7) Filter and anti-vignetting neutral density spot

AERIAL CAMERA FILTER

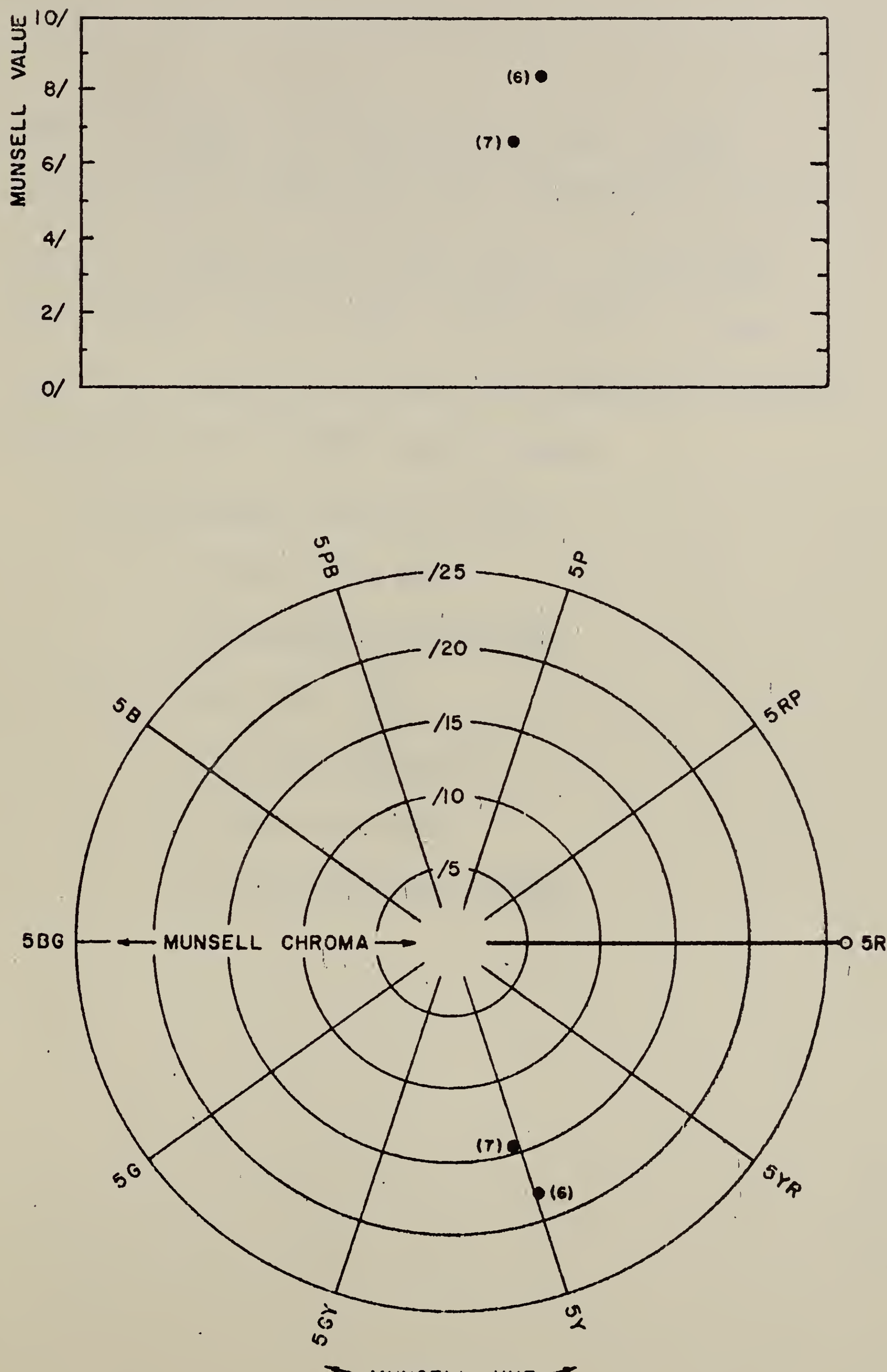


FIGURE 7

Figure 8. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram of several components of two aerial-camera lenses:

B & L Metrogon lens, 6", f/6.3

(1) Rear lens cell

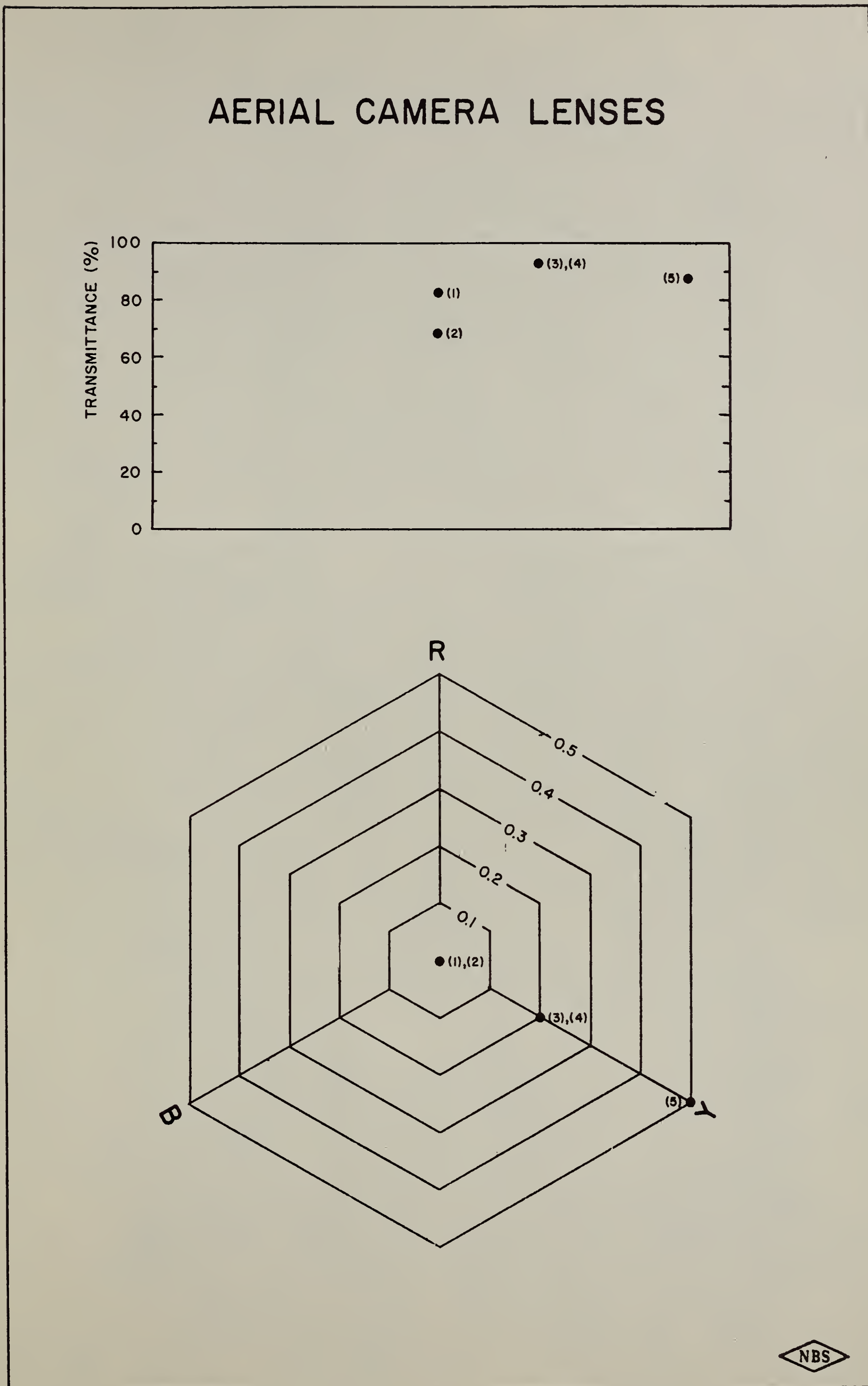
(2) Assembled lens system

B & L lens, 12", f/4.5

(3) Front lens cell

(4) Rear lens cell

(5) Assembled lens system



AERIAL CAMERA LENSES
TRANSMITTANCE (%)
100
80
60
40
20
0
(1)
(2)
(3),(4)
(5)
R
B
Y
0.1
0.2
0.3
0.4
0.5
(1),(2)
(3),(4)
(5)
NBS

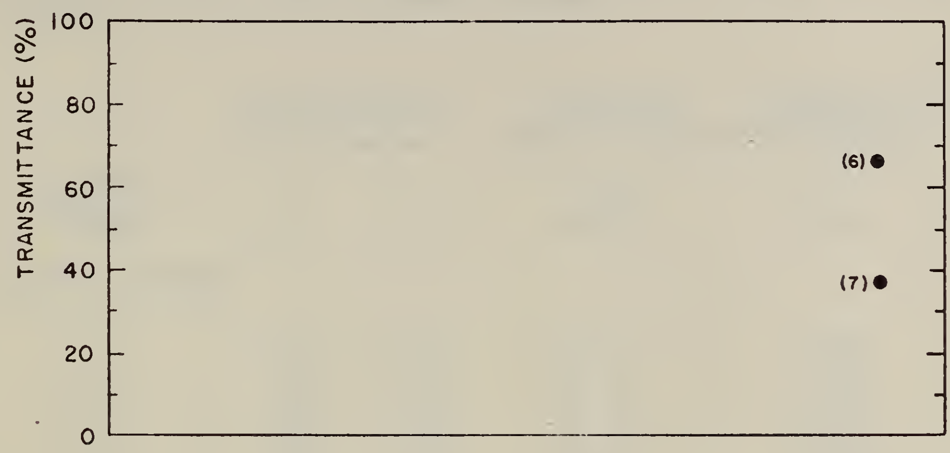
FIGURE 8

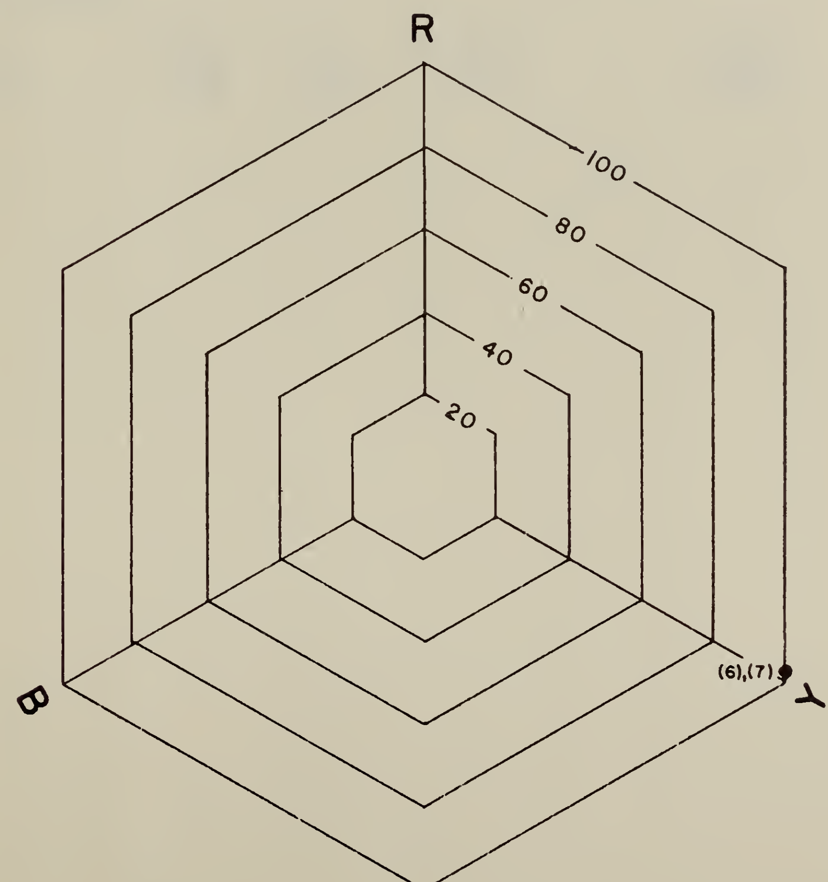
Figure 9. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color systems, based on Red, Yellow, and Blue glass standards, projected from the lower diagram of a yellow-glass filter used with a B & L Metrogon lens:

(6) Filter only

(7) Filter and anti-vignetting neutral density spot

AERIAL CAMERA FILTER





NBS

FIGURE 9

Table II

Aerial Camera Lenses and Filter

Chromaticity Coordinates, Daylight Transmittance, Dominant Wavelength, and Excitation Purity Determinations, for Source C, of the Two Aerial-Camera Lenses and the Aerial-Camera Filter.

Object Number	Chromaticity Coordinates x	Chromaticity Coordinates y	Luminous Transmittance Y(%)	Dominant Wavelength λ	Excitation Purity p(%)
AERIAL CAMERA LENSES:					
(1)	0.310	0.318	82.5	550.	0.5
(2)	.310	.319	68.2	550.	1.0
(3)	.314	.324	93.4	567.	3.0
(4)	.314	.324	93.3	569.	3.3
(5)	.318	.332	87.2	565.5	6.2
AERIAL CAMERA FILTER:					
(6)	0.483	0.505	66.0	576.4	97.1
(7)	.484	.504	37.1	576.5	97.1

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table III

Aerial Camera Lenses and Filter

Munsell Renotations and ISCC-NBS Color Designations of the Two Aerial-Camera Lenses and the Aerial-Camera Filter.

Object Number	Munsell Renotation	ISCC-NBS Color Designation
AERIAL CAMERA LENSES:		
(1)	2.0G 9.2/0.2	Colorless
(2)	1.2G 8.5/0.2	Light gray
(3)	5.0GY 9.6/0.4	Colorless
(4)	5.0GY 9.6/0.4	Colorless
(5)	5.0GY 9.4/0.8	Faint green
AERIAL CAMERA FILTER:		
(6)	4.9Y 8.4/18.0	Vivid yellow
(7)	5.4Y 6.6/14.5	Vivid yellow

[illegible]

Table IV

Aerial Camera Lenses and Filter

Lovibond Analyses and Daylight Transmittance of the Two Aerial-Camera Lenses and the Aerial-Camera Filter.

Object Number	Lovibond Analysis R	Y	B	Luminous Transmittance Y(%)
AERIAL CAMERA LENSES:				
(1)	0.0	0.0	0.0	82.5
(2)	.0	.0	.0	68.2
(3)	.0	.2	.0	93.4
(4)	.0	.2	.0	93.3
(5)	.0	.5	.0	87.2
AERIAL CAMERA FILTER:				
(6)	2.5	100.	0.0	66.0
(7)	2.8	100.	.0	37.1

IX. Hand-Camera Lenses and Filters

The following 32 illustrations and three tables of data contain the spectrophotometric and colorimetric specifications of five hand camera lenses and 23 photographic filters.

Figures 10 to 22 show the visible and near infrared spectral transmittance of 28 hand-camera lenses and filters, plotted from the tables of data listed in Appendix B. These data were read from the original recordings of spectral transmittance taken from the General Electric recording spectrophotometer and corrected for wavelength and photometric scale errors. Ozalid copies of these recordings are shown in Appendix A.

Figures 23 to 27 show the chromaticity coordinates of these five hand-camera lenses and twenty-three photographic filters computed from the visible portion of the spectral transmittance data (400 to 750 millimicrons) of these materials and converted into terms of the International Commission on Illumination (C.I.E.) standard observer and coordinate system for Source C. The chromaticity coordinates, daylight transmittance, dominant wavelength and excitation purity of these materials are listed in Table V.

Also shown on Figures 24 and 25 is a portion of the Planckian locus which connects the values of the chromaticity coordinates of the light sources.

Figures 28 to 34 show the Munsell renotations of these 28 materials schematically illustrated. These data were obtained graphically by means of the C.I.E. chromaticity coordinates and daylight transmittance. The Munsell renotations are listed in Table VI together with the ISCC-NBS color designations of the hand camera lenses and filters.

Figures 35 to 41 show the "ideal" Lovibond units of red, yellow, and blue glasses for each of the five hand camera lenses and of the twenty-three photographic filters. These Lovibond analyses were obtained graphically by means of the C.I.E. chromaticity coordinates and are listed in Table VII together with the computed daylight transmittance which served as the ordinate for the upper portion of the diagrams in Figures 35 to 41.

Figure 10. Visible and near infrared spectral transmittance of the lens of a hand camera:

(8) Ansco Xenon Lens, 50 mm focal length, f/2, Serial No. 2563656

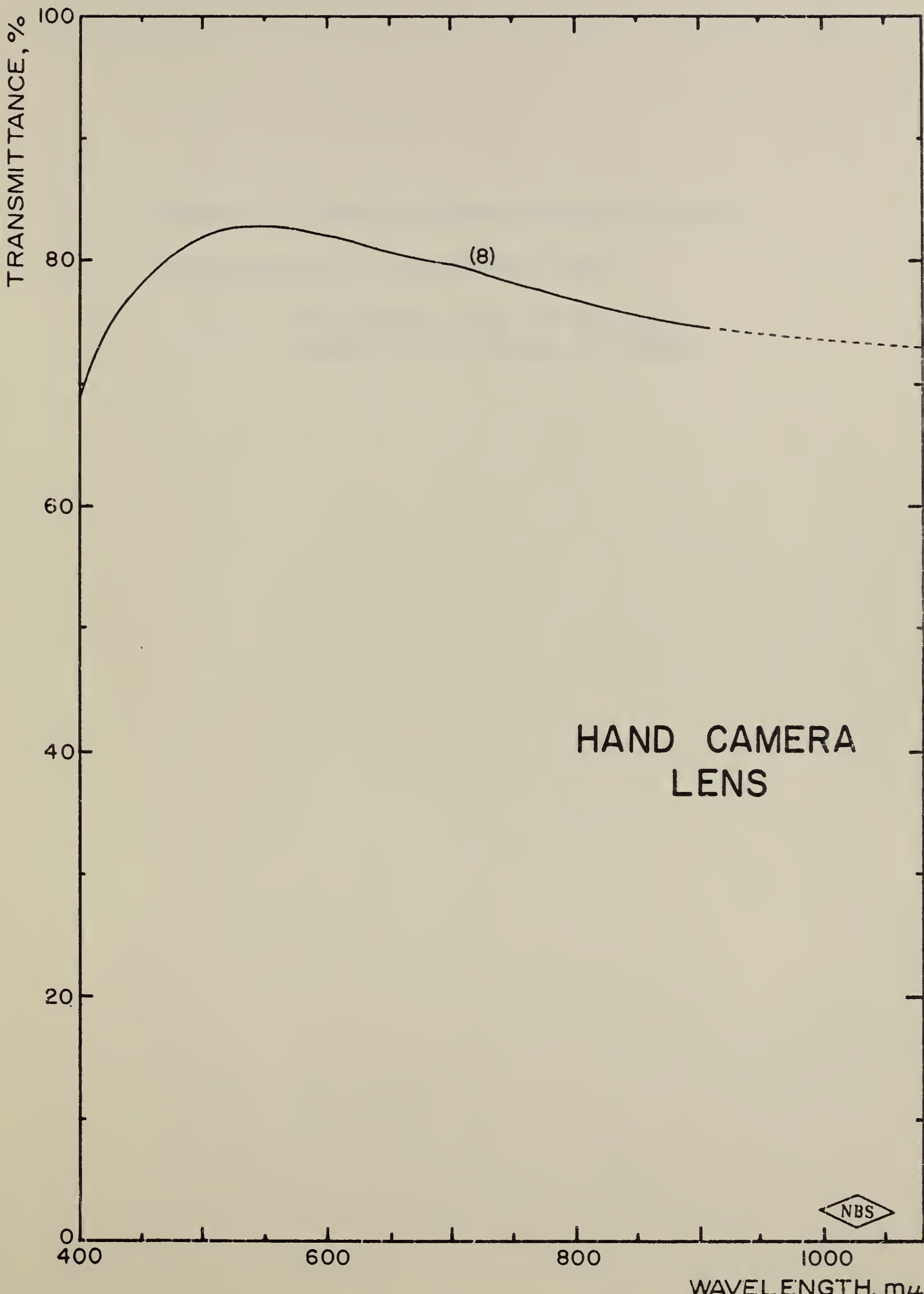
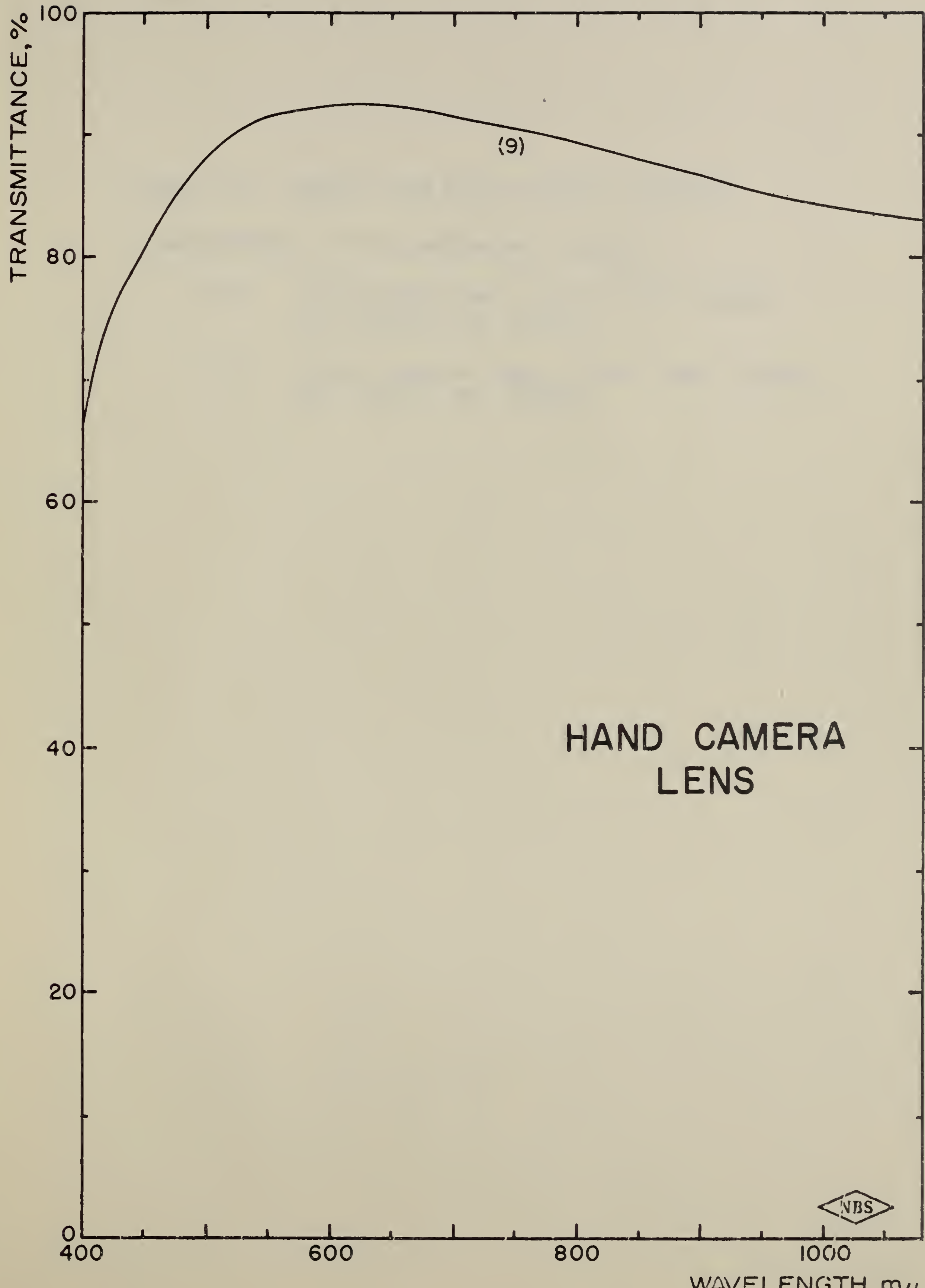

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(8)
HAND CAMERA
LENS
NBS

FIGURE 10

Figure 11. Visible and near infrared spectral transmittance of a hand-camera lens:

(9) Kodak Ektar Lens, 80 mm focal length, f/2.8, Serial No. ET814L



TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(9)
HAND CAMERA LENS
NBS

FIGURE 11

Figure 12. Visible and near infrared spectral transmittance of two hand-camera lenses:

(10) Leitz Elmar Lens, 90 mm focal length, f/4, Serial No. 720367

(11) Leitz Summitar Lens, 50 mm focal length, f/2, Serial No. 603453

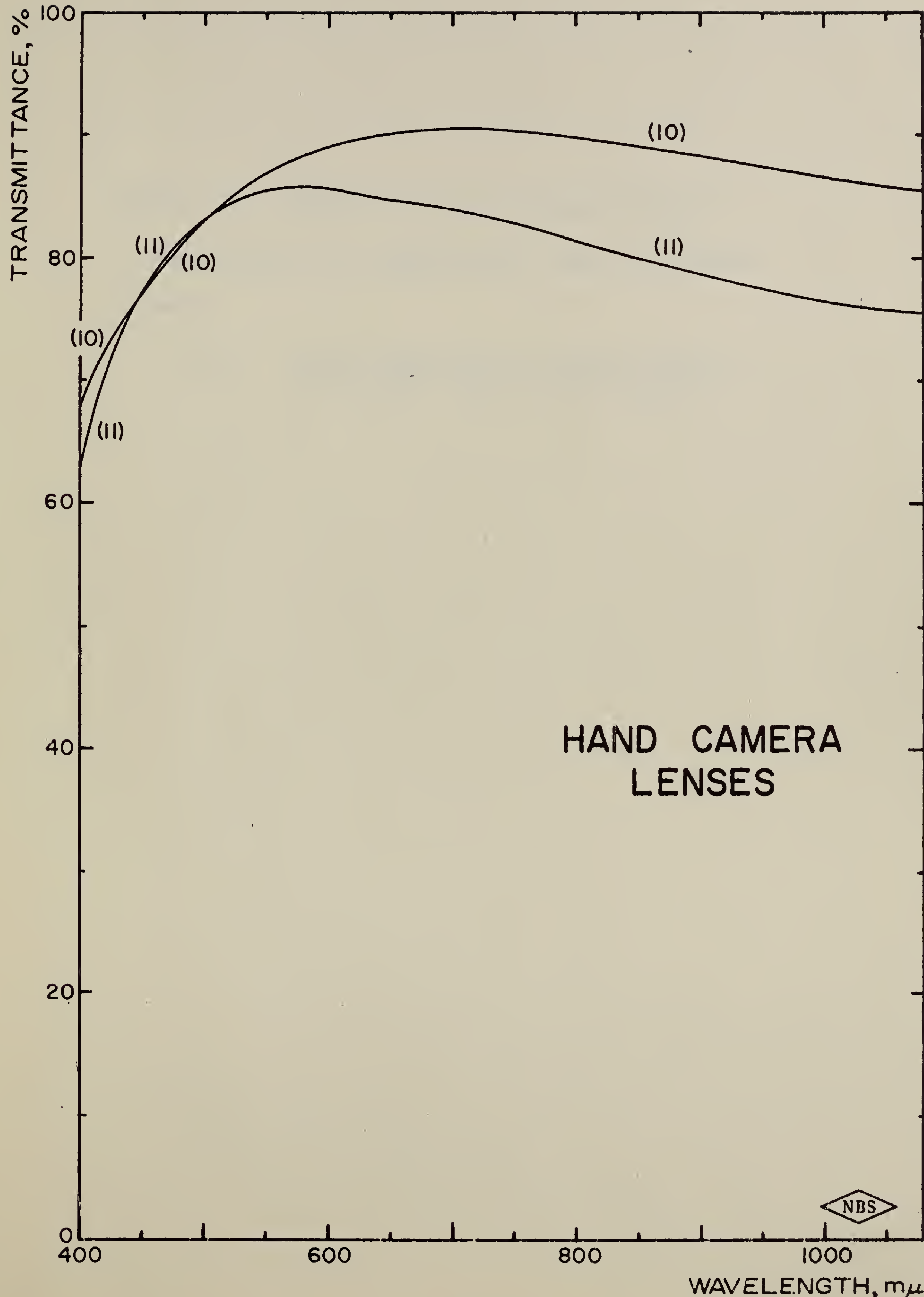

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(10)
(11)
(11)
(10)
(10)
(11)
HAND CAMERA
LENSES
NBS

FIGURE 12

Figure 13. Visible and near infrared spectral transmittance of a supplementary lens for a hand camera:

(12) Ansco supplementary camera lens No. 30 Portrait Lens, Plus 1, Size 6

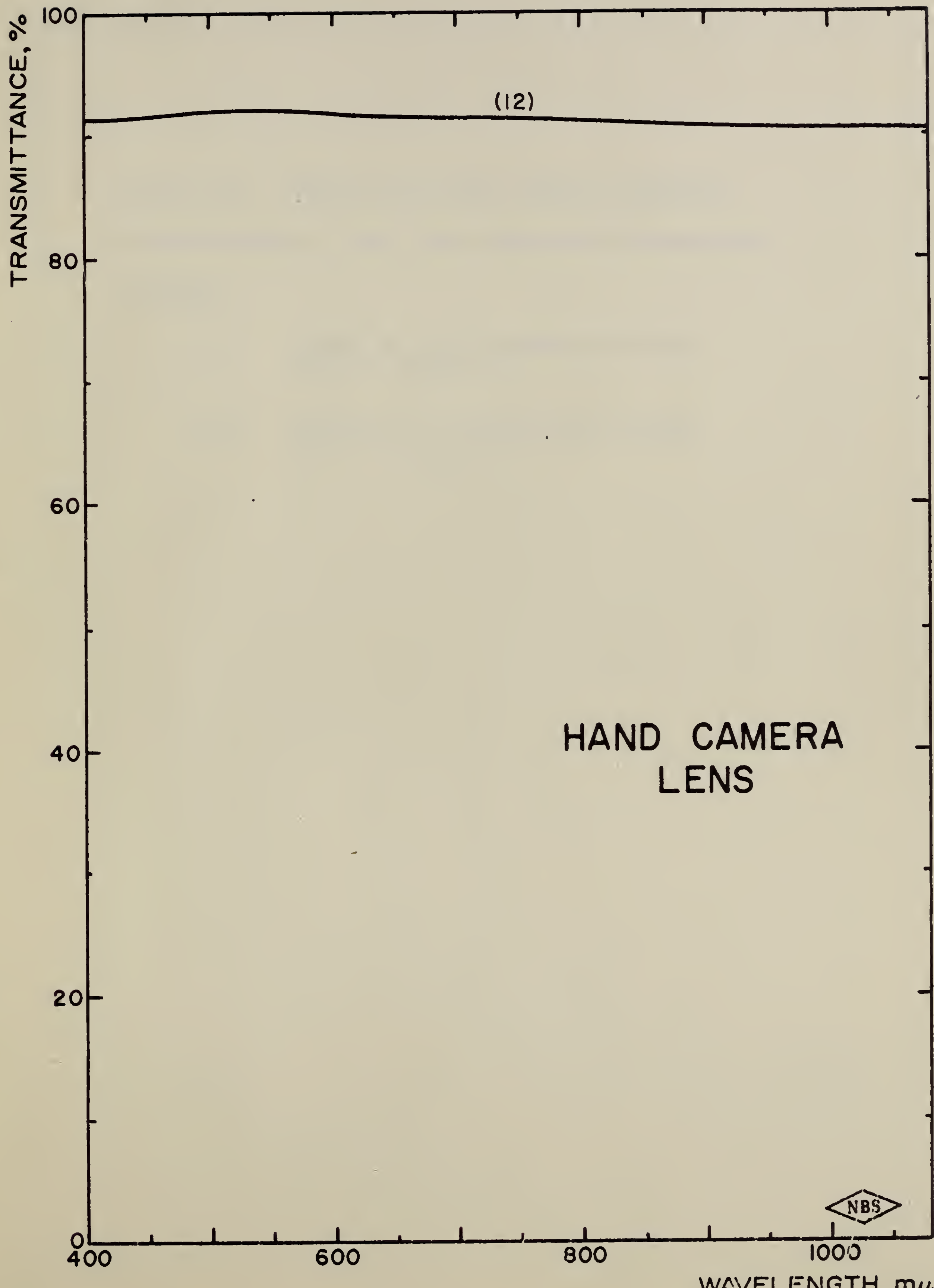

TRANSMITTANCE, %
100
80
60
40
20
0
(12)
HAND CAMERA
LENS
NBS
400
600
800
1000
WAVELENGTH, mμ

FIGURE 13

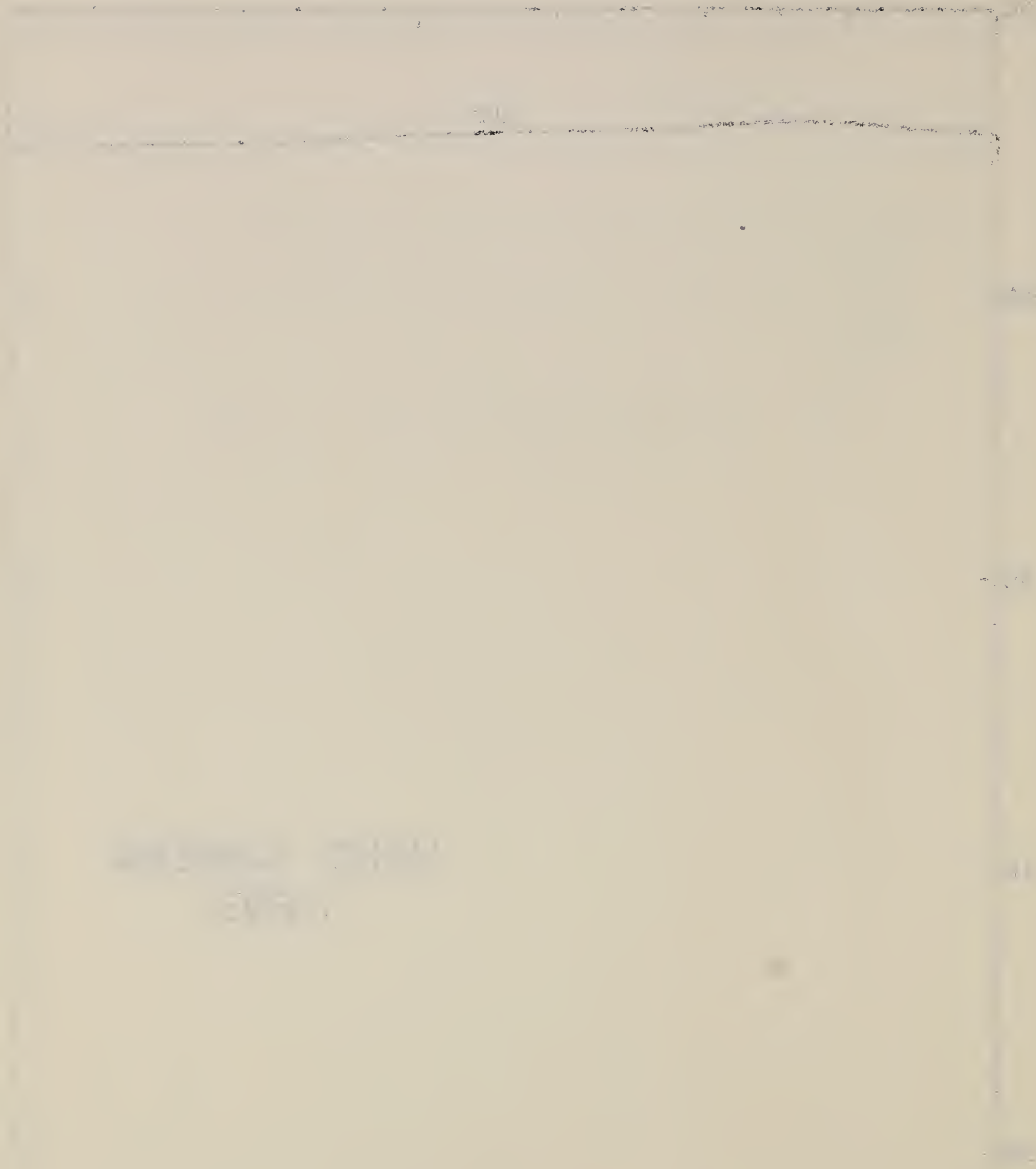
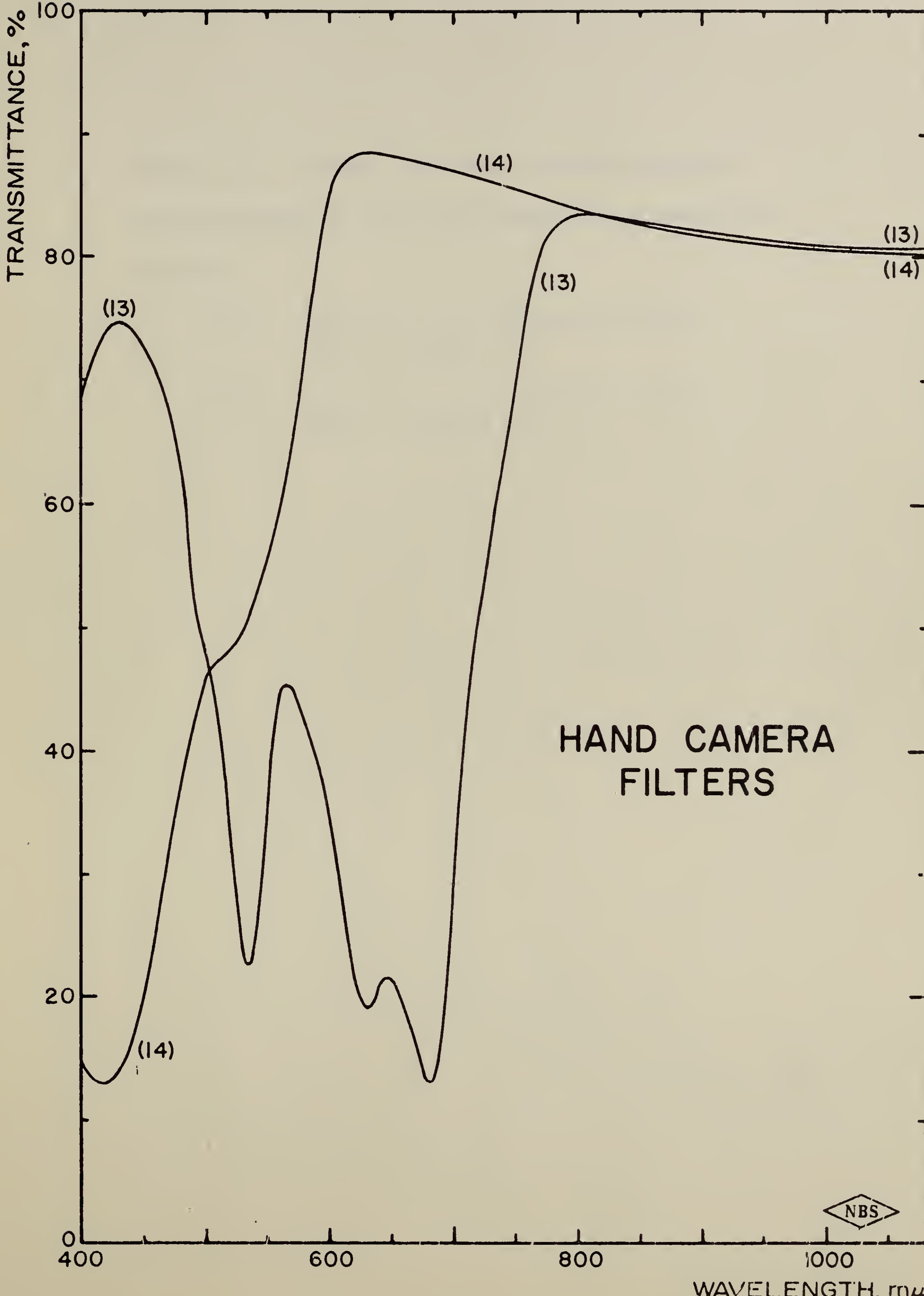


Figure 14. Visible and near infrared spectral transmittance of two color-temperature-conversion filters:

(13) Ansco No. 10 Conversion Filter, Size 5 (sample a)

(14) Ansco No. 11 Conversion Filter, Size 5 (sample a)



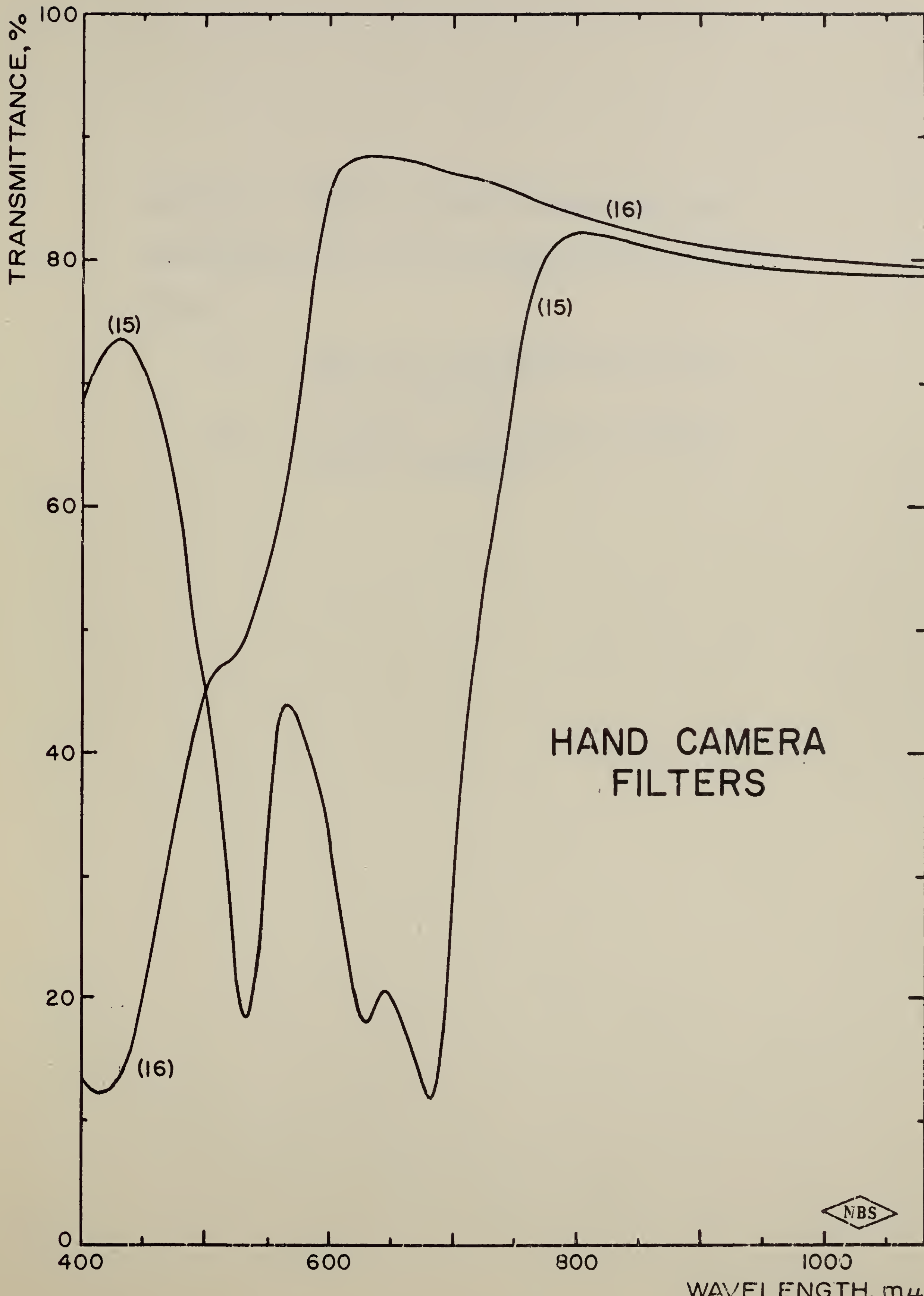
TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(14)
(13)
(13)
(14)
(13)
(14)
HAND CAMERA FILTERS
NBS

FIGURE 14

Figure 15. Visible and near infrared spectral transmittance of two color-temperature-conversion filters:

(15) Ansco No. 10 Conversion Filter, Size 6 (sample a)

(16) Ansco No. 11 Conversion Filter, Size 6 (sample a)



TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(15)
(16)
(15)
(16)
HAND CAMERA FILTERS
NBS

FIGURE 15

Figure 16. Visible and near infrared spectral transmittance of two color-temperature-conversion filters:

(17) Ansco No. 10 Conversion Filter, Size 5 (sample b)

(18) Ansco No. 11 Conversion Filter, Size 5 (sample b)

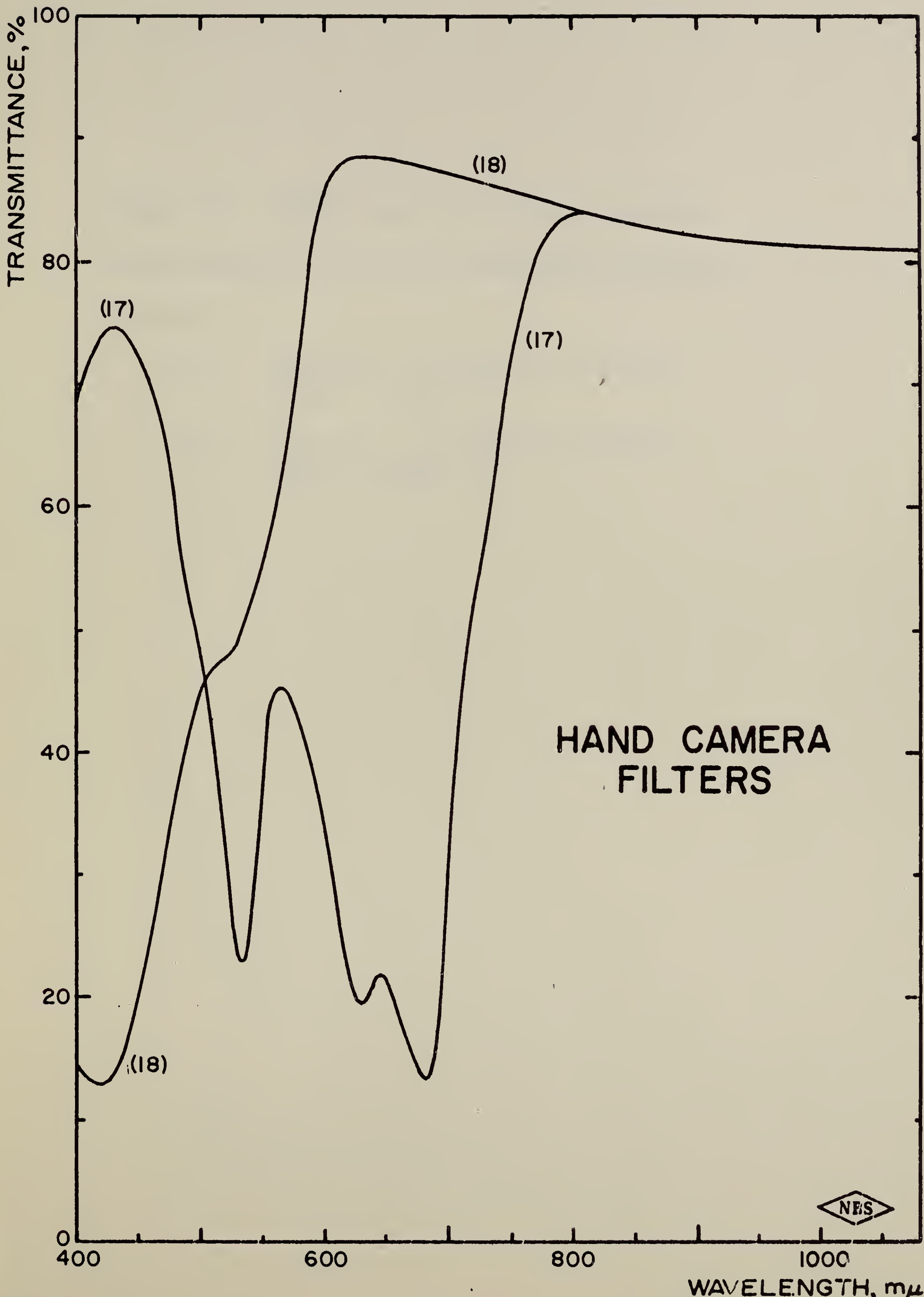

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(17)
(18)
(17)
(18)
HAND CAMERA
FILTERS
NBS

FIGURE 16

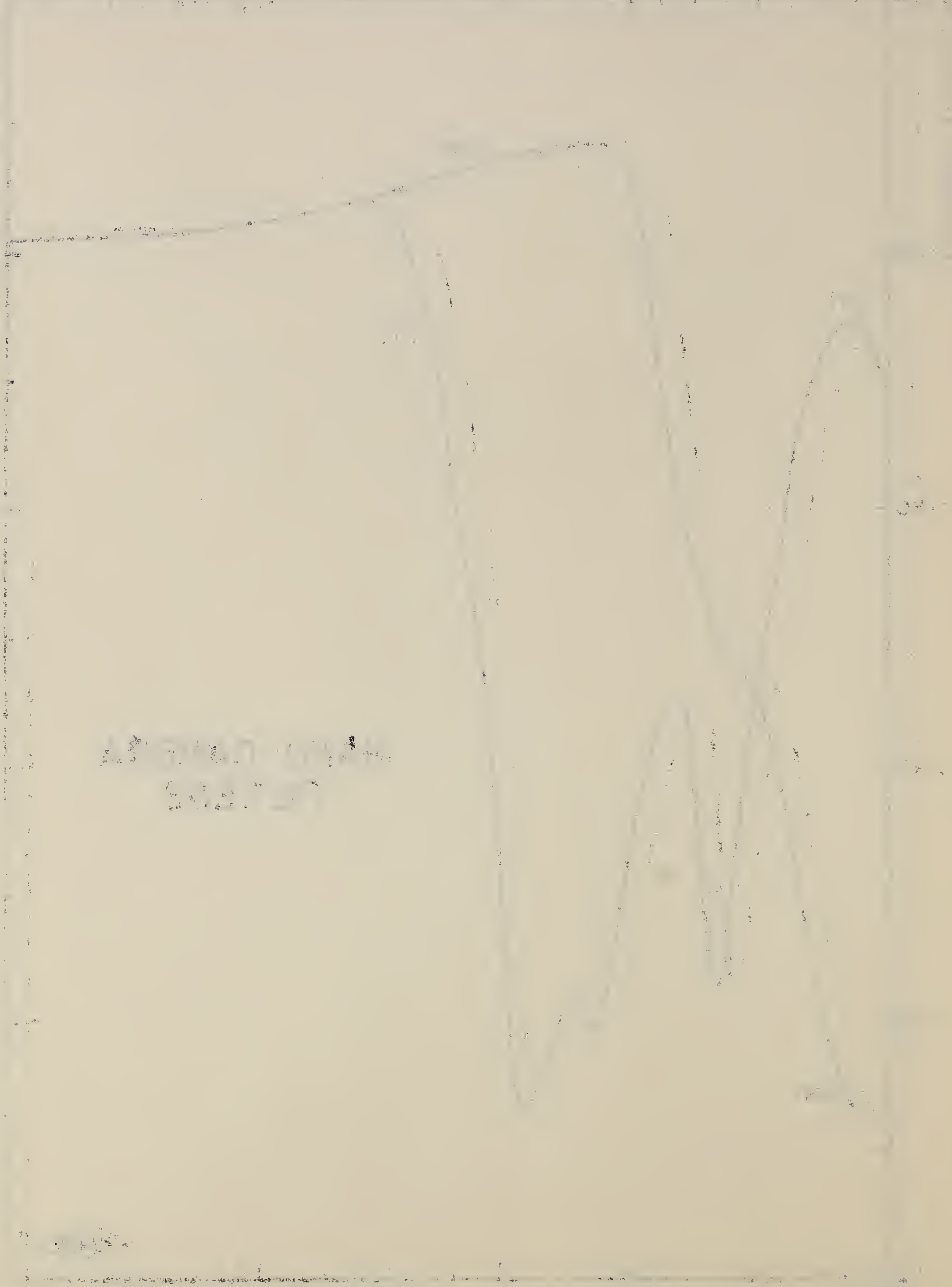


Figure 17. Visible and near infrared spectral transmittance of two color-temperature-conversion filters:

(19) Ansco No. 10 Conversion Filter, Size 6 (sample b)

(20) Ansco No. 11 Conversion Filter, Size 6 (sample b)

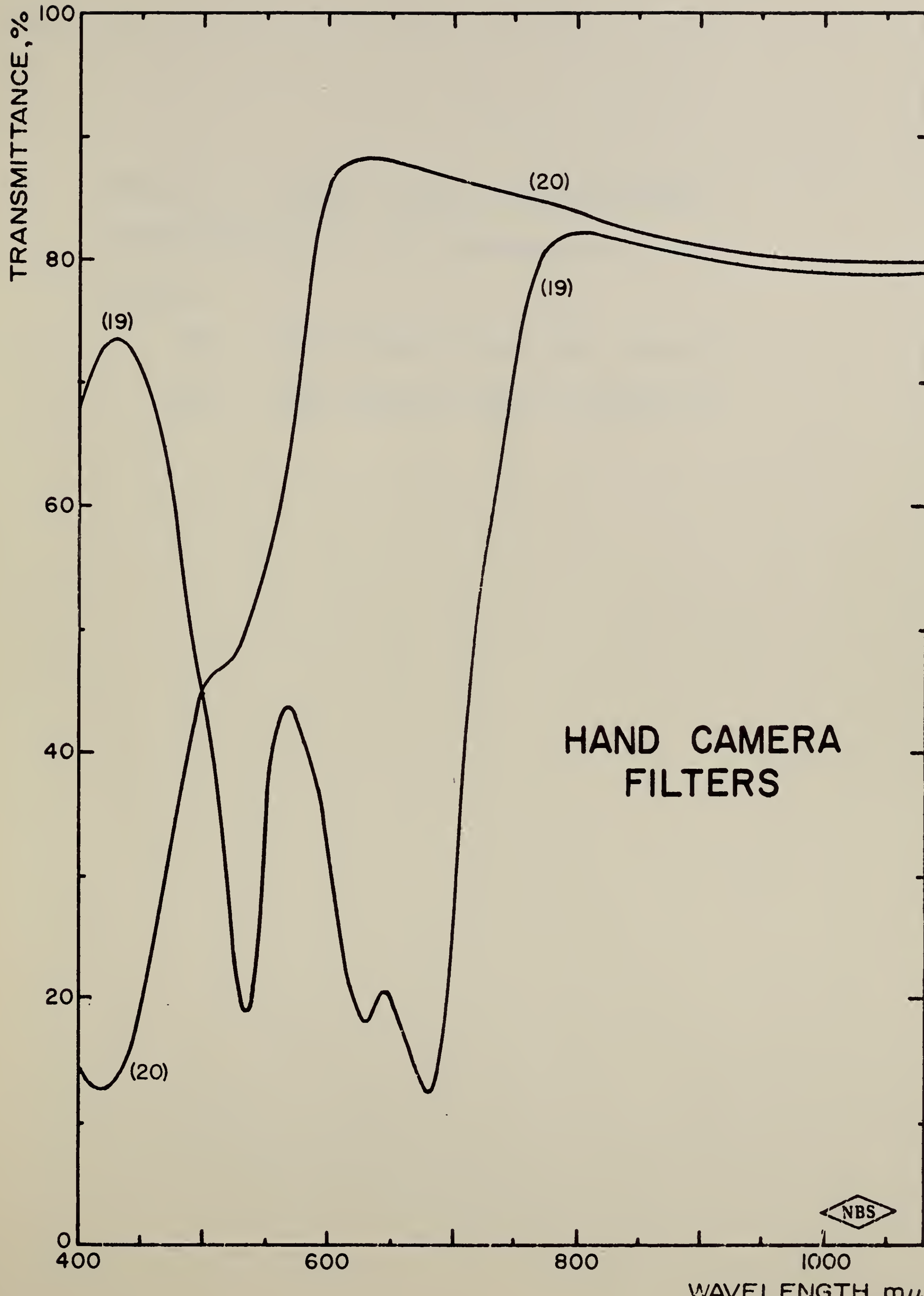

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(19)
(20)
(20)
(19)
HAND CAMERA
FILTERS
NBS

FIGURE 17

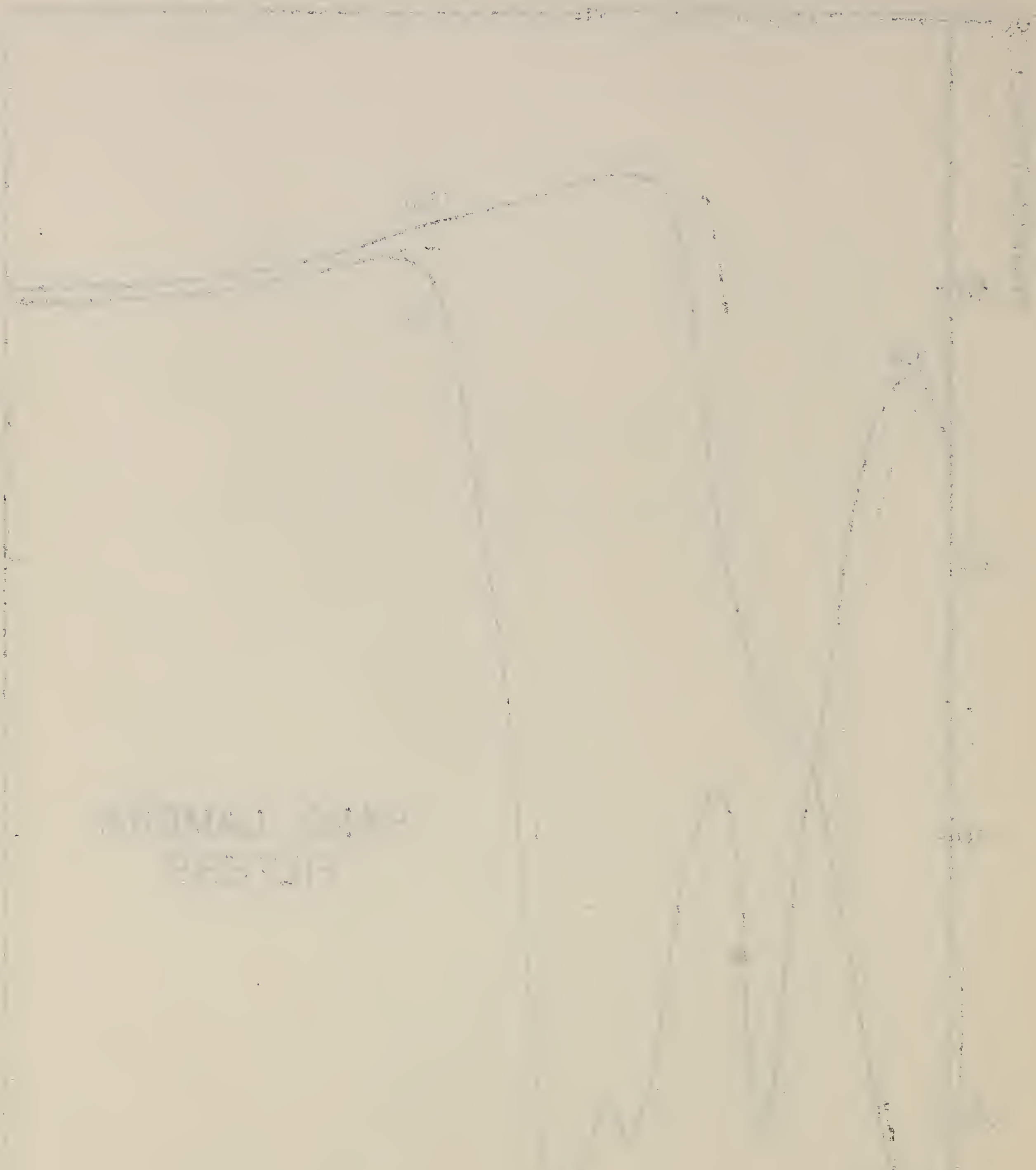


Figure 18. Visible and near infrared spectral transmittance of two color-temperature-conversion filters:

(21) Kodak Wratten Filter 80A, Series VI

(22) Kodak Wratten Filter 85, Series VI

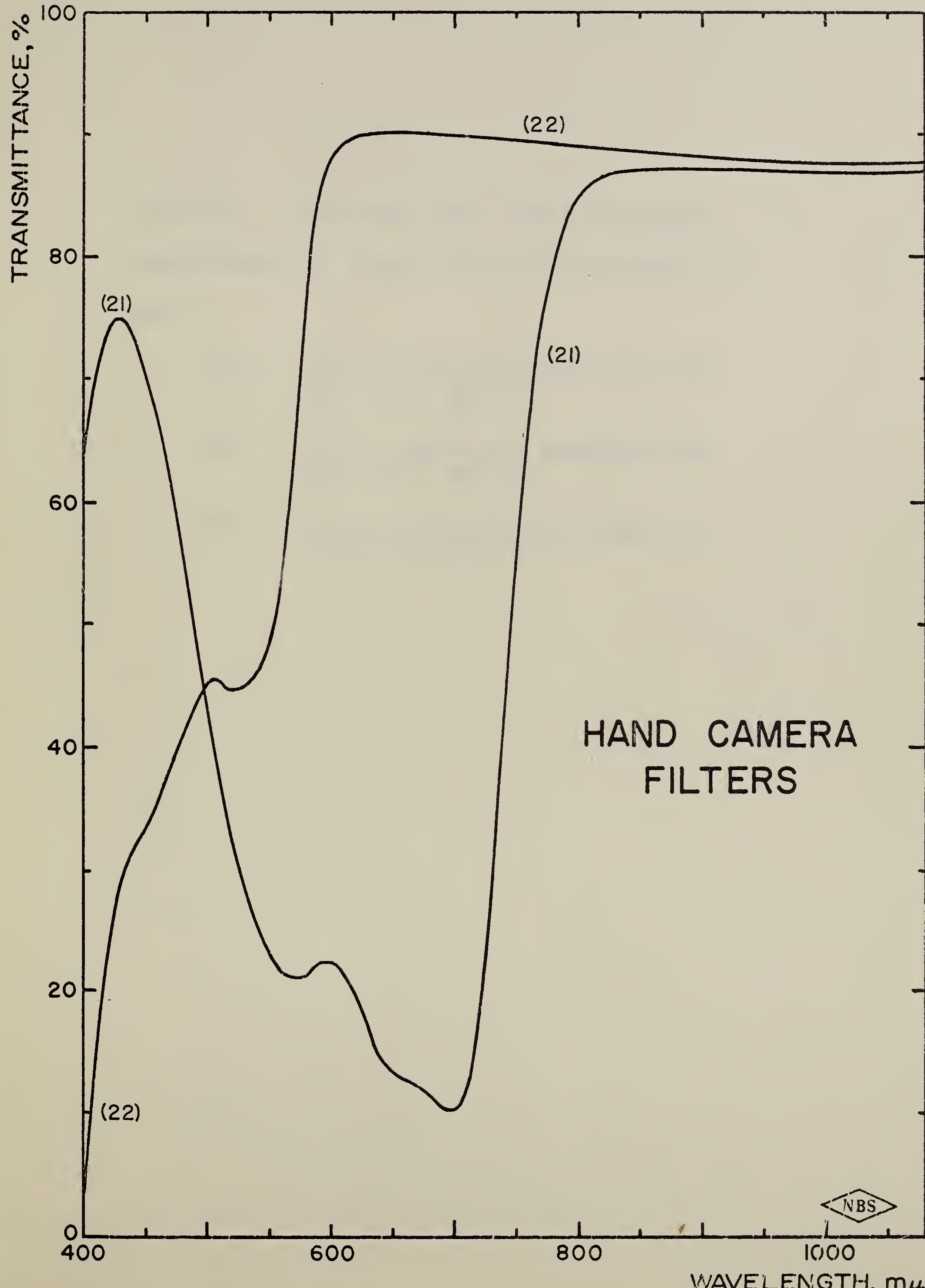

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(22)
(21)
(21)
(22)
HAND CAMERA
FILTERS
NBS

FIGURE 18

Figure 19. Visible and near infrared spectral transmittance of three ultraviolet-absorbing filters:

(23) Ansco Ultraviolet Absorbing Filter UV-15, Size 5

(24) Ansco Ultraviolet Absorbing Filter UV-16, Size 5

(25) Ansco Ultraviolet Absorbing Filter UV-17, Size 5

[illegible]

[illegible]

[illegible]

[illegible]

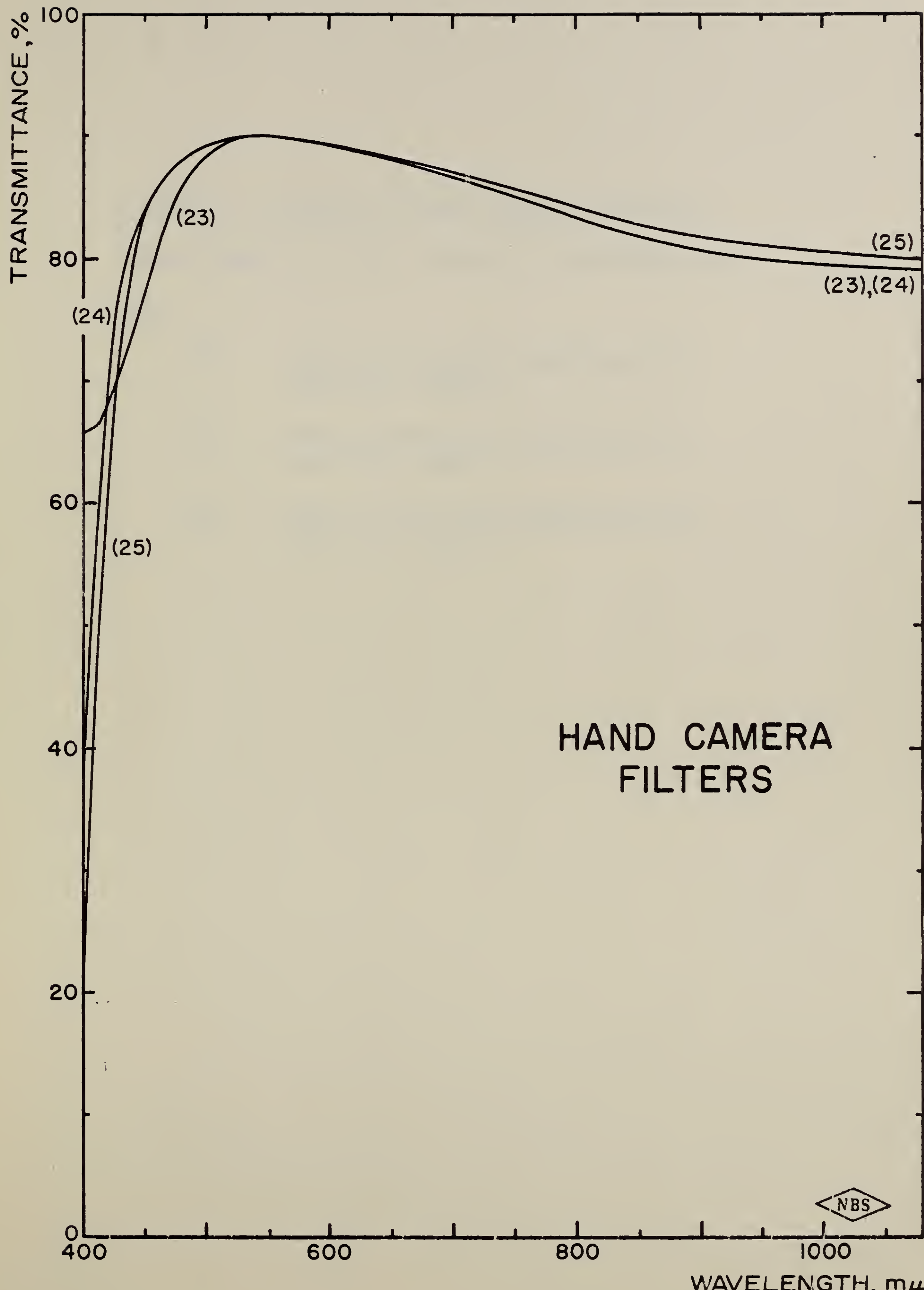

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(23)
(24)
(25)
(25)
(23),(24)
HAND CAMERA FILTERS
NBS

FIGURE 19

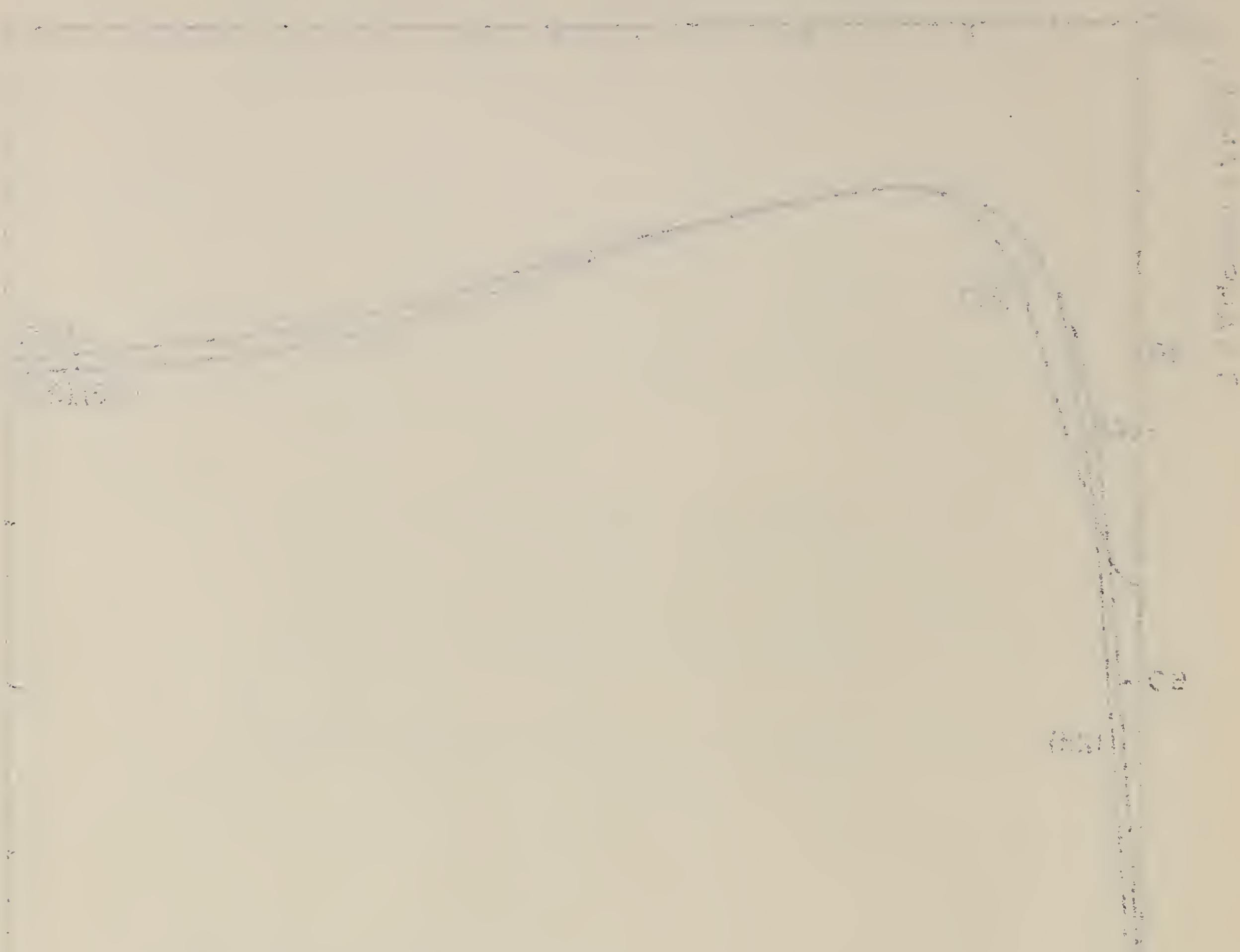


Figure 20. Visible and near infrared spectral transmittance of three ultraviolet-absorbing filters:

(26) Ansco Ultraviolet Absorbing Filter UV-15, Size 6

(27) Ansco Ultraviolet Absorbing Filter UV-16, Size 6

(28) Ansco Ultraviolet Absorbing Filter UV-17, Size 6

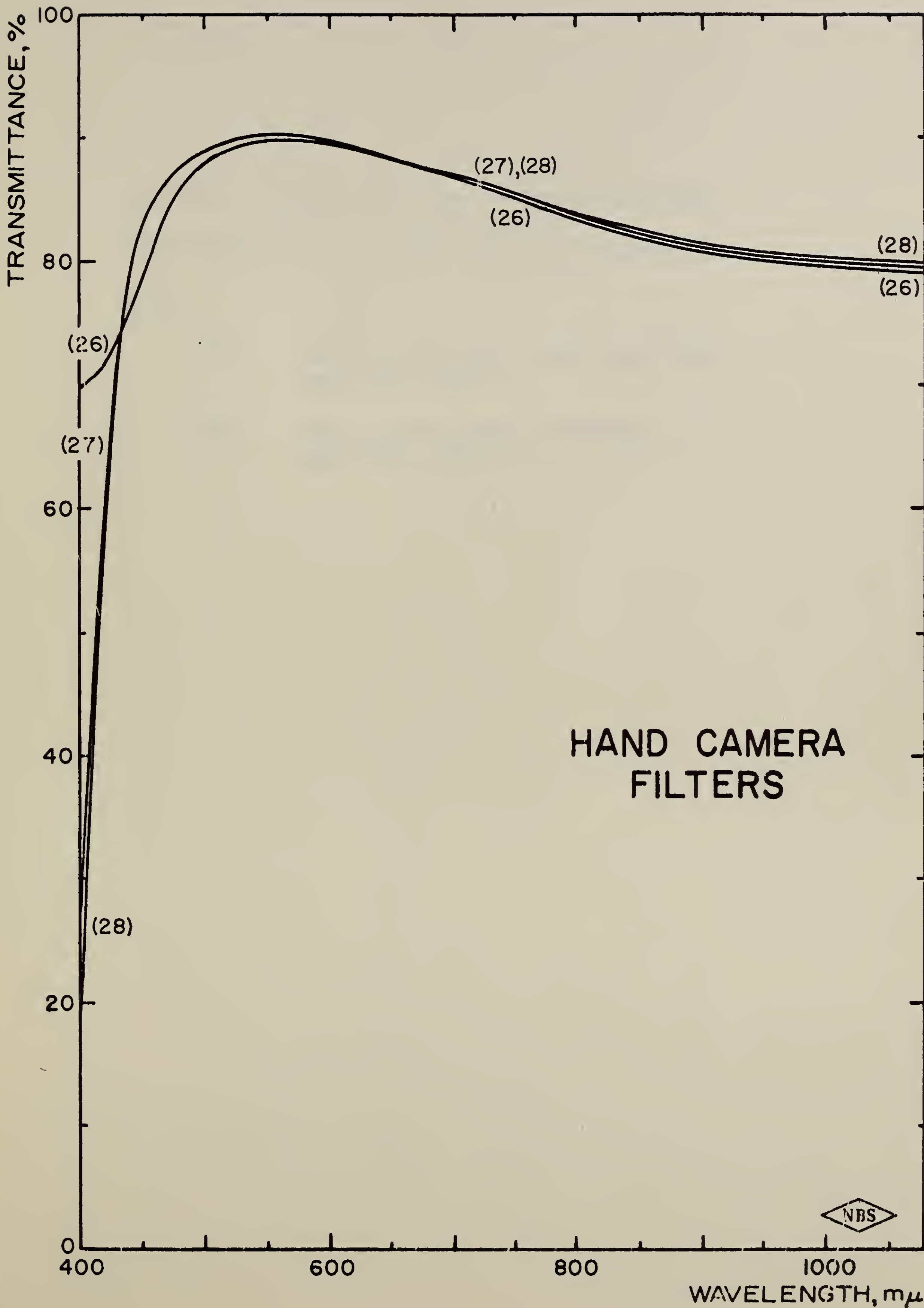

TRANSMITTANCE, %
100
80
60
40
20
0
(27),(28)
(26)
(28)
(26)
(26)
(27)
(28)
HAND CAMERA
FILTERS
NBS
400
600
800
1000
WAVELENGTH, mμ

FIGURE 20

Figure 21. Visible and near infrared spectral transmittance of two ultraviolet-absorbing filters:

(29) Ansco Ultraviolet Absorbing Filter UV-16, Size 7

(30) Ansco Ultraviolet Absorbing Filter UV-17, Size 7

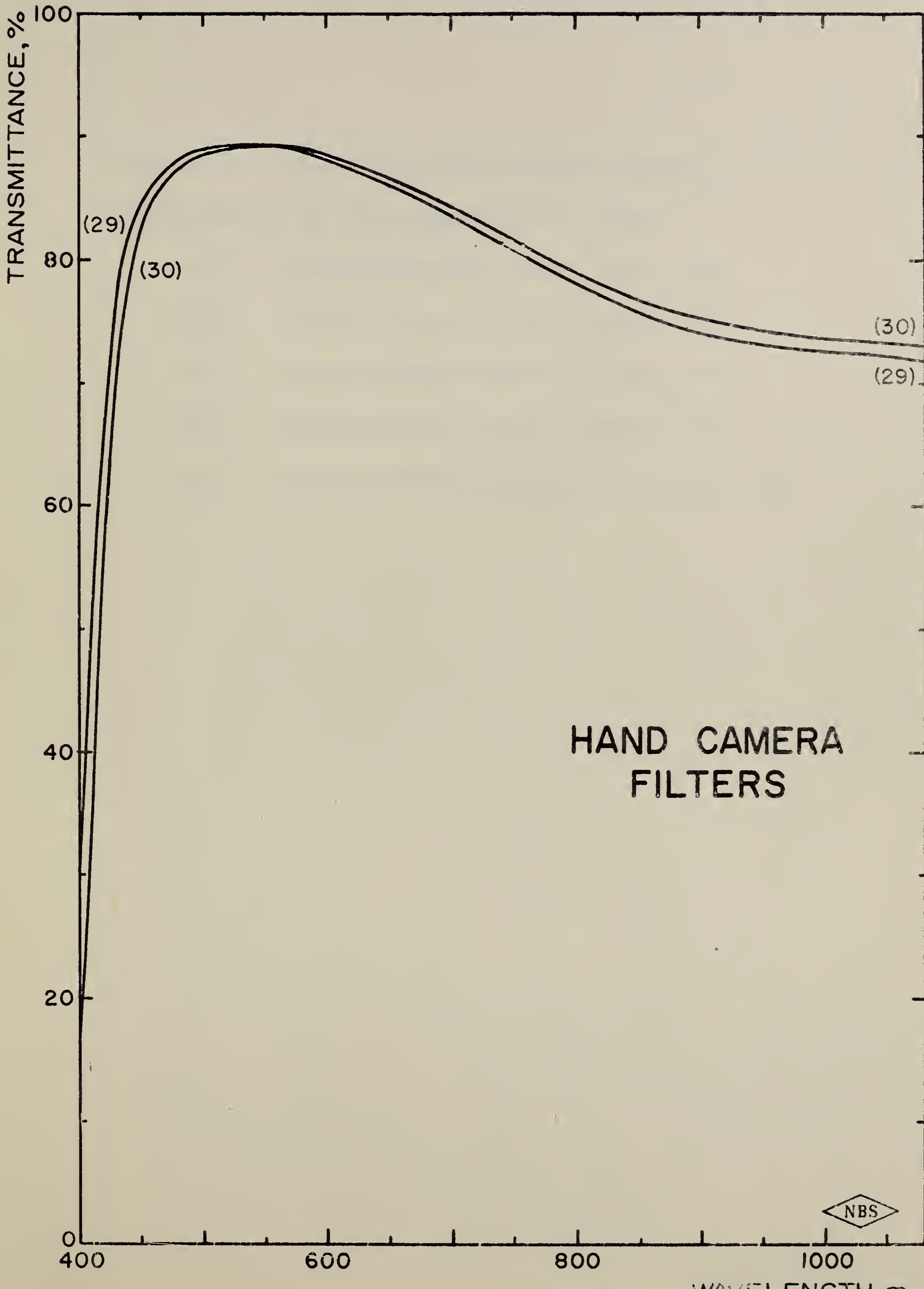

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(29)
(30)
(30)
(29)
HAND CAMERA
FILTERS
NBS

FIGURE 21

Figure 22. Visible and near infrared spectral transmittance of five photographic filters:

(31) Kodak Wratten Filter A, Series VII

(32) Kodak Wratten Filter B, Series VII

(33) Kodak Wratten Filter C5, Series VII

(34) Kodak Wratten Filter N, Series VII

(35) Kodak Wratten Filter Aero 2, Series VII

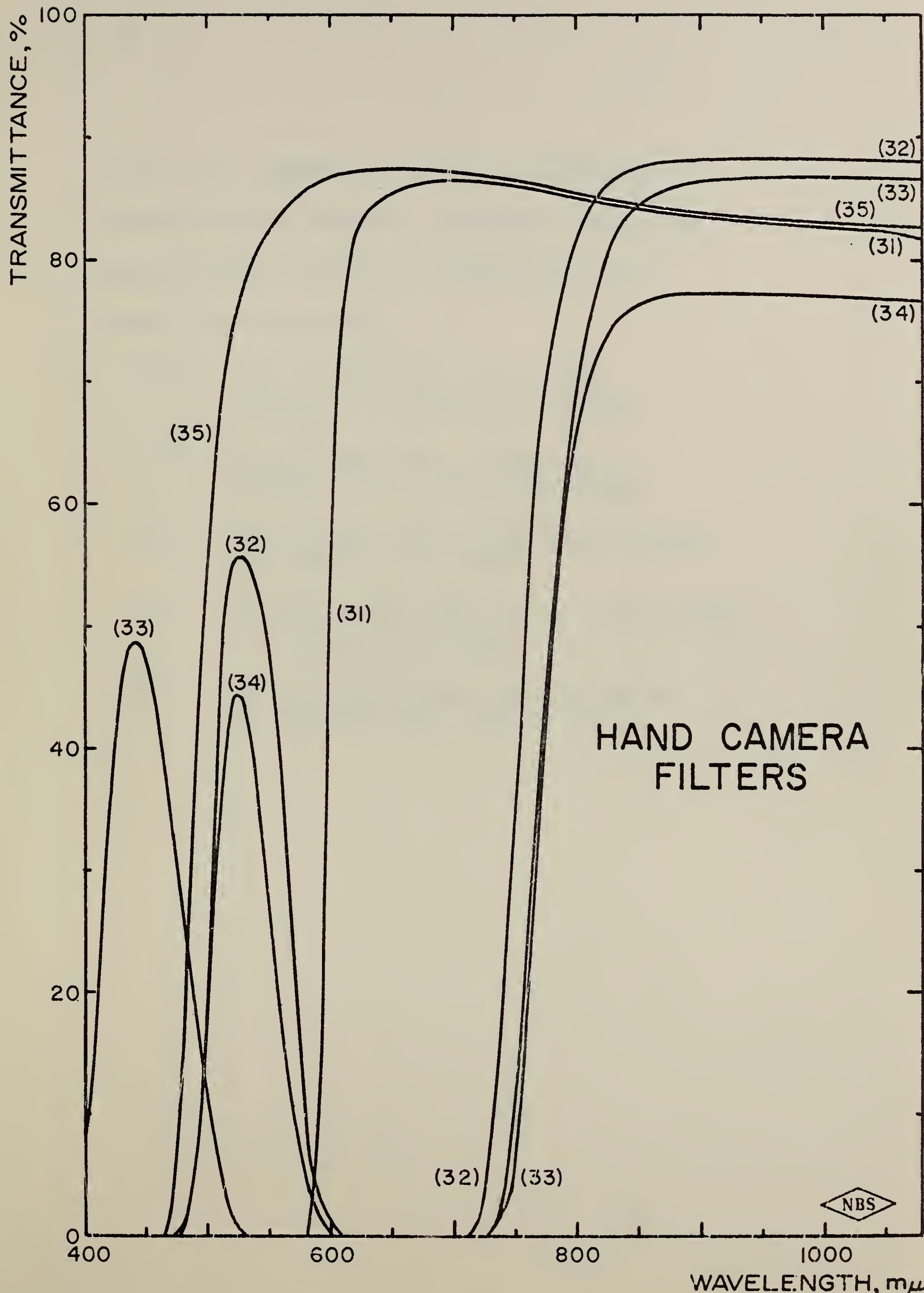

TRANSMITTANCE, %
100
80
60
40
20
0
400
600
800
1000
WAVELENGTH, mμ
(32)
(33)
(35)
(31)
(34)
(35)
(32)
(33)
(34)
(31)
(32)
(33)
HAND CAMERA
FILTERS
NBS

FIGURE 22

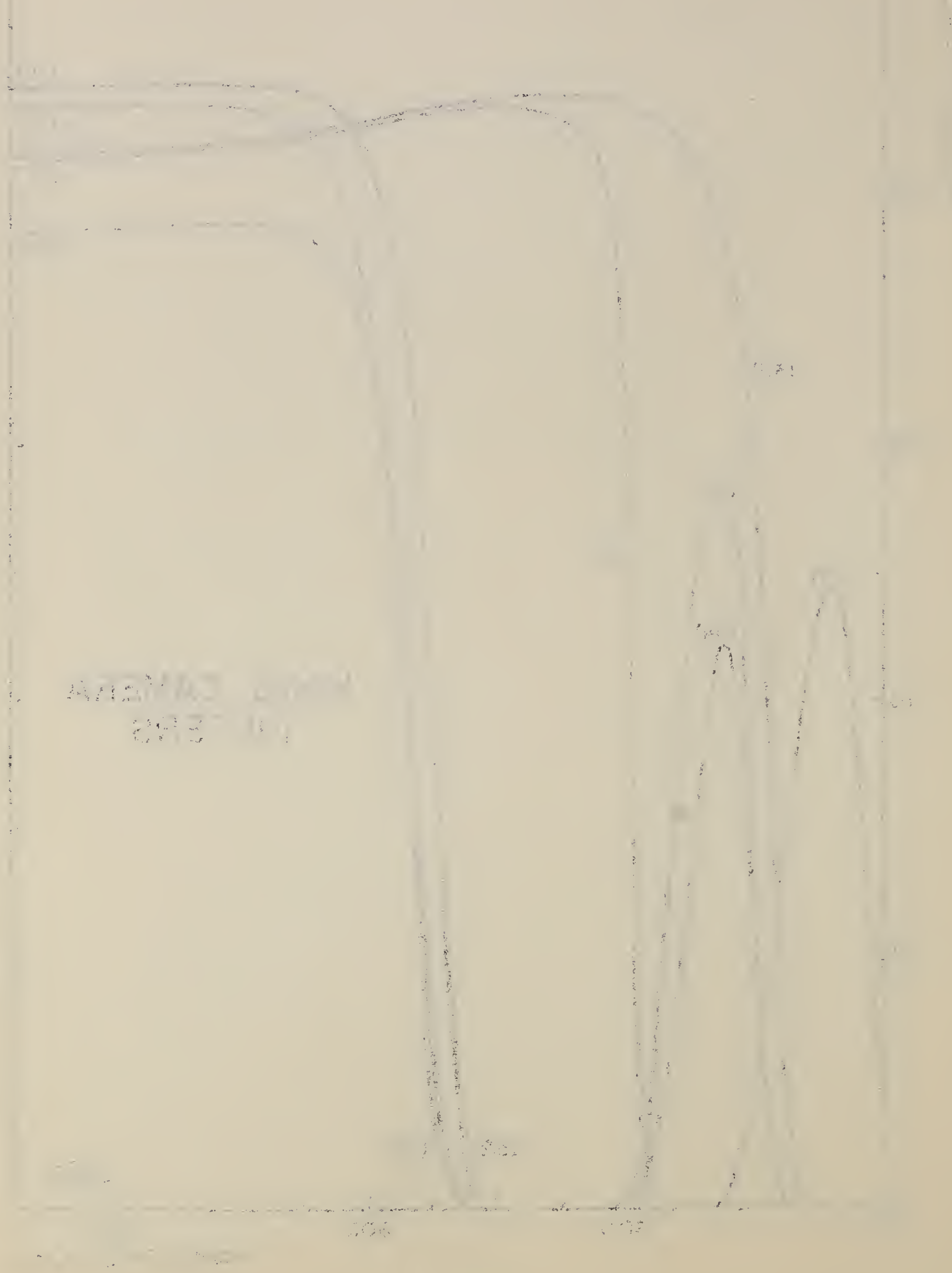


Figure 23. Segment of the C.I.E. chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates of five lenses for hand cameras:

(8) Ansco Xenon Lens, 50 mm focal length, f/2, Serial No. 2563656

(9) Kodak Ektar Lens, 80 mm focal length, f/2.8, Serial No. ET814L

(10) Leitz Elmar Lens, 90 mm focal length, f/4, Serial No. 720367

(11) Leitz Summitar Lens, 50 mm focal length, f/2, Serial No. 603453

(12) Ansco supplementary camera lens No. 30 Portrait Lens, Plus 1, Size 6

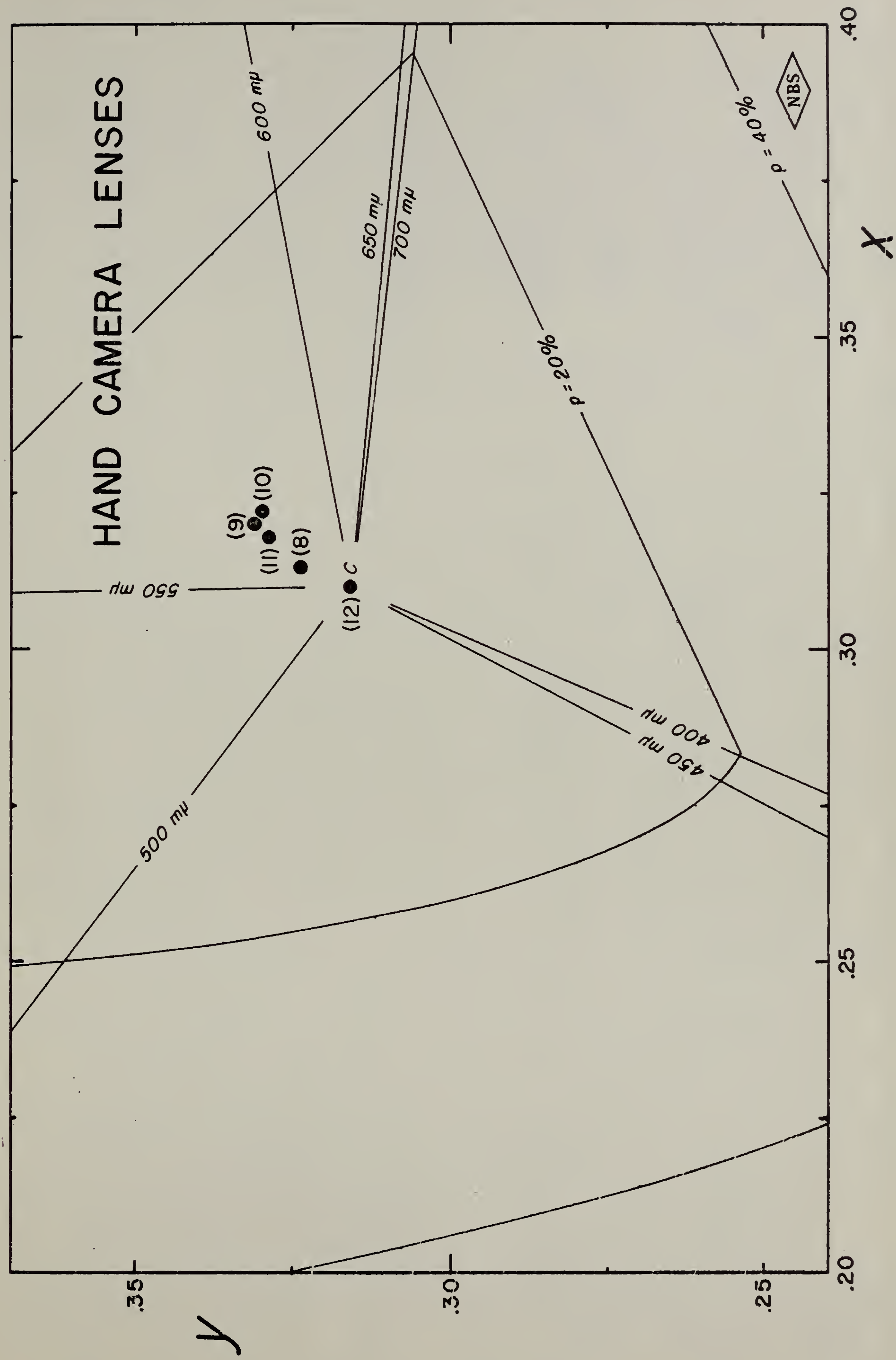

HAND CAMERA LENSES
600 mμ
650 mμ
700 mμ
550 mμ
500 mμ
450 mμ
400 mμ
ρ = 20%
ρ = 40%
(8)
(9)
(10)
(11)
(12)
C
x
y
.20
.25
.30
.35
.40

FIGURE 23

Figure 24. Segment of the C.I.E. chromaticity diagram showing the Planckian locus and dominant wavelength, excitation purity, and chromaticity coordinates of two sets of color-temperature-conversion filters:

(13) Ansco No. 10 Conversion Filter, Size 5 (sample a)

(14) Ansco No. 11 Conversion Filter, Size 5 (sample a)

(17) Ansco No. 10 Conversion Filter, Size 5 (sample b)

(18) Ansco No. 11 Conversion Filter, Size 5 (sample b)

and of three ultraviolet-absorbing filters:

(23) Ansco Ultraviolet-Absorbing Filter UV-15, Size 5

(24) Ansco Ultraviolet-Absorbing Filter UV-16, Size 5

(25) Ansco Ultraviolet-Absorbing Filter UV-17, Size 5

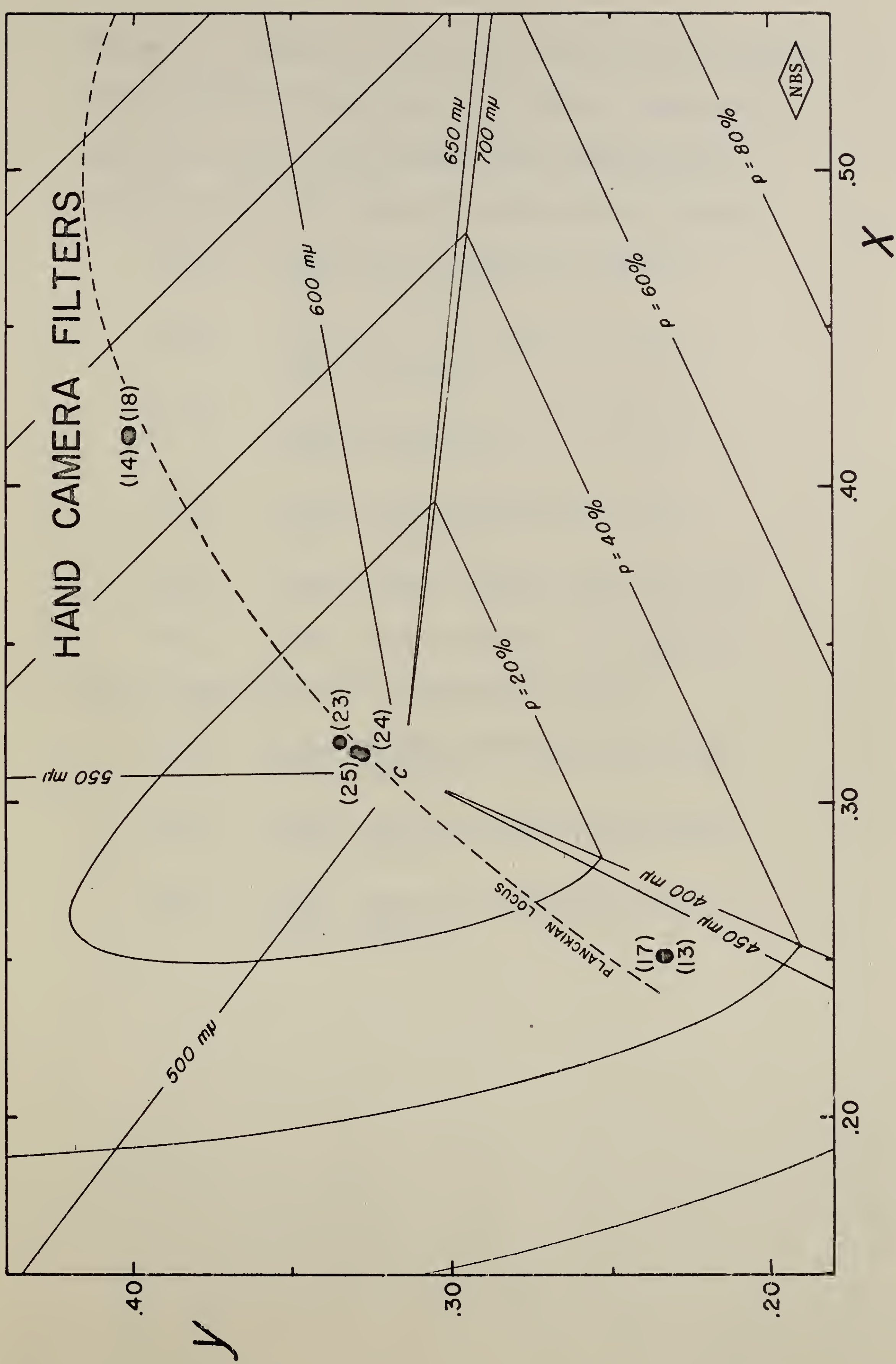

HAND CAMERA FILTERS
(14)
(18)
(23)
(24)
(25)
(17)
(13)
C
PLANCKIAN LOCUS
500 mμ
550 mμ
600 mμ
650 mμ
700 mμ
400 mμ
450 mμ
ρ = 20%
ρ = 40%
ρ = 60%
ρ = 80%
NBS
.20
.30
.40
.50
x
.20
.30
.40
y

FIGURE 24

Figure 25. Segment of the C.I.E. chromaticity diagram showing the Planckian locus and dominant wavelength, excitation purity, and chromaticity coordinates of three sets of color-temperature-conversion filters:

(15) Ansco No. 10 Conversion Filter, Size 6 (sample a)

(16) Ansco No. 11 Conversion Filter, Size 6 (sample a)

(19) Ansco No. 10 Conversion Filter, Size 6 (sample b)

(20) Ansco No. 11 Conversion Filter, Size 6 (sample b)

(21) Kodak Wratten Filter 80A, Series VI

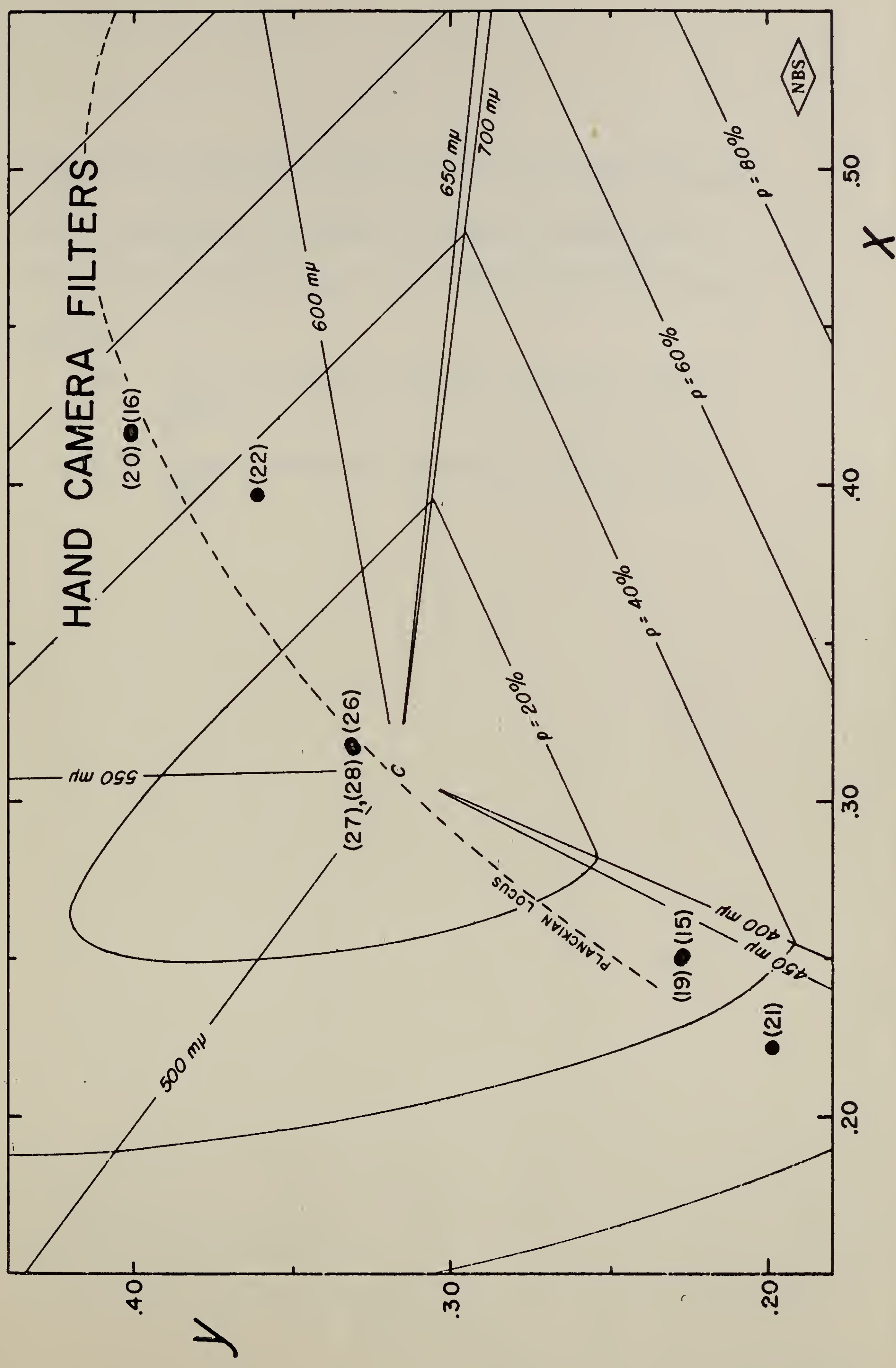
(22) Kodak Wratten Filter 85, Series VI

and of three ultraviolet absorbing filters:

(26) Ansco Ultraviolet-Absorbing Filter UV-15, Size 6

(27) Ansco Ultraviolet-Absorbing Filter UV-16, Size 6

(28) Ansco Ultraviolet-Absorbing Filter UV-17, Size 6



HAND CAMERA FILTERS
x
y
.20
.30
.40
.50
500 mμ
550 mμ
600 mμ
650 mμ
700 mμ
400 mμ
450 mμ
ρ = 20%
ρ = 40%
ρ = 60%
ρ = 80%
PLANCKIAN LOCUS
C
(20) (16)
(22)
(27),(28) (26)
(19) (15)
(21)
NBS

FIGURE 25

Figure 26. Segment of the C.I.E. chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates of two ultraviolet-absorbing filters:

(29) Ansco Ultraviolet Absorbing Filter UV-16, Size 7

(30) Ansco Ultraviolet Absorbing Filter UV-17, Size 7

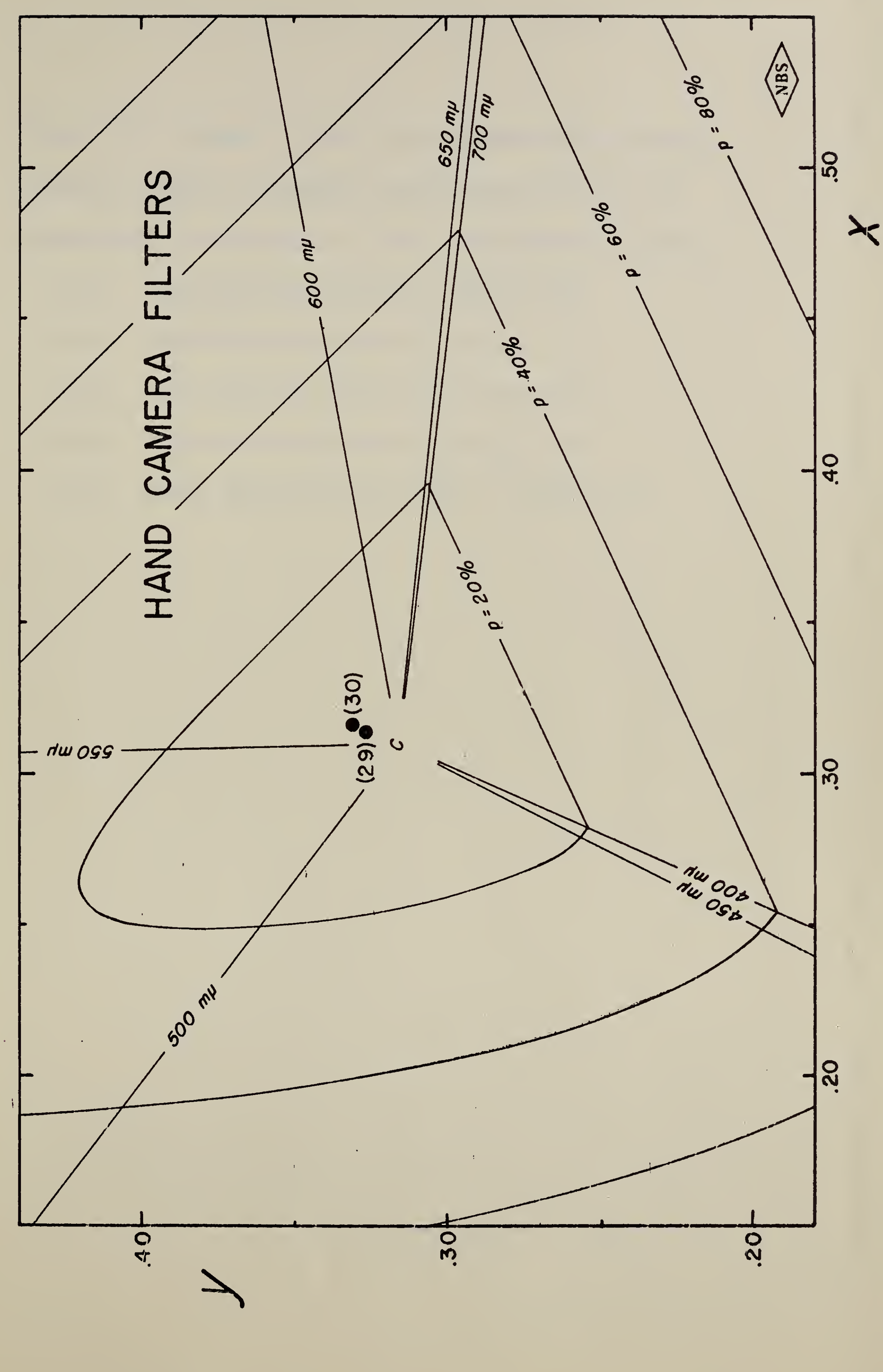

HAND CAMERA FILTERS
NBS
600 mμ
650 mμ
700 mμ
550 mμ
500 mμ
450 mμ
400 mμ
ρ = 20%
ρ = 40%
ρ = 60%
ρ = 80%
(29)
(30)
C
x
y
.20
.30
.40
.50

FIGURE 26

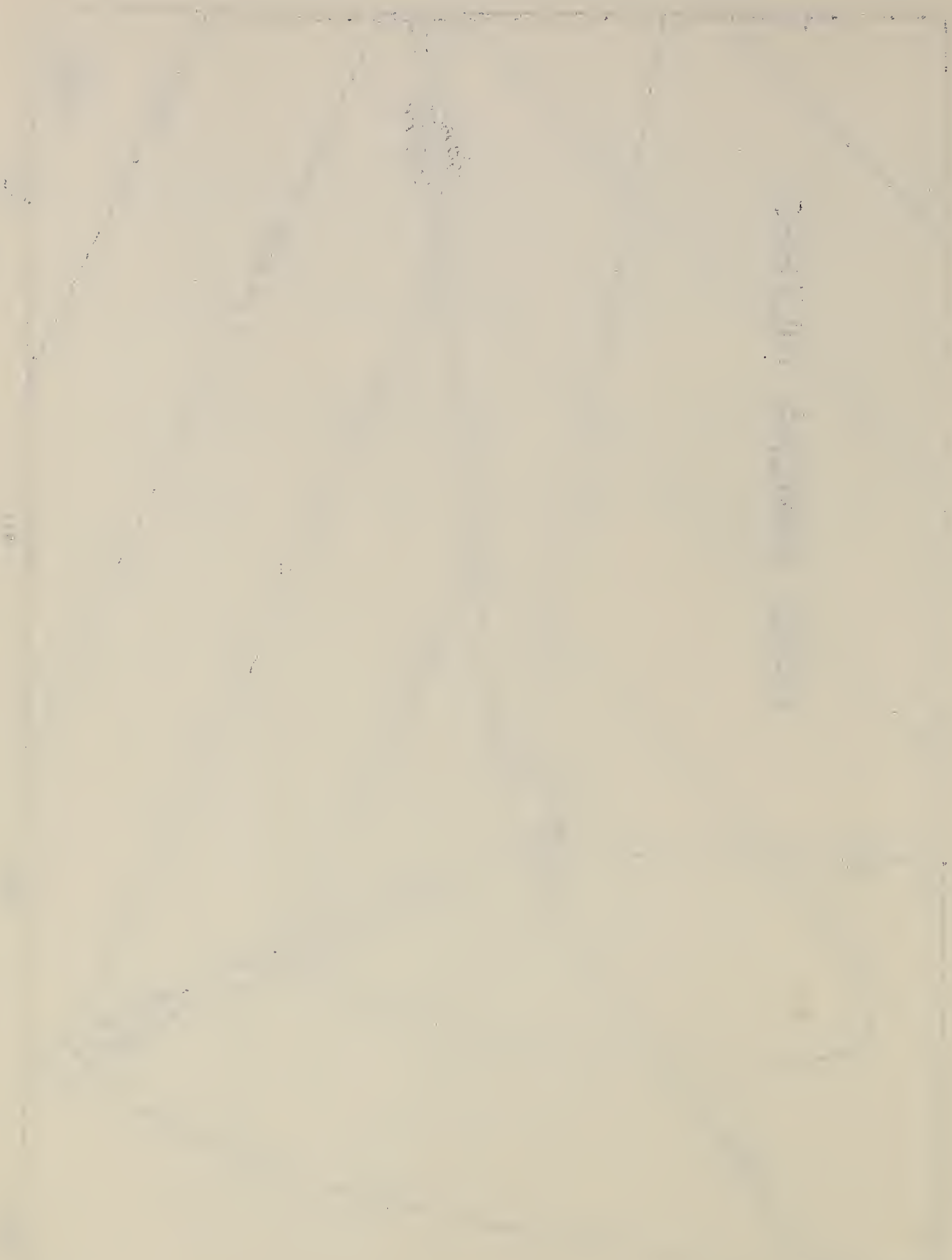


Figure 27. Segment of the C.I.E. chromaticity diagram showing dominant wavelength, excitation purity, and chromaticity coordinates of five photographic filters:

(31) Kodak Wratten Filter A, Series VII

(32) Kodak Wratten Filter B, Series VII

(33) Kodak Wratten Filter C5, Series VII

(34) Kodak Wratten Filter N, Series VII

(35) Kodak Wratten Filter Aero 2, Series VII

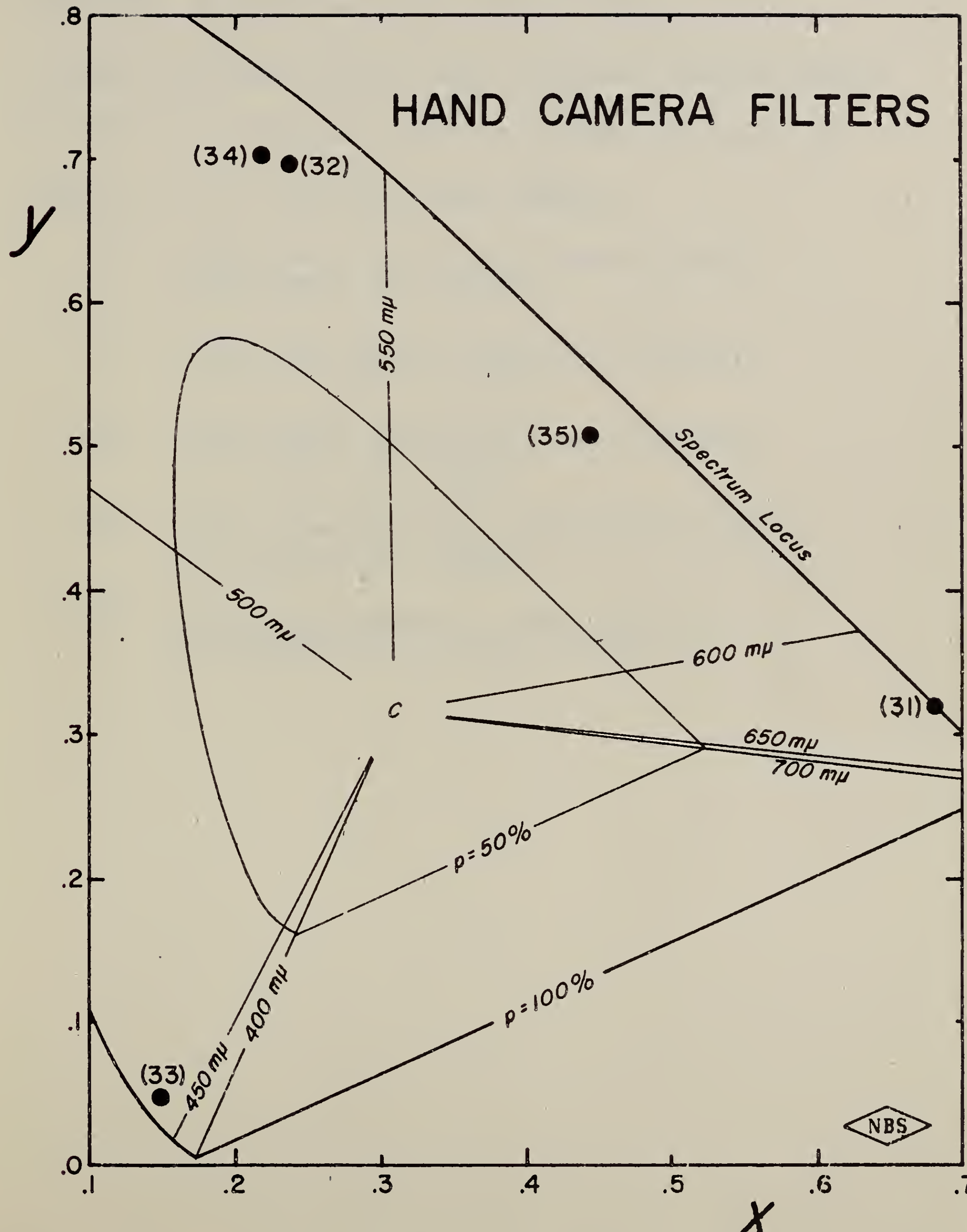

HAND CAMERA FILTERS
(34)
(32)
(35)
(31)
(33)
550 mμ
500 mμ
600 mμ
650 mμ
700 mμ
450 mμ
400 mμ
C
p=50%
p=100%
Spectrum Locus
NBS
y
x
.8
.7
.6
.5
.4
.3
.2
.1
.0
.1
.2
.3
.4
.5
.6
.7

FIGURE 27

Figure 28. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram of five lenses for hand cameras:

(8) Ansco Xenon Lens, 50 mm focal length, f/2, Serial No. 2563656

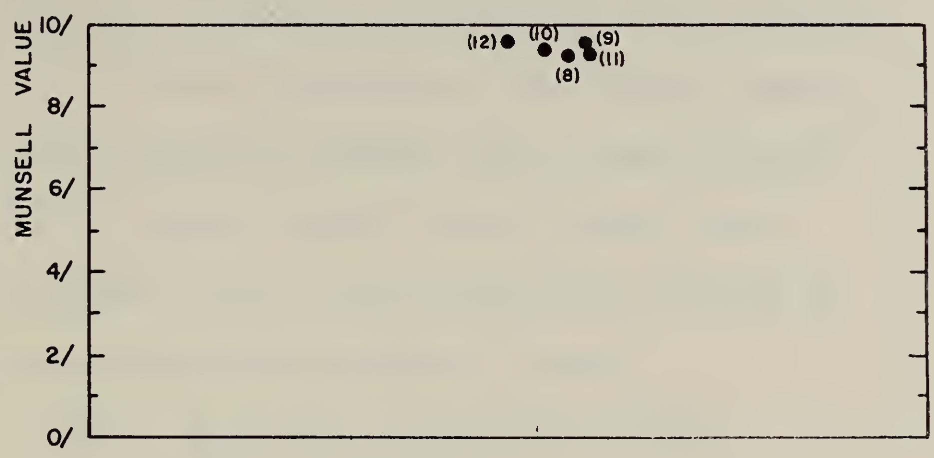
(9) Kodak Ektar Lens, 80 mm focal length, f/2.8, Serial No. ET814L

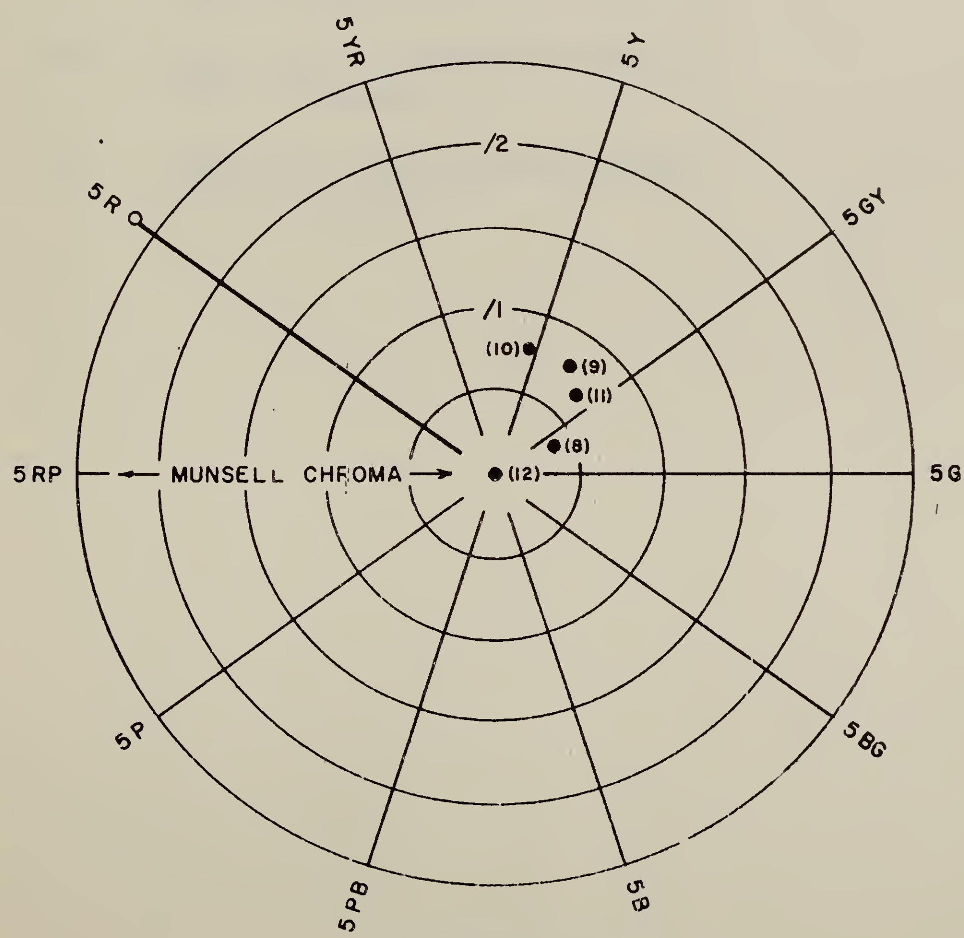
(10) Leitz Elmar Lens, 90 mm focal length, f/4, Serial No. 720367

(11) Leitz Summitar Lens, 50 mm focal length, f/2, Serial No. 603453

(12) Ansco supplementary camera lens No. 30 Portrait Lens, Plus 1, Size 6

HAND CAMERA LENSES





NBS

FIGURE 28

Figure 29. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram for two sets of color-temperature-conversion filters:

(13) Ansco No. 10 Conversion Filter, Size 5 (sample a)

(14) Ansco No. 11 Conversion Filter, Size 5 (sample a)

(17) Ansco No. 10 Conversion Filter, Size 5 (sample b)

(18) Ansco No. 11 Conversion Filter, Size 5 (sample b)

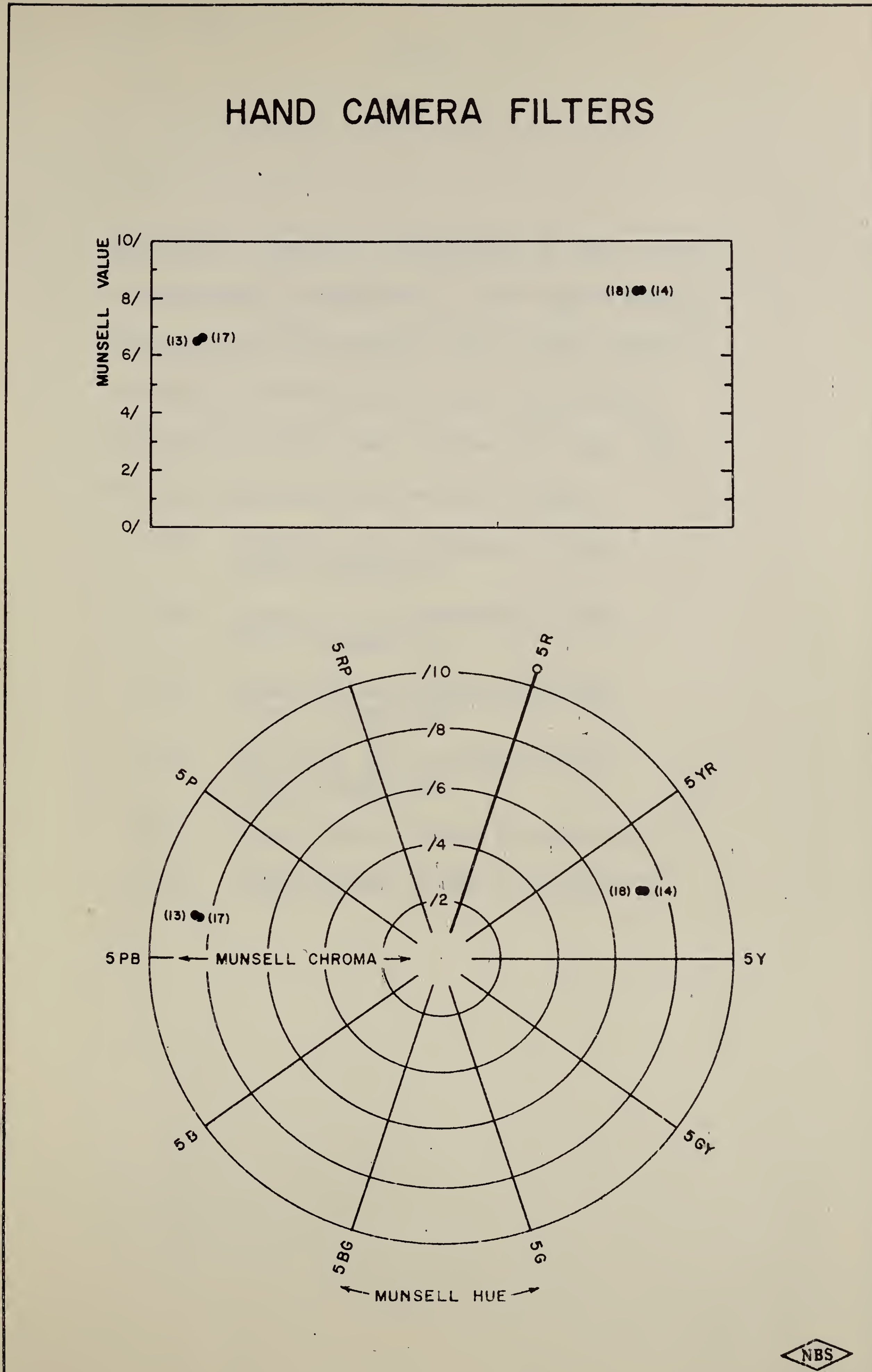

HAND CAMERA FILTERS
MUNSELL VALUE
10/
8/
6/
4/
2/
0/
(13)
(17)
(18)
(14)
5R
5RP
/10
/8
/6
/4
/2
5P
5YR
5PB
MUNSELL CHROMA
5Y
5B
5GY
5BG
5G
MUNSELL HUE
NBS

FIGURE 29

Figure 30. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram for three sets of color-temperature-conversion filters:

(15) Ansco No. 10 Conversion Filter, Size 6 (sample a)

(16) Ansco No. 11 Conversion Filter, Size 6 (sample a)

(19) Ansco No. 10 Conversion Filter, Size 6 (sample b)

(20) Ansco No. 11 Conversion Filter, Size 6 (sample b)

(21) Kodak Wratten Filter 80A, Series VI

(22) Kodak Wratten Filter 85, Series VI

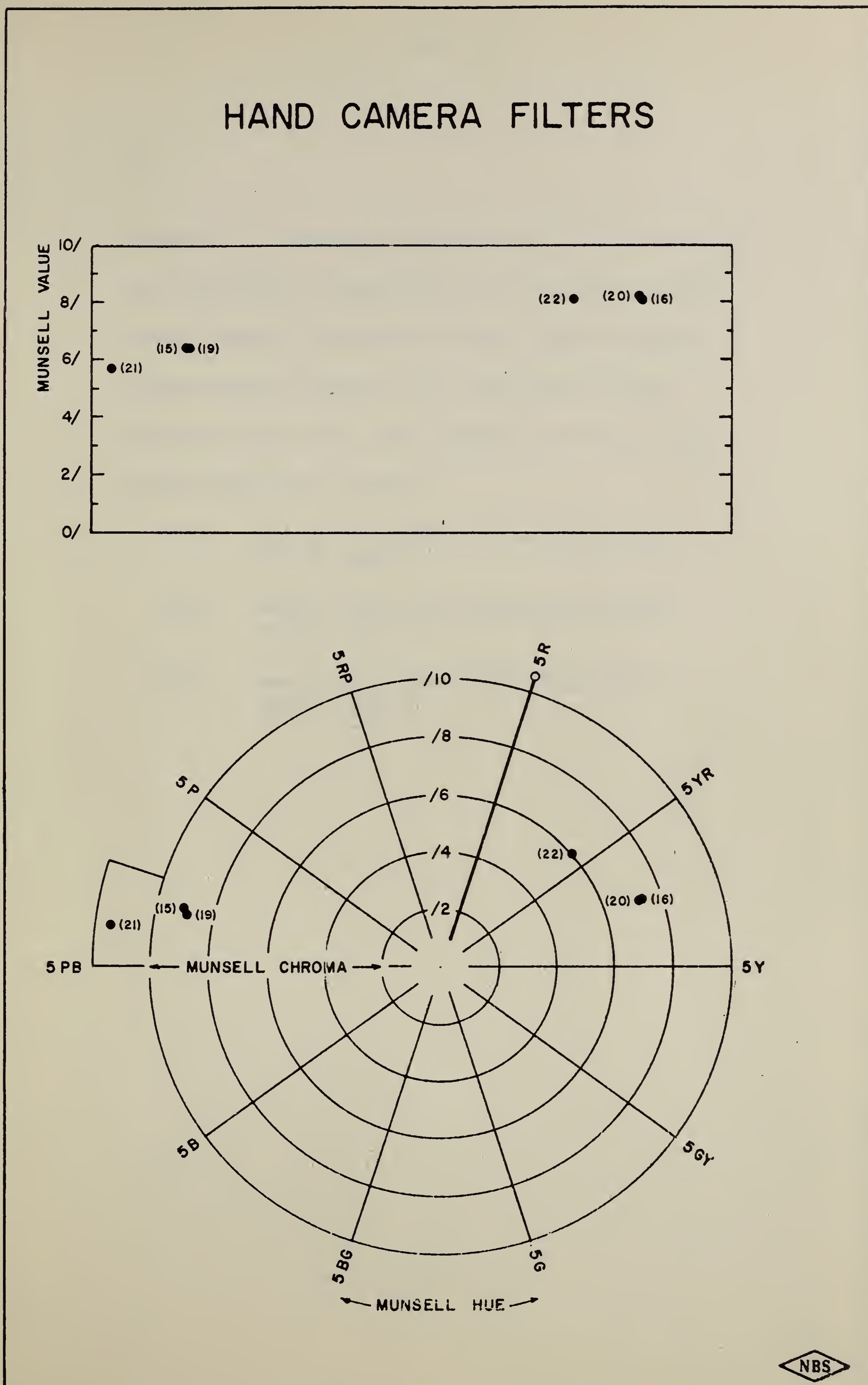

HAND CAMERA FILTERS
MUNSELL VALUE
10/
8/
6/
4/
2/
0/
(22)
(20)
(16)
(15)
(19)
(21)
5RP
/10
5R
/8
5P
/6
5YR
/4
(22)
(20)
(16)
(15)
(19)
/2
(21)
5 PB
MUNSELL CHROMA
5Y
5B
5GY
5BG
5G
MUNSELL HUE
NBS

FIGURE 30

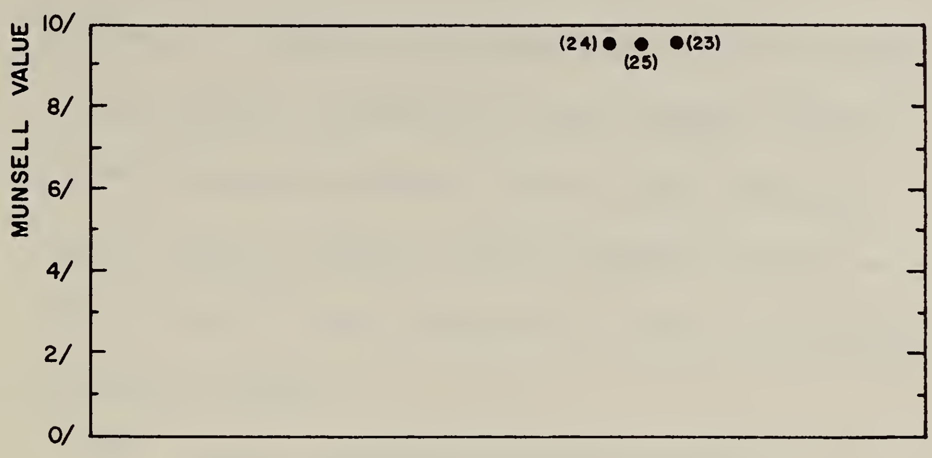
Figure 31. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram for three ultra-violet-absorbing filters:

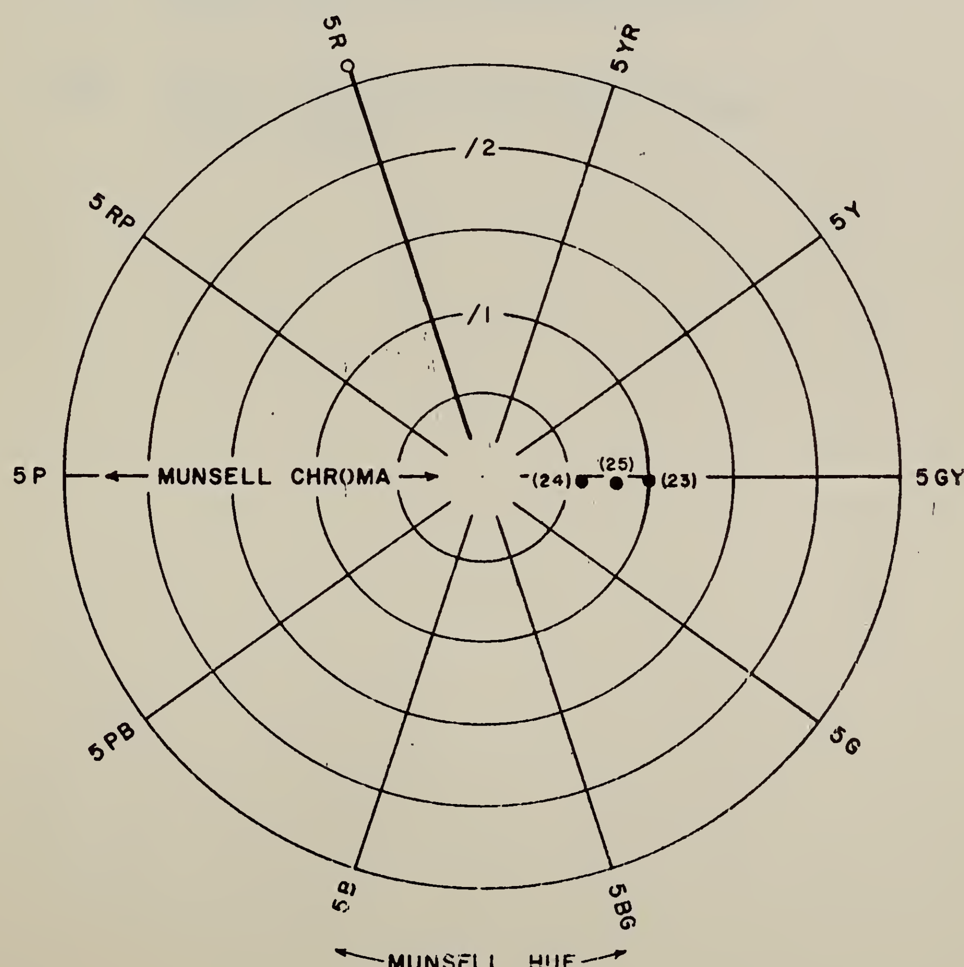
(23) Ansco Ultraviolet Absorbing Filter UV-15, Size 5

(24) Ansco Ultraviolet Absorbing Filter UV-16, Size 5

(25) Ansco Ultraviolet Absorbing Filter UV-17, Size 5

HAND CAMERA FILTERS





NBS

FIGURE 31

Figure 32. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram for three ultraviolet-absorbing filters:

(26) Ansco Ultraviolet Absorbing Filter UV-15, Size 6

(27) Ansco Ultraviolet Absorbing Filter UV-16, Size 6

(28) Ansco Ultraviolet Absorbing Filter UV-17, Size 6

HAND CAMERA FILTERS

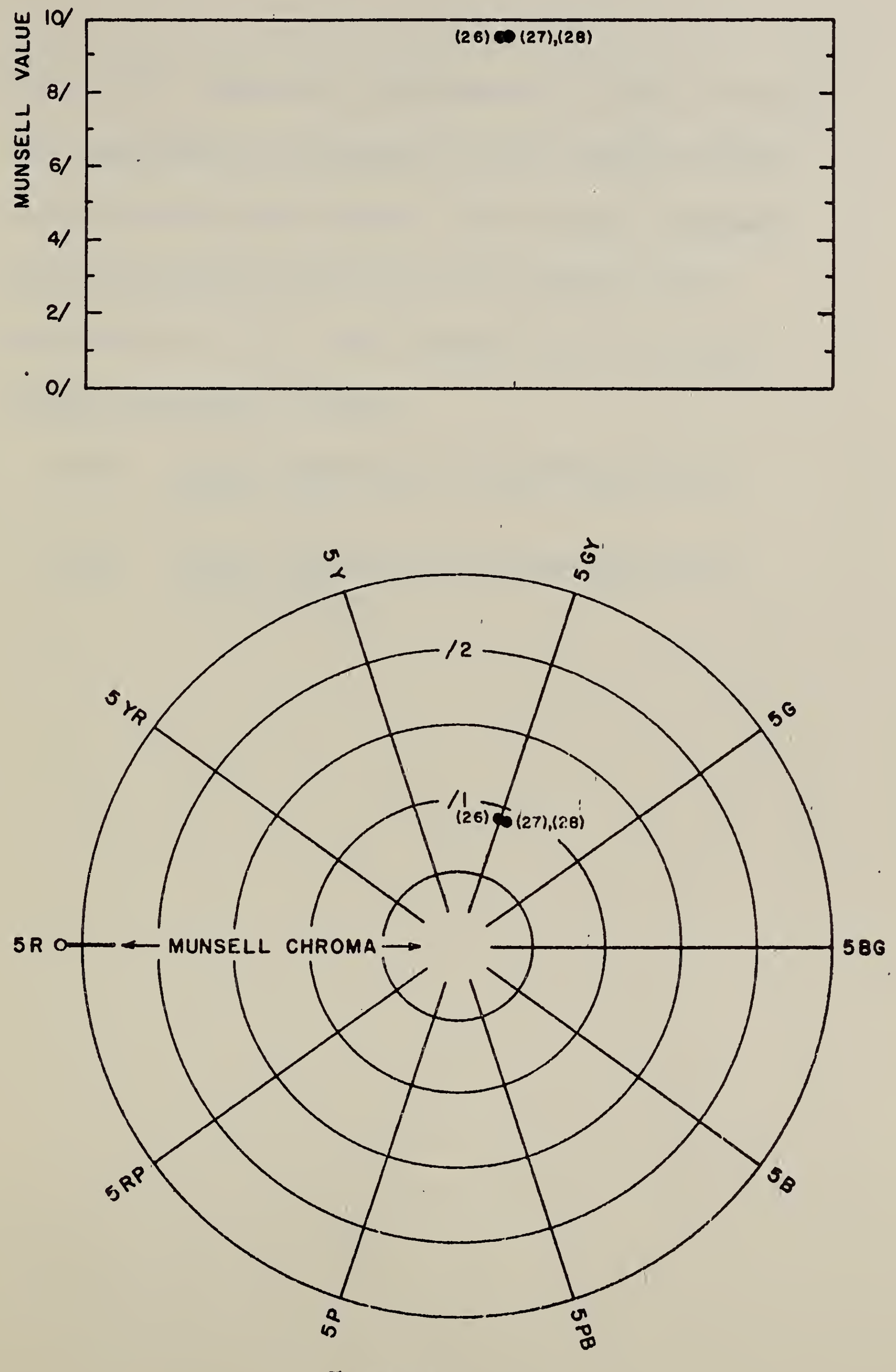


FIGURE 32

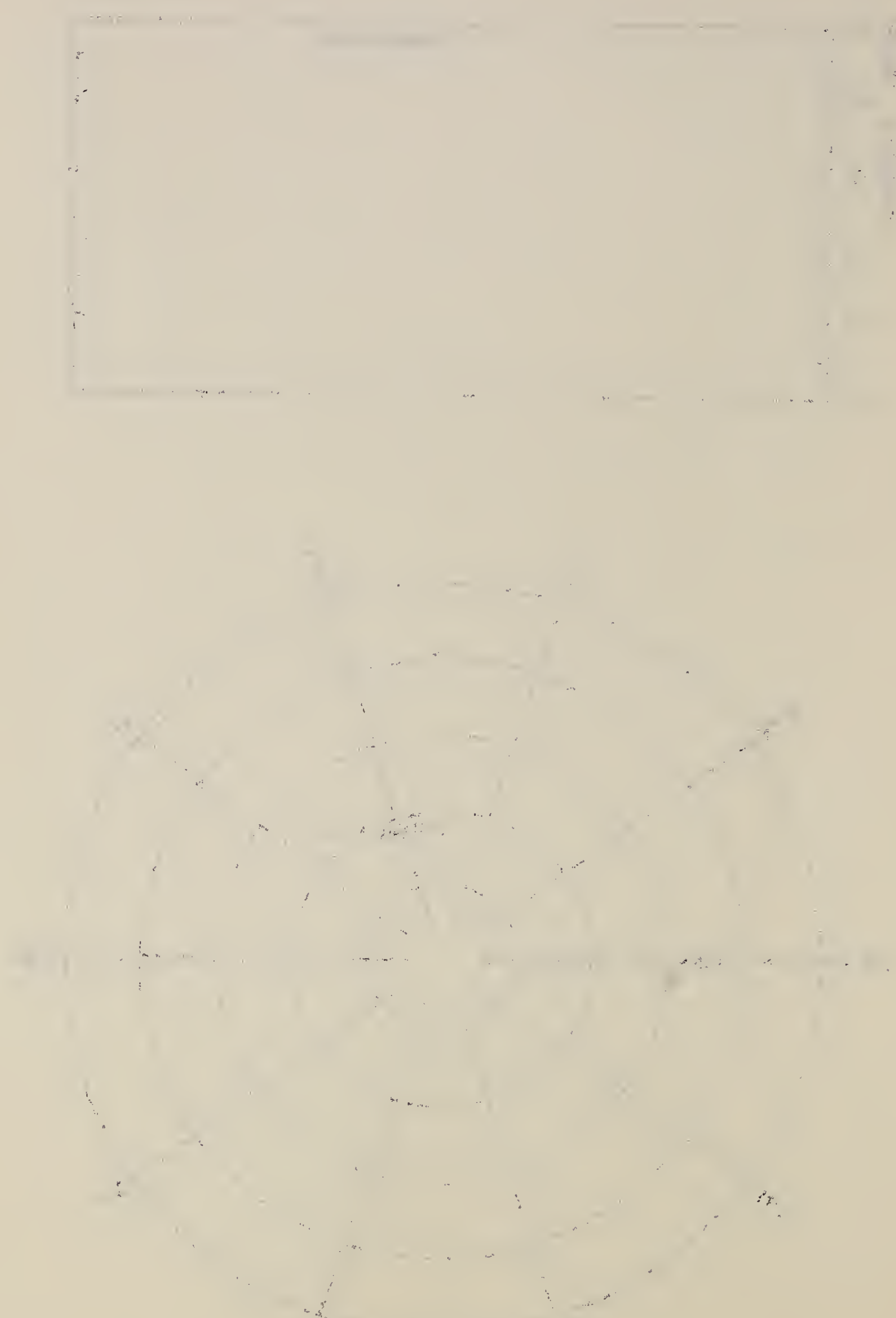


Figure 33. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram for two ultra-violet-absorbing filters:

(29) Ansco Ultraviolet Absorbing Filter UV-16, Size 7

(30) Ansco Ultraviolet Absorbing Filter UV-17, Size 7

HAND CAMERA FILTERS

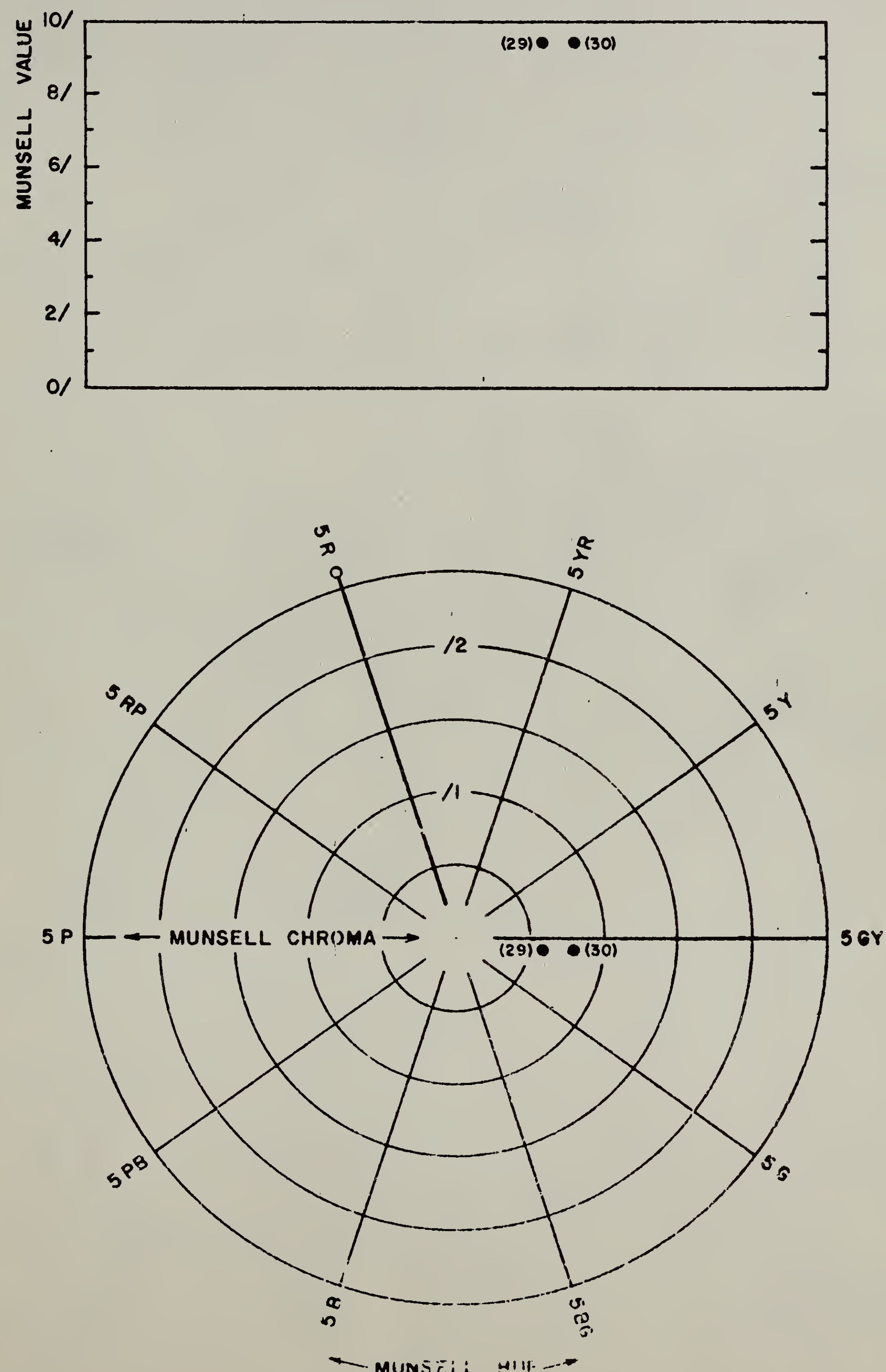


FIGURE 33

[illegible]

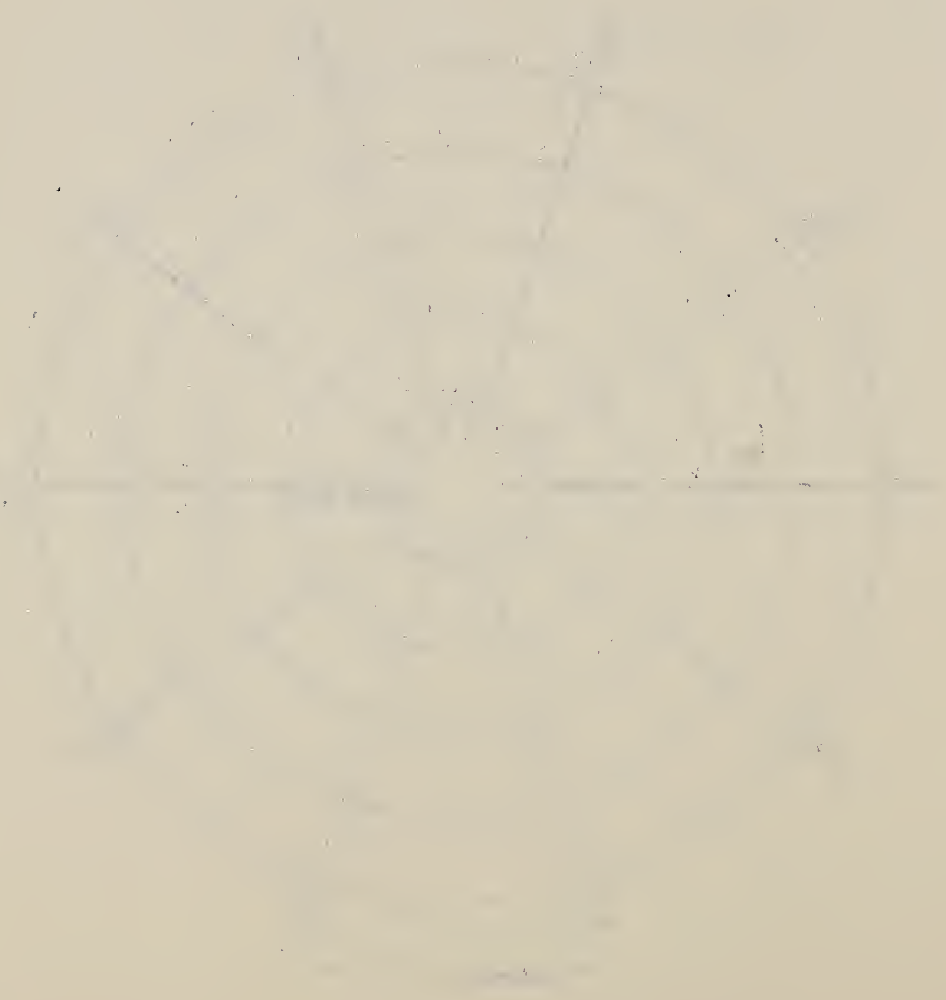


Figure 34. Schematic illustration of the vertical and horizontal projections of the "ideal" Munsell system showing the Munsell Value (upper diagram) plotted against Munsell Hue and Chroma points projected from the lower diagram for five photographic filters:

(31) Kodak Wratten Filter A, Series VII

(32) Kodak Wratten Filter B, Series VII

(33) Kodak Wratten Filter C5, Series VII

(34) Kodak Wratten Filter N, Series VII

(35) Kodak Wratten Filter Aero 2, Series VII

HAND CAMERA FILTERS

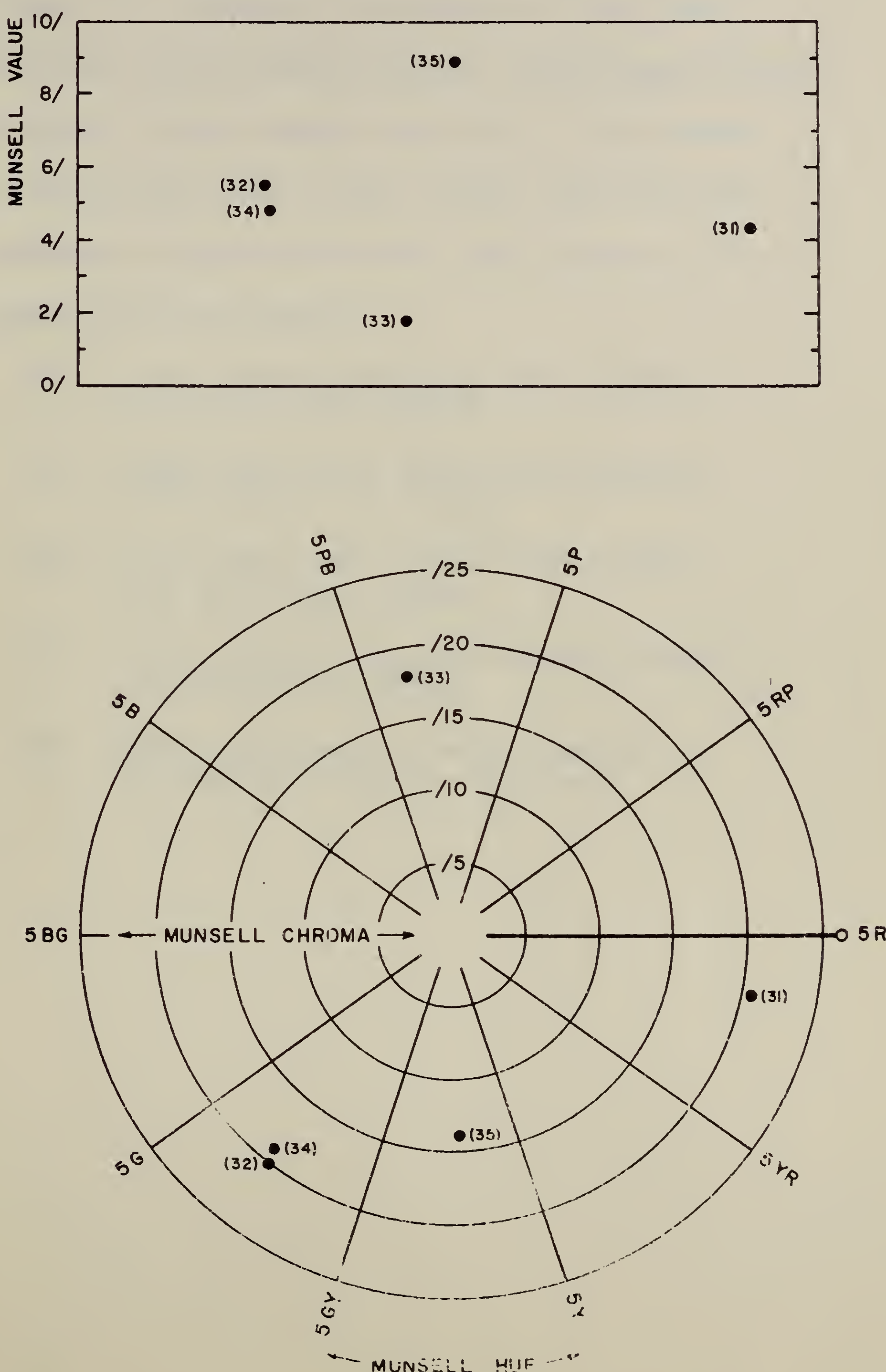


FIGURE 34

Figure 35. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram of five lenses for hand cameras:

(8) Ansco Xenon Lens, 50 mm focal length, f/2, Serial No. 2563656

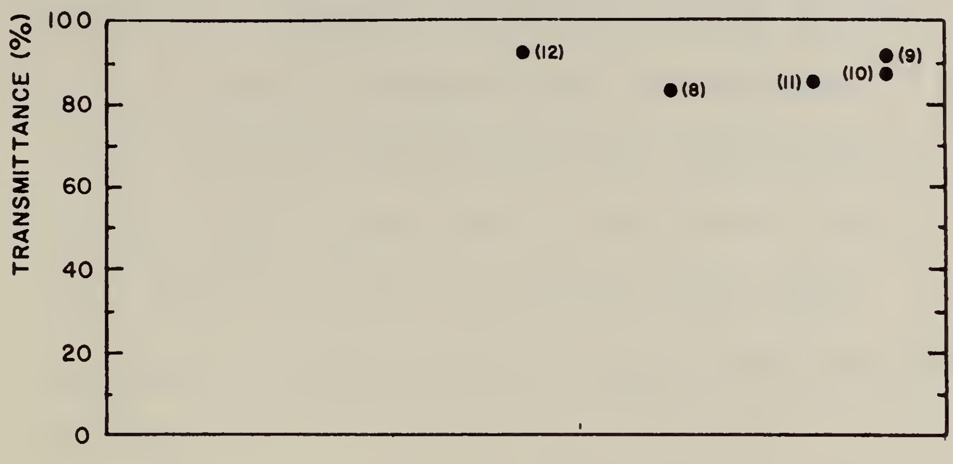
(9) Kodak Ektar Lens, 80 mm focal length, f/2.8, Serial No. ET814L

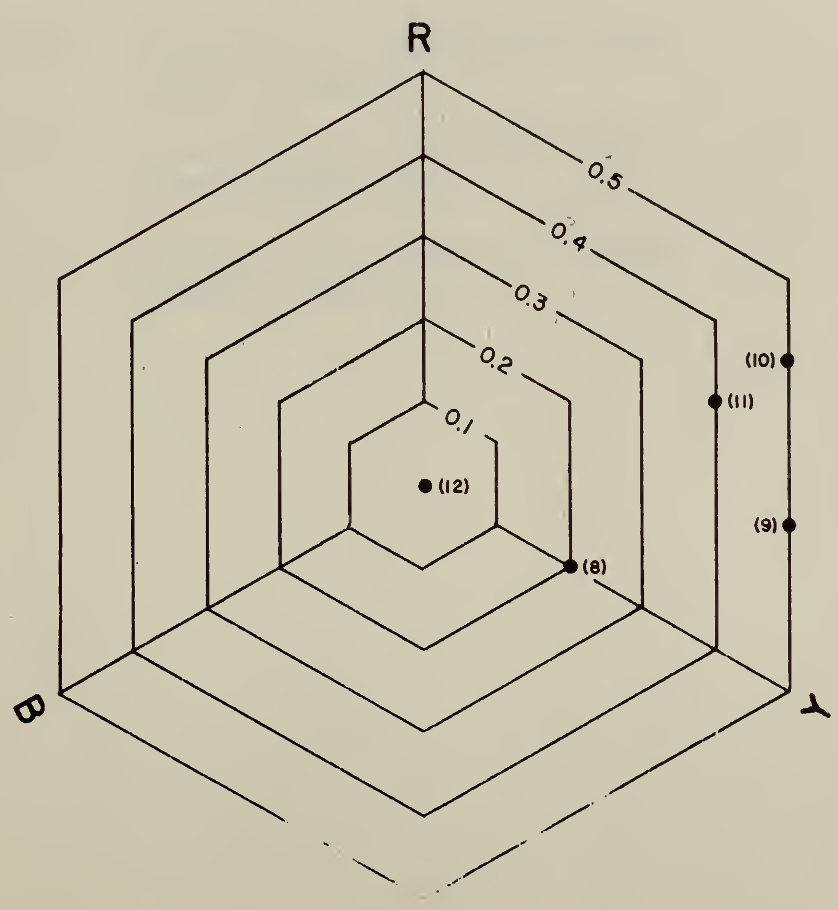
(10) Leitz Elmar Lens, 90 mm focal length, f/4, Serial No. 720367

(11) Leitz Summitar Lens, 50 mm focal length, f/2, Serial No. 603453

(12) Ansco supplementary camera lens No. 30 Portrait Lens, Plus 1, Size 6

HAND CAMERA LENSES





NBS

FIGURE 35

Figure 36. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram for two sets of color-temperature-conversion filters:

(13) Ansco No. 10 Conversion Filter, Size 5 (sample a)

(14) Ansco No. 11 Conversion Filter, Size 5 (sample a)

(17) Ansco No. 10 Conversion Filter, Size 5 (sample b)

(18) Ansco No. 11 Conversion Filter, Size 5 (sample b)

HAND CAMERA FILTERS

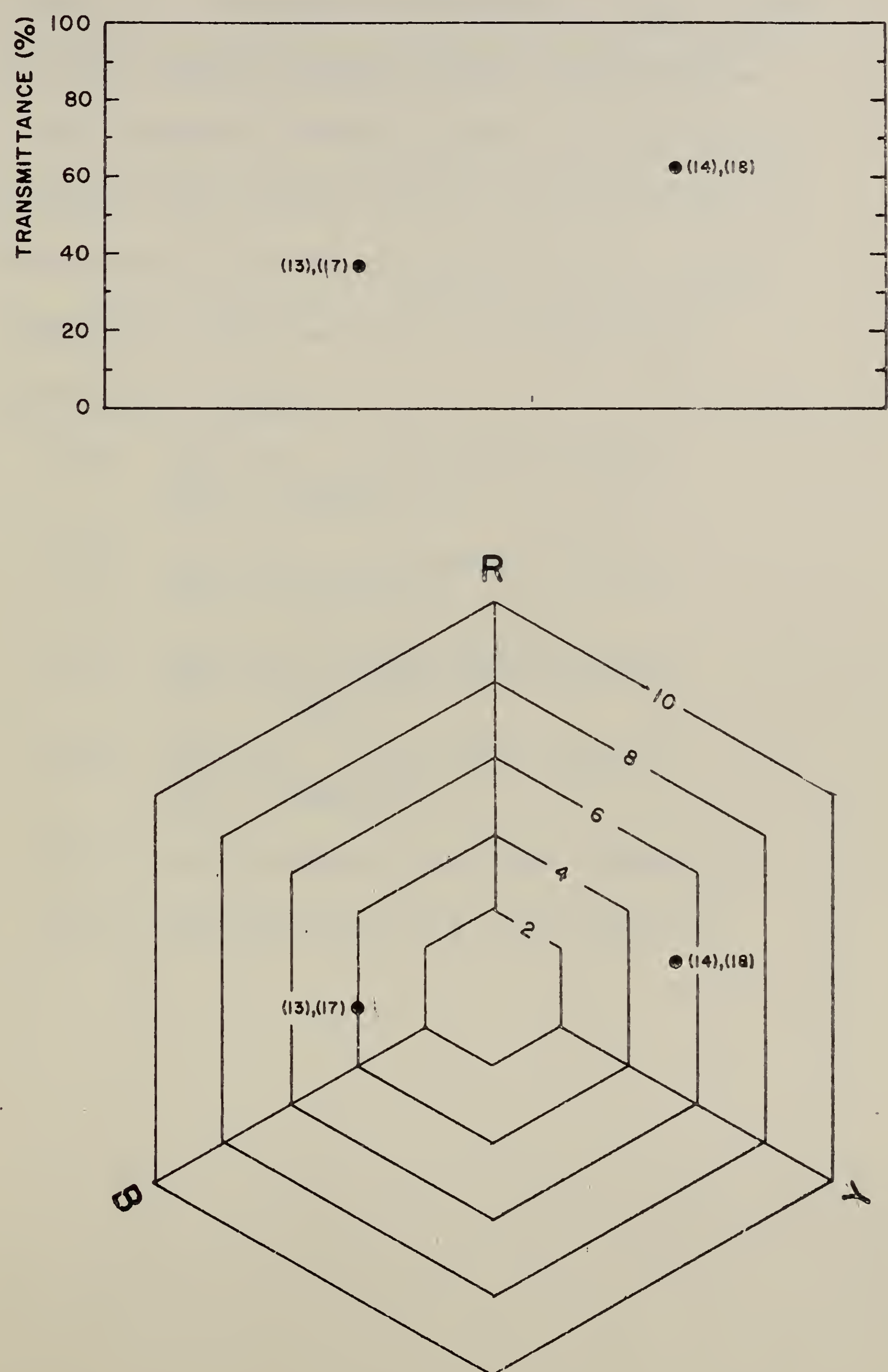


FIGURE 36

Figure 37. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram for three sets of color-temperature-conversion filters:

(15) Ansco No. 10 Conversion Filter, Size 6 (sample a)

(16) Ansco No. 11 Conversion Filter, Size 6 (sample a)

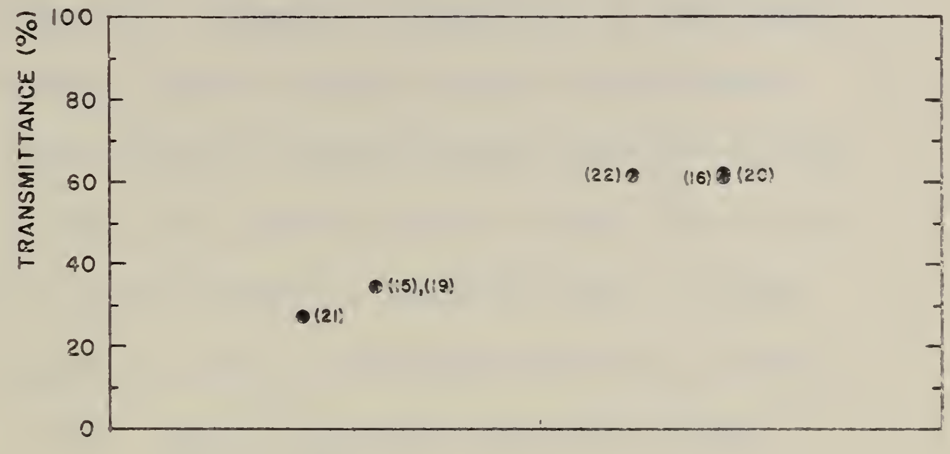
(19) Ansco No. 10 Conversion Filter, Size 6 (sample b)

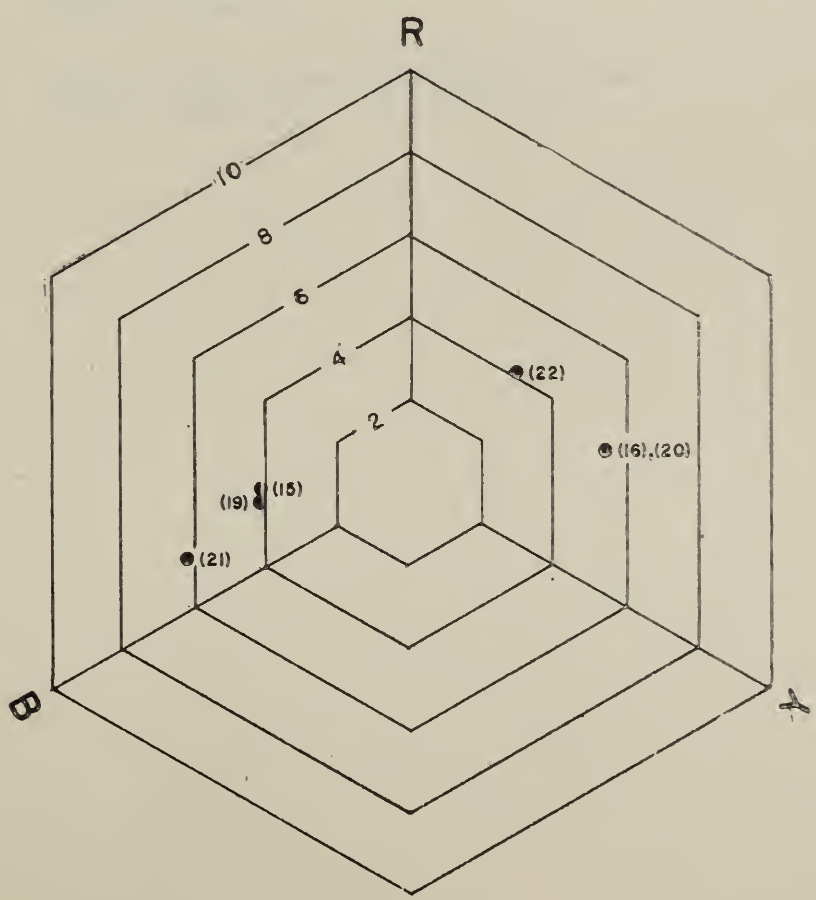
(20) Ansco No. 11 Conversion Filter, Size 6 (sample b)

(21) Kodak Wratten Filter 80A, Series VI

(22) Kodak Wratten Filter 85, Series VI

HAND CAMERA FILTERS





NBS

FIGURE 37

Figure 38. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram for three ultraviolet-absorbing filters:

(23) Ansco Ultraviolet Absorbing Filter UV-15, Size 5

(24) Ansco Ultraviolet Absorbing Filter UV-16, Size 5

(25) Ansco Ultraviolet Absorbing Filter UV-17, Size 5

HAND CAMERA FILTERS

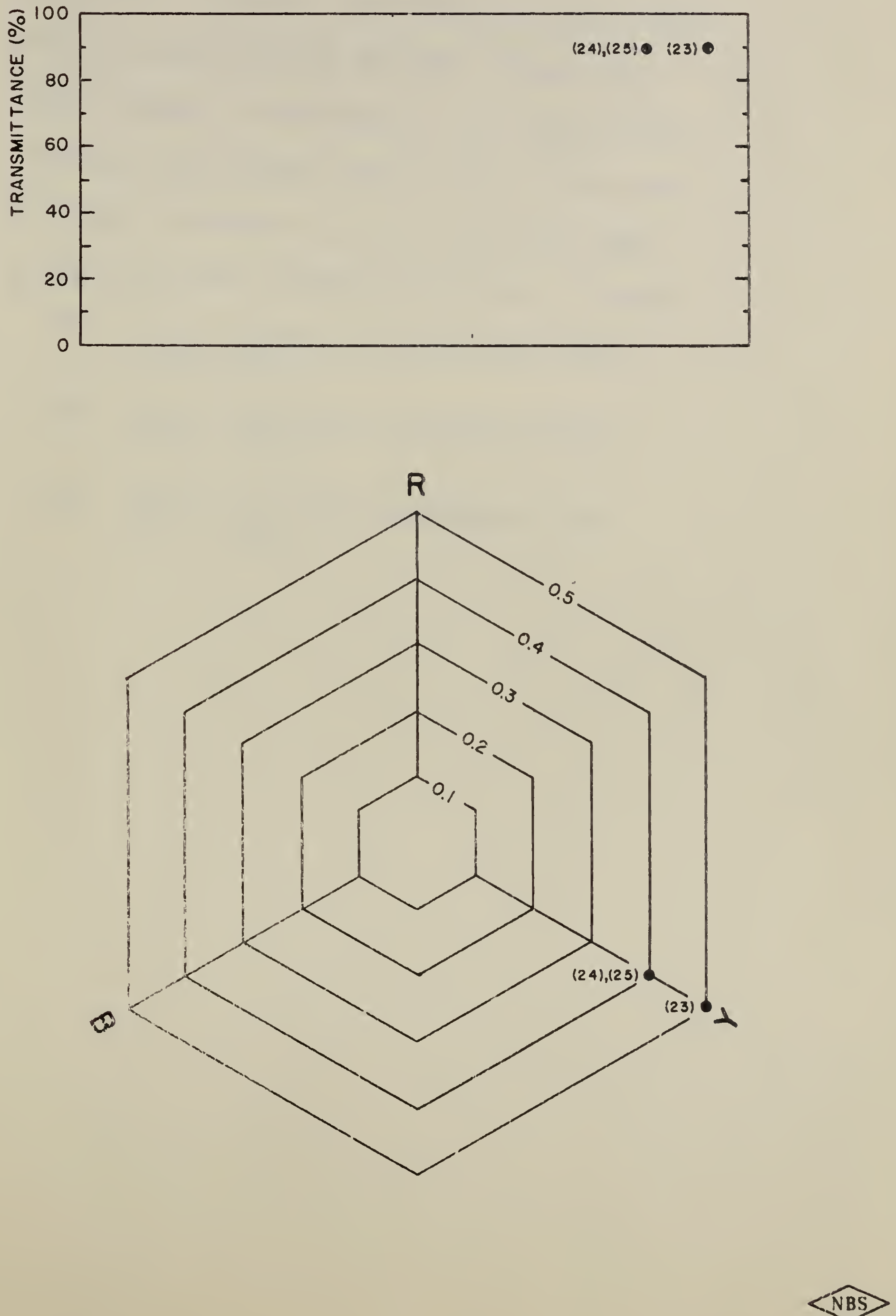


FIGURE 38

Figure 39. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram for three ultraviolet-absorbing filters:

(26) Ansco Ultraviolet Absorbing Filter UV-15, Size 6

(27) Ansco Ultraviolet Absorbing Filter UV-16, Size 6

(28) Ansco Ultraviolet Absorbing Filter UV-17, Size 6

HAND CAMERA FILTERS

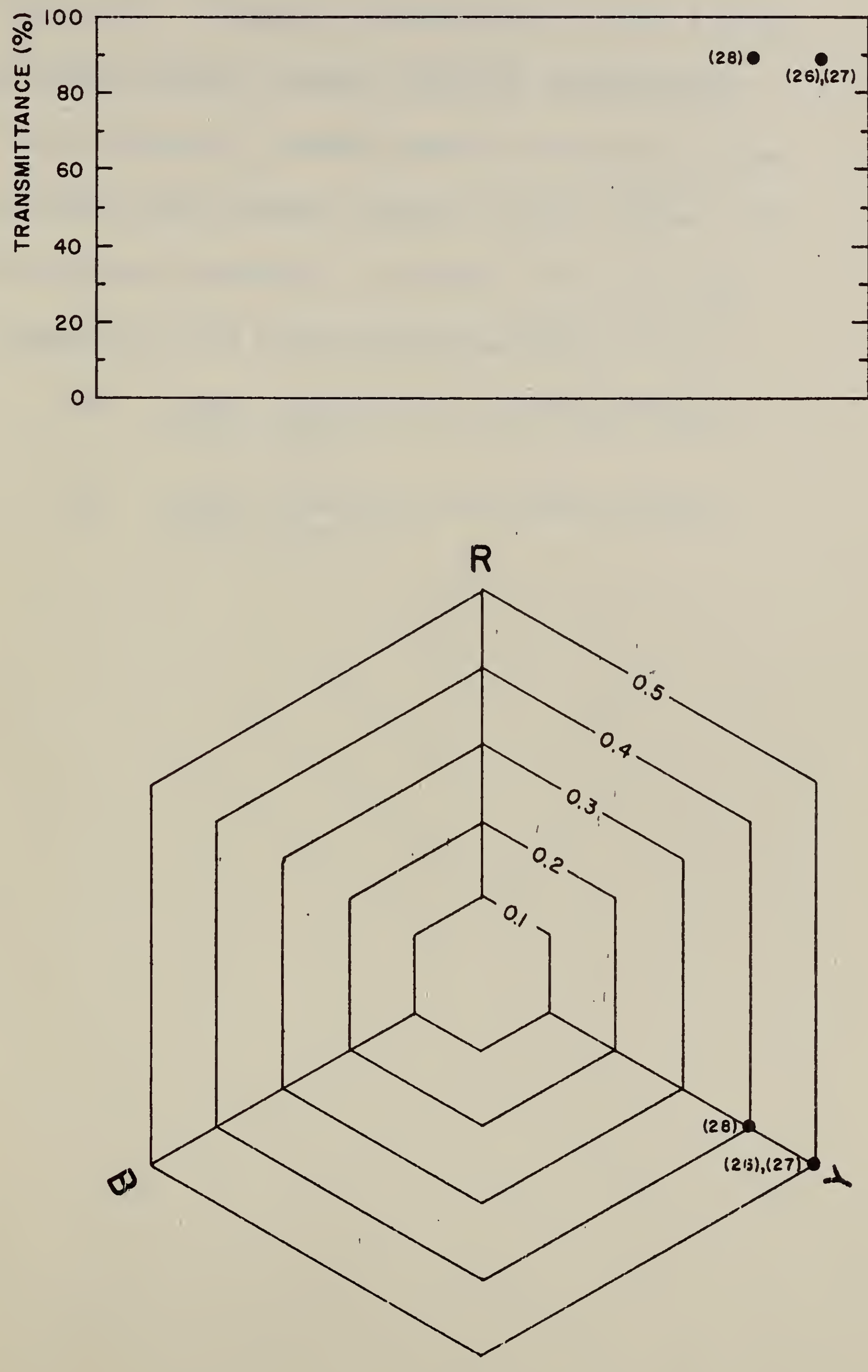


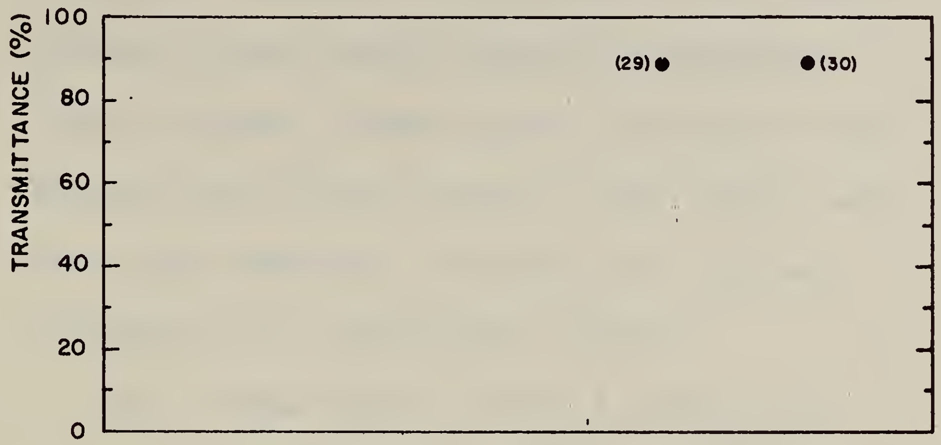
FIGURE 39

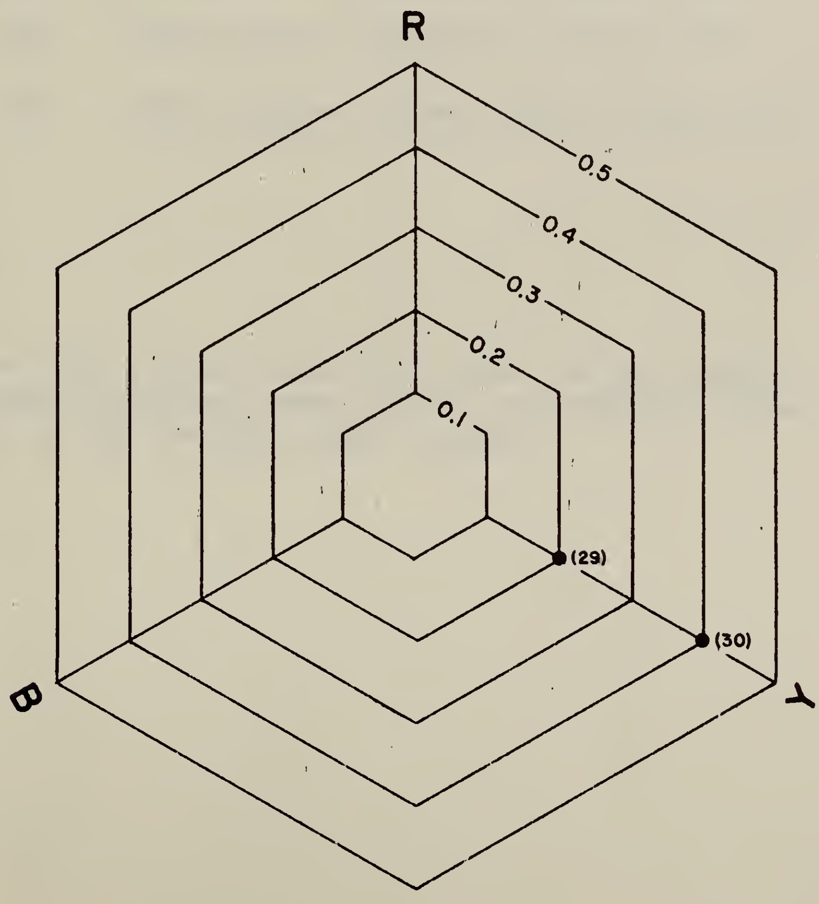
Figure 40. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram for two ultraviolet-absorbing filters:

(29) Ansco Ultraviolet Absorbing Filter UV-16, Size 7

(30) Ansco Ultraviolet Absorbing Filter UV-17, Size 7

HAND CAMERA FILTERS





NBS

FIGURE 40

Figure 41. Schematic illustration of the "ideal" Lovibond system showing daylight transmittance (upper diagram) plotted against the units of the Lovibond color system, based on Red, Yellow, and Blue glass standards, projected from the lower diagram for five photographic filters:

(31) Kodak Wratten Filter A, Series VII

(32) Kodak Wratten Filter B, Series VII*

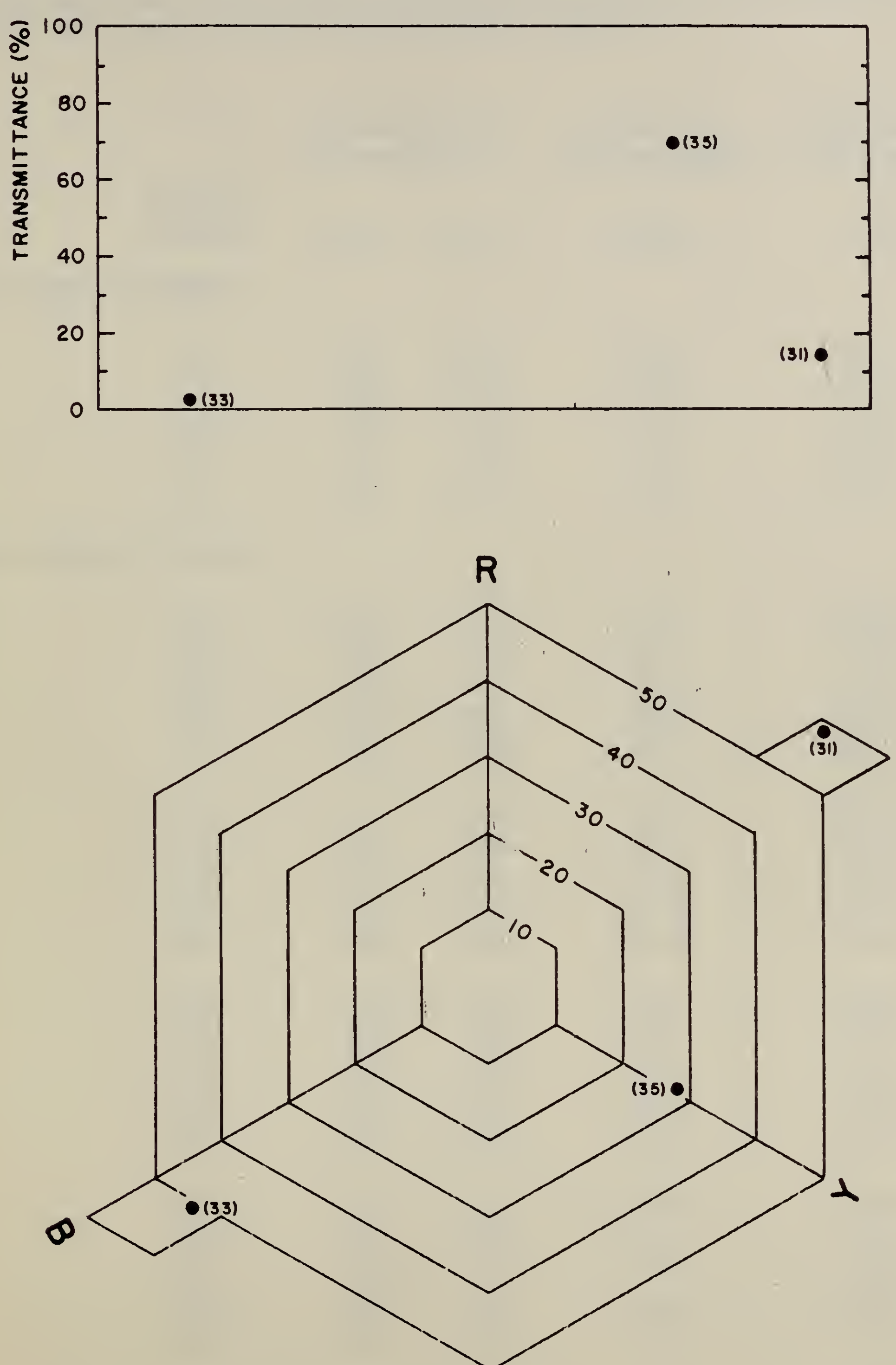
(33) Kodak Wratten Filter C5, Series VII

(34) Kodak Wratten Filter N, Series VII*

(35) Kodak Wratten Filter Aero 2, Series VII

*Object Nos. 32 and 34 are not shown on the diagram as these saturated green colors are outside of the gamut of the Lovibond color system.

HAND CAMERA FILTERS



NBS

FIGURE 41

Table V

Hand Camera Lenses and Filters

Chromaticity Coordinates, Daylight Transmittance, Dominant Wavelength, and Excitation Purity Determinations for Source C of Five Hand Camera Lenses and Twenty-Three Photographic Filters.

Object Number	Chromaticity Coordinates x	y	Luminous Transmittance Y(%)	Dominant Wavelength λ	Excitation Purity p(%)
HAND CAMERA LENSES:					
(8)	0.313	0.324	82.3	566.	2.7
(9)	.320	.331	90.9	567.2	6.6
(10)	.322	.330	86.6	575.2	6.8
(11)	.318	.329	84.8	570.0	5.4
(12)	.310	.317	91.8	550.	0.1
HAND CAMERA FILTERS:					
(13)	0.251	.233	36.7	469.9	32.0
(14)	.415	.401	62.2	580.6	50.8
(15)	.251	.227	34.5	467.0	33.0
(16)	.417	.401	61.7	580.9	51.4
(17)	.251	.234	36.8	470.0	31.8
(18)	.416	.401	62.0	580.6	51.0
(19)	.250	.228	34.6	467.6	32.9
(20)	.416	.401	61.9	580.6	51.0
(21)	.222	.199	26.9	471.3	46.6
(22)	.397	.361	61.2	586.9	35.3
(23)	.319	.335	89.1	568.1	7.4
(24)	.315	.328	89.4	567.	4.5
(25)	.316	.330	89.4	567.2	5.6
(26)	.318	.332	89.2	569.5	6.5
(27)	.317	.331	89.5	567.8	5.6
(28)	.317	.331	89.6	567.4	5.7
(29)	.314	.327	88.7	563.	3.7
(30)	.316	.331	88.7	566.5	5.6
(31)	.680	.320	14.1	615.	100.
(32)	.237	.696	24.5	539.4	86.0
(33)	.145	.048	2.7	463.6	96.
(34)	.218	.702	18.4	536.0	83.8
(35)	.445	.508	77.0	572.9	87.6

Table VI

Hand Camera Lenses and Filters

Munsell Renotations and ISCC-NBS Color Designations of the Five Hand Camera Lenses and Twenty-Three Photographic Filters.

Object Number	Munsell Renotation	ISCC-NBS Color Designation
HAND CAMERA LENSES:		
(8)	6.4GY 9.2/0.4	Colorless
(9)	9.8Y 9.5/0.8	Faint yellow
(10)	4.2Y 9.4/0.8	Faint yellow
(11)	2.5GY 9.3/0.7	Faint yellow
(12)	N 9.6/	Colorless
HAND CAMERA FILTERS:		
(13)	7.8PB 6.5/8.6	Light purplish blue
(14)	9.9YR 8.2/7.3	Light orange yellow
(15)	8.6PB 6.4/9.1	Brilliant purplish blue
(16)	9.8YR 8.1/7.4	Light orange yellow
(17)	7.7PB 6.6/8.4	Light purplish blue
(18)	9.8YR 8.2/7.2	Light orange yellow
(19)	8.2PB 6.4/8.9	Light purplish blue
(20)	9.8YR 8.2/7.2	Light orange yellow
(21)	7.1PB 5.7/11.4	Brilliant purplish blue
(22)	3.6YR 8.1/6.0	Light yellowish pink
(23)	5.2GY 9.5/1.0	Faint green
(24)	6.0GY 9.5/0.6	Faint green
(25)	5.9GY 9.5/0.8	Faint green
(26)	5.0GY 9.5/0.8	Faint green
(27)	5.6GY 9.5/0.8	Faint green
(28)	5.6GY 9.5/0.8	Faint green
(29)	7.4GY 9.4/0.6	Faint green
(30)	6.0GY 9.4/0.8	Faint green
(31)	8.4R 4.3/20.6	Vivid red
(32)	0.6G 5.5/20.	Vivid yellowish green
(33)	7.6PB 1.8/18.0	Vivid purplish blue
(34)	0.8G 4.8/19.	Vivid yellowish green
(35)	9.4Y 8.9/13.9	Vivid greenish yellow

Table VII

Hand Camera Lenses and Filters

Lovibond Analyses and Daylight Transmittance of the Five Hand Camera Lenses and Twenty-Three Photographic Filters.

Object Number	Lovibond Analysis R	Lovibond Analysis Y	Lovibond Analysis B	Luminous Transmittance Y(%)
HAND CAMERA LENSES:				
(8)	0.0	0.2	0.0	82.3
(9)	.2	.5	.0	90.9
(10)	.4	.5	.0	86.6
(11)	.3	.4	.0	84.8
(12)	.0	.0	.0	91.8
HAND CAMERA FILTERS:				
(13)	1.5	0.0	4.0	36.7
(14)	3.4	5.4	.0	62.2
(15)	1.9	.0	4.2	34.5
(16)	3.5	5.4	.0	61.7
(17)	1.5	.0	4.0	36.8
(18)	3.4	5.4	.0	62.0
(19)	1.6	.0	4.2	34.6
(20)	3.4	5.4	.0	61.9
(21)	1.2	.0	6.1	26.9
(22)	4.1	2.9	.0	61.2
(23)	.0	.5	.0	89.1
(24)	.0	.4	.0	89.4
(25)	.0	.4	.0	89.4
(26)	.0	.5	.0	89.2
(27)	.0	.5	.0	89.5
(28)	.0	.4	.0	89.6
(29)	.0	.2	.0	88.7
(30)	.0	.4	.0	88.7
(31)	58.0	50.0	.0	14.1
(32)	---	---	---	24.5
(33)	.0	6.5	51.0	2.7
(34)	---	---	---	18.4
(35)	.6	28.0	.0	77.0

X. Color-Temperature-Conversion Filters

A comparison has been made in the next four illustrations (Figures 42 to 45) and four tables of data (Tables VIII to XI) of how well the commercially available color-temperature-conversion filters, studied in this report, serve their purpose in converting the spectral energy distribution of one illuminant to approximate the spectral energy distribution of a second illuminant. Six filters have been selected for study. They carried the object designations in Part IX of this report as (17), (18), (19), (20), (21), and (22). Two sets of these blue and orange filters are near duplicates available from one manufacturer (Ansco) differing only in size of filter (diameter). They are (17) Ansco No. 10 Conversion filter size 5 (sample b), (19) Ansco No. 10 Conversion filter size 6 (sample b), (18) Ansco No. 11 Conversion filter size 5 (sample b), and (20) Ansco No. 11 Conversion filter size 6 (sample b). The other set of blue and orange filters are (21) Kodak Wratten 80A, Series VI, and (22) Kodak Wratten 85, Series VI.

The three orange filters have been compared for effectiveness of conversion of both CIE Source C to CIE Source A and conventional color temperature for outdoor film (5500°K) to that for indoor film (3250°K). The three blue filters have been compared for effectiveness of conversion in the opposite direction. The data for the standard sources were taken from the Handbook of Colorimetry [15], and the spectral distribution of sources 3250°K and 5500°K were taken from the Frehafer-Snow tables [23].

The conversions from near daylight illuminant to near incandescent illuminant are shown in Figures 42 and 44; and conversions from near incandescent illuminant to near daylight illuminant are shown in Figures 43 and 45. It should be noted that the ordinates of these four figures are in relative energy units and that all of the curves represented in the figures have been reduced to equality (50.0 units) at wavelength 560 millimicrons.

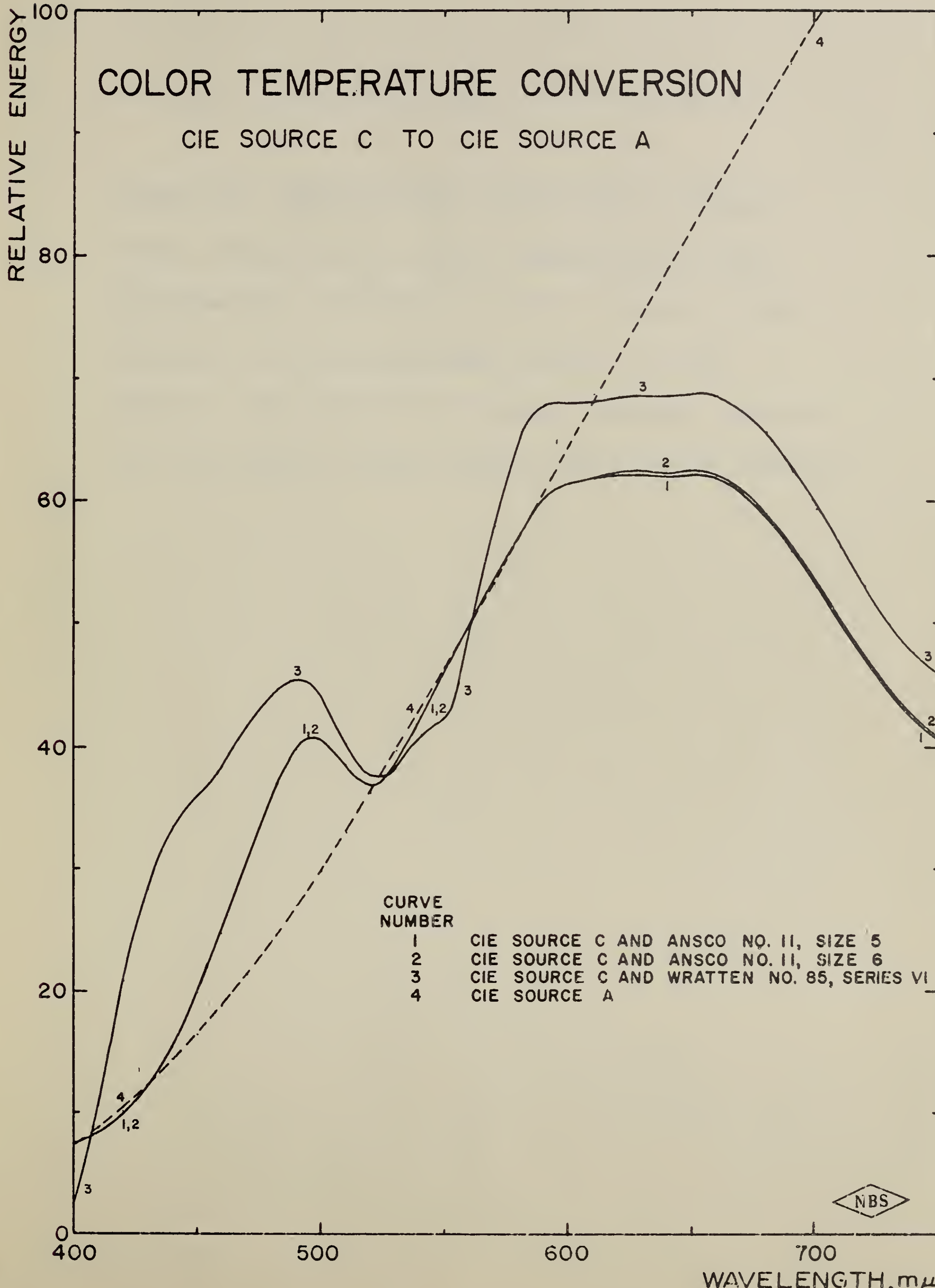
[illegible]

[illegible]

[illegible]

[illegible]

Figure 42. Spectral energy distribution of radiant energy transmitted by several orange-yellow filters approximating a conversion of C.I.E. Source C, representative of average daylight, to C.I.E. Source A, representative of incandescent illuminant, compared with the spectral energy distribution of C.I.E. Source A.



COLOR TEMPERATURE CONVERSION
CIE SOURCE C TO CIE SOURCE A
RELATIVE ENERGY
WAVELENGTH, mμ
0
20
40
60
80
100
400
500
600
700
CURVE NUMBER
1 CIE SOURCE C AND ANSCO NO. 11, SIZE 5
2 CIE SOURCE C AND ANSCO NO. 11, SIZE 6
3 CIE SOURCE C AND WRATTEN NO. 85, SERIES VI
4 CIE SOURCE A
NBS

FIGURE 42

Figure 43. Spectral energy distribution of radiant energy transmitted by several purplish-blue filters approximating a conversion of C.I.E. Source A, representative of incandescent-lamp light, to C.I.E. Source C, representative of average daylight, compared with the spectral energy distribution of C.I.E. Source C.

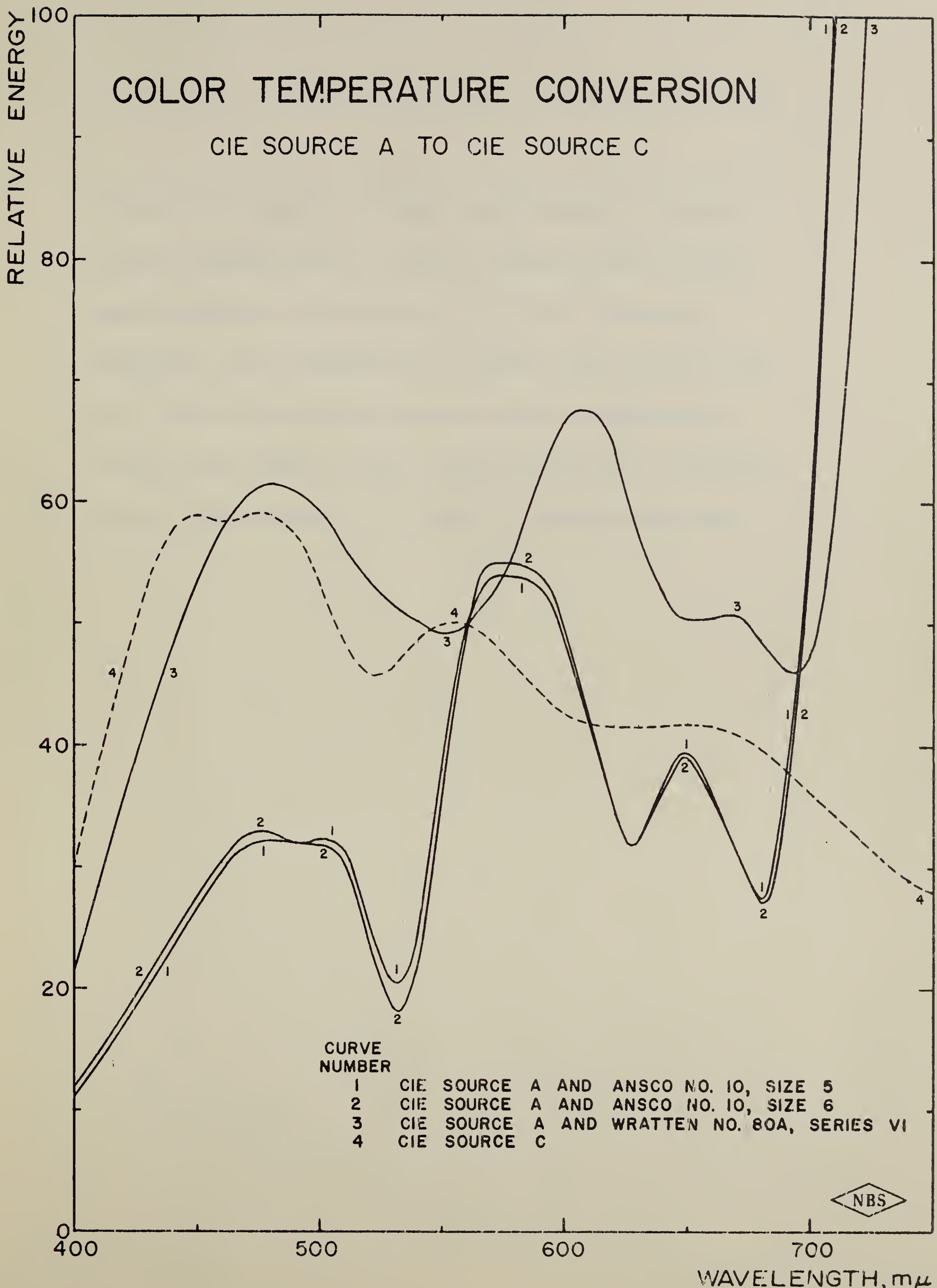

COLOR TEMPERATURE CONVERSION
CIE SOURCE A TO CIE SOURCE C
RELATIVE ENERGY
WAVELENGTH, mμ
0
20
40
60
80
100
400
500
600
700
CURVE NUMBER
1 CIE SOURCE A AND ANSCO NO. 10, SIZE 5
2 CIE SOURCE A AND ANSCO NO. 10, SIZE 6
3 CIE SOURCE A AND WRATTEN NO. 80A, SERIES VI
4 CIE SOURCE C
NBS

FIGURE 43

Figure 44. Spectral energy distribution of radiant energy transmitted by several orange-yellow filters approximating a conversion of a 5500°K Planckian Radiator (color temperature balance for outdoor film) to a 3250°K Planckian Radiator (color temperature balance for indoor film), compared with the spectral energy distribution of a 3250°K Planckian Radiator.

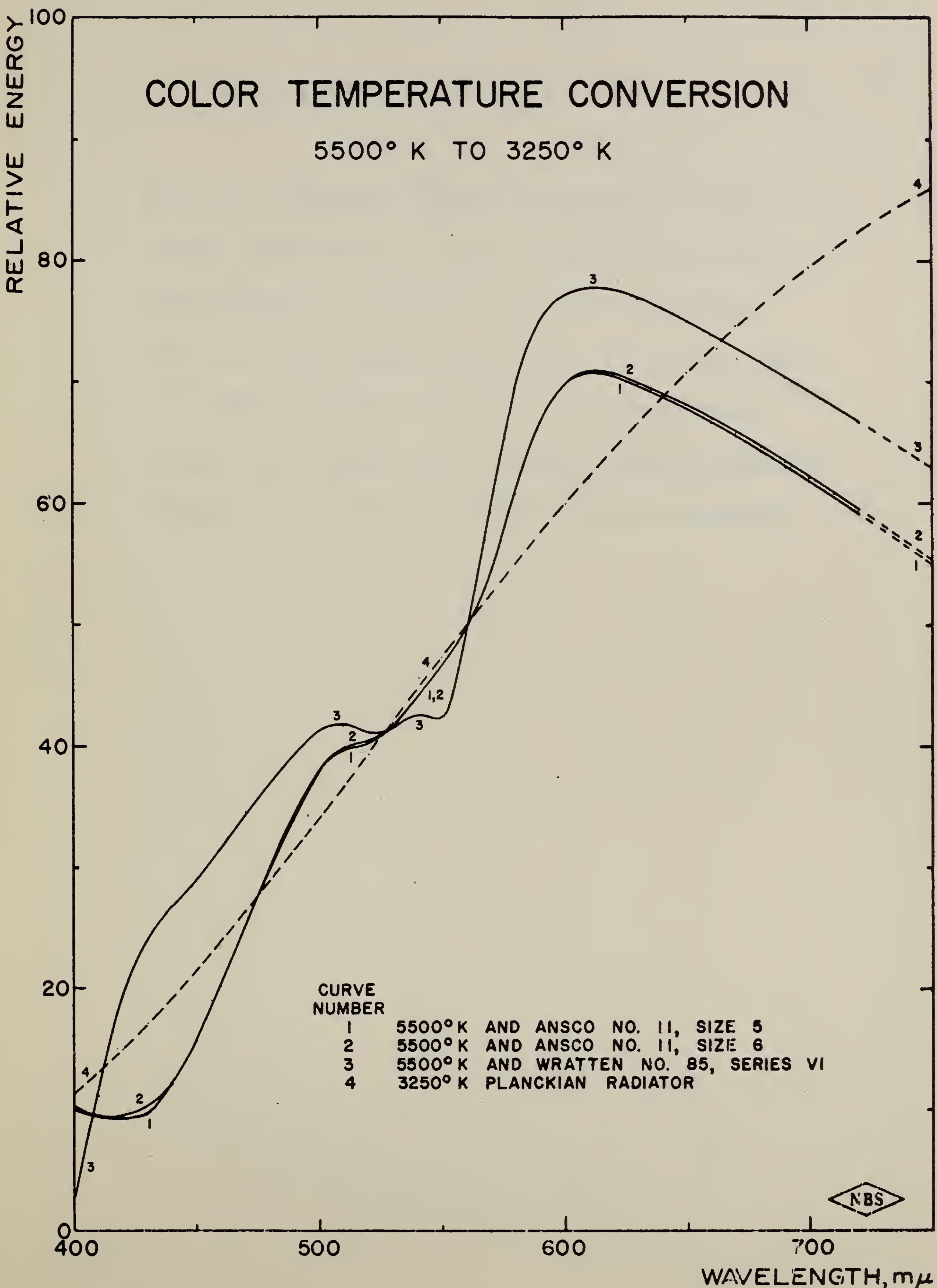

COLOR TEMPERATURE CONVERSION
5500° K TO 3250° K
RELATIVE ENERGY
WAVELENGTH, mμ
0
20
40
60
80
100
400
500
600
700
CURVE NUMBER
1 5500° K AND ANSCO NO. 11, SIZE 5
2 5500° K AND ANSCO NO. 11, SIZE 6
3 5500° K AND WRATTEN NO. 85, SERIES VI
4 3250° K PLANCKIAN RADIATOR
NBS

FIGURE 44

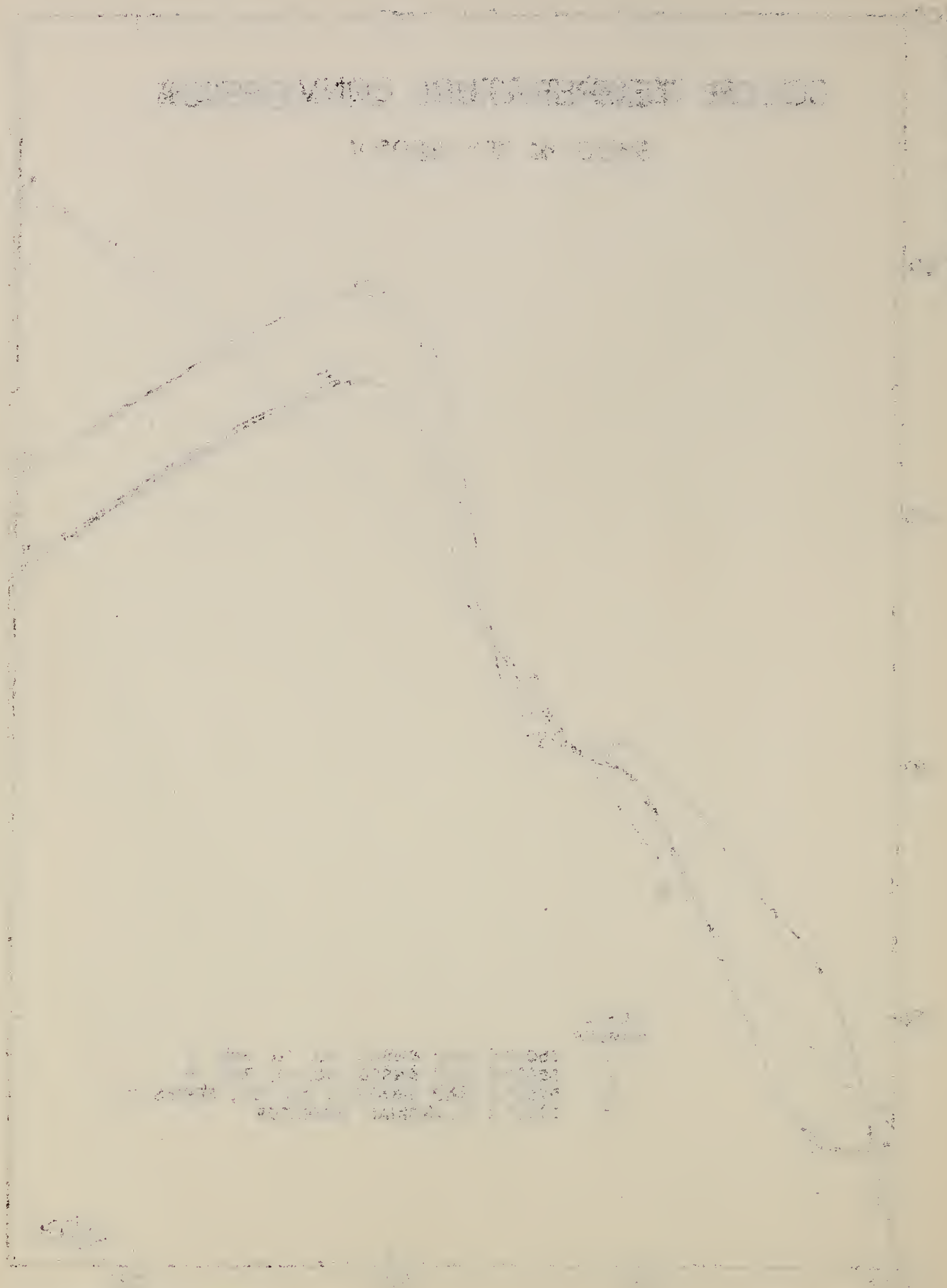


Figure 45. Spectral energy distribution of radiant energy transmitted by several purplish-blue filters approximating a conversion of a 3250°K Planckian Radiator (color temperature balance for indoor film) to a 5500°K Planckian Radiator (color temperature balance for outdoor film), compared with the spectral energy distribution of a 5500°K Planckian Radiator.

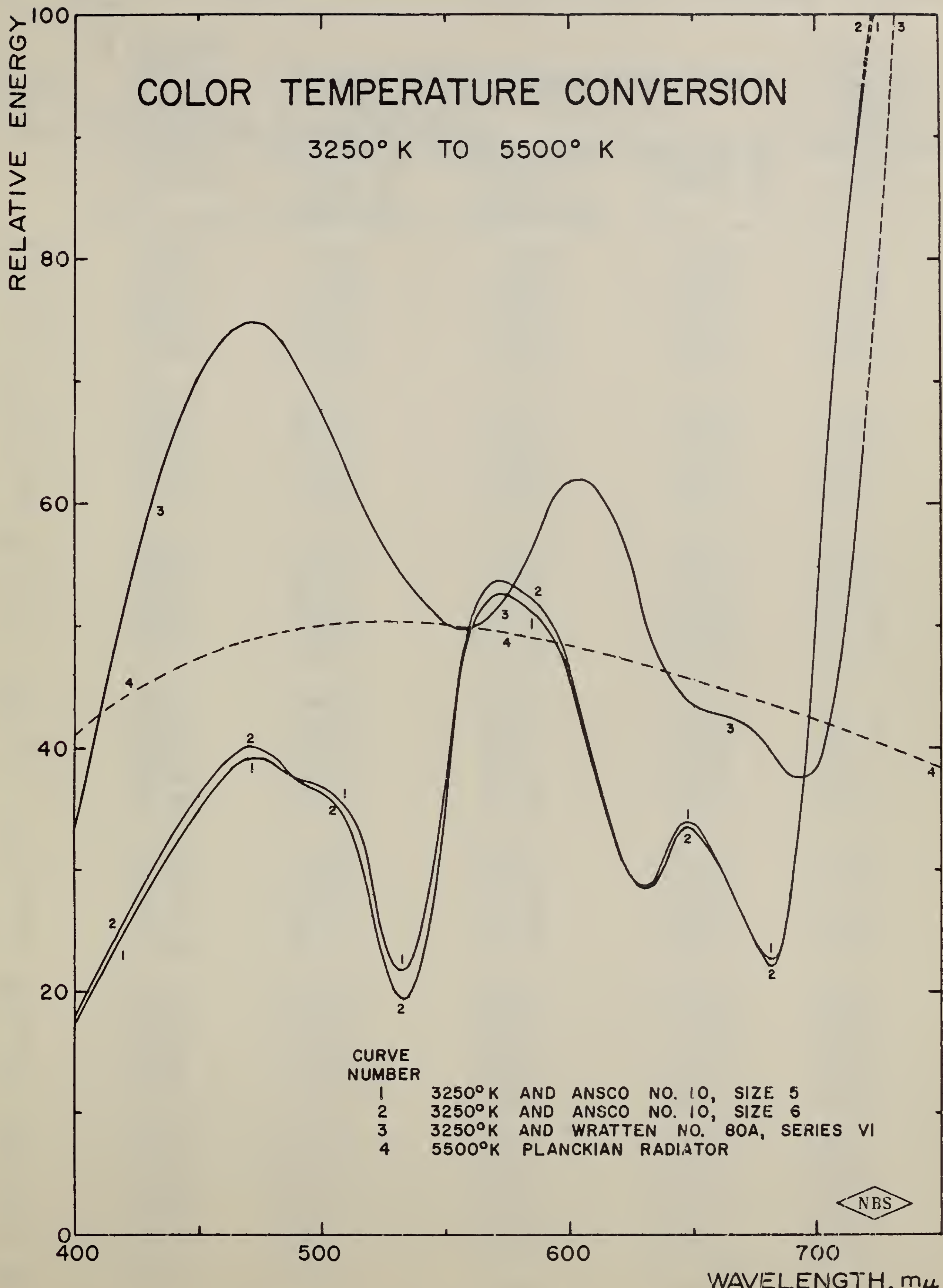

COLOR TEMPERATURE CONVERSION
3250° K TO 5500° K
RELATIVE ENERGY
WAVELENGTH, mμ
0
20
40
60
80
100
400
500
600
700
CURVE NUMBER
1 3250°K AND ANSCO NO. 10, SIZE 5
2 3250°K AND ANSCO NO. 10, SIZE 6
3 3250°K AND WRATTEN NO. 80A, SERIES VI
4 5500°K PLANCKIAN RADIATOR
NBS

FIGURE 45

Table VIII

Relative Spectral Energy Distribution of Light Sources Before and After Transmission by Color-Temperature-Conversion Filters. (Reduced to Equality at 560 mμ.)

Wave length mμ	Incident Spectral Energy Distribution	Relative Spectral Energy Distribution of Incident Radiant Energy after Transmission by:			Desired Spectral Energy Distribution
	C.I.E. Source C	Ansco No. 11 Size 5 (sample b)	Ansco No. 11 Size 6 (sample b)	Wratten 85 Series VI	C.I.E. Source A
400	30.06	7.39	7.59	2.23	7.36
10	38.27	8.46	8.62	10.56	8.84
20	46.58	10.05	10.20	20.93	10.50
30	53.37	12.32	12.32	28.40	12.34
40	57.69	15.40	15.40	33.50	14.35
450	58.88	19.88	19.88	36.00	16.54
60	58.45	24.71	24.71	38.40	18.91
70	58.78	30.56	30.56	41.81	21.44
80	58.83	36.07	36.07	44.15	24.12
90	57.31	39.83	39.83	45.41	26.96
500	53.23	40.39	40.39	44.05	29.93
10	48.58	38.29	38.49	40.24	33.03
20	46.01	36.81	36.92	37.61	36.25
30	46.53	38.44	38.44	38.34	39.56
40	48.48	42.52	42.52	40.97	42.98
550	49.95	46.68	46.68	42.45	46.46
60	50.00	50.00	50.00	50.00	50.00
70	48.58	53.21	53.21	58.00	53.59
80	46.44	57.29	57.29	65.22	57.22
90	44.26	60.32	60.32	67.83	60.86
600	42.59	61.40	61.40	67.97	64.52
10	41.98	61.89	62.00	68.09	68.67
20	41.83	62.14	62.38	68.51	71.81
30	41.78	62.22	62.39	68.50	75.41
40	41.69	62.04	62.25	68.50	78.99
650	41.88	62.18	62.46	68.82	82.51
60	41.74	61.86	62.11	68.58	85.98
70	40.98	60.56	60.84	67.33	89.38
80	39.89	58.79	59.05	65.58	92.71
90	38.08	55.90	56.19	62.44	95.96
700	36.23	53.03	53.31	59.37	99.13
10	34.38	50.12	50.41	56.31	102.20
20	32.43	47.17	47.42	53.06	105.18
30	30.58	44.30	44.56	50.00	108.06
40	29.20	42.13	42.43	47.68	110.83
750	28.11	40.40	40.66	45.89	113.50

Table IX

Relative Spectral Energy Distribution of Light Sources Before and After Transmission by Color-Temperature-Conversion Filters. (Reduced to Equality at 560 mμ.)

Wave length mμ	Incident Spectral Energy Distribution	Relative Spectral Energy Distribution of Incident Radiant Energy after Transmission by:			Desired Spectral Energy Distribution
	C.I.E. Source A	Ansco No. 10 Size 5 (sample b)	Ansco No. 10 Size 6 (sample b)	Wratten 80A Series VI	C.I.E. Source C
400	7.36	11.15	11.69	21.51	30.06
10	8.84	14.11	14.62	28.42	38.27
20	10.50	17.25	17.95	35.66	46.58
30	12.34	20.48	21.29	42.39	53.37
40	14.35	23.64	24.54	48.31	57.69
450	16.54	26.66	27.57	53.67	58.88
60	18.91	29.48	30.41	57.65	58.45
70	21.44	31.79	32.61	60.42	58.78
80	24.12	32.22	32.81	61.60	58.83
90	26.96	31.95	31.89	60.75	57.31
500	29.93	32.36	31.88	59.21	53.23
10	33.03	31.42	30.28	56.20	48.58
20	36.25	25.65	24.11	53.71	46.01
30	39.56	20.60	18.44	51.40	46.53
40	42.98	24.49	22.05	50.24	48.48
550	46.46	37.95	36.89	49.21	49.95
60	50.00	50.00	50.00	50.00	50.00
70	53.59	53.71	54.96	52.48	48.58
80	57.22	53.91	54.86	56.43	46.44
90	60.86	52.84	53.83	62.25	44.26
600	64.52	48.33	49.12	66.55	42.59
10	68.67	41.59	41.93	67.35	41.98
20	71.81	34.43	34.39	64.05	41.83
30	75.41	32.54	32.30	57.42	41.78
40	78.99	36.98	36.42	52.56	41.69
650	82.51	39.36	38.72	50.56	41.88
60	85.98	36.04	36.12	50.52	41.74
70	89.38	31.51	31.39	50.68	40.98
80	92.71	27.61	27.12	48.75	39.89
90	95.96	37.02	36.04	46.28	38.08
700	99.13	68.60	65.94	48.04	36.23
10	102.20	99.91	98.34	60.00	34.38
20	105.18	120.22	122.98	88.61	32.43
30	108.06	127.21	144.40	139.89	30.58
40	110.83	157.02	165.25	207.17	29.20
750	113.50	165.75	174.44	284.15	28.11

Table X

Relative Spectral Energy Distribution of Light Sources Before and After Transmission by Color-Temperature-Conversion Filters. (Reduced to Equality at 560 mμ.)

Wave length mμ	Incident Spectral Energy Distribution	Relative Spectral Energy Distribution of Incident Radiant Energy after Transmission by:			Desired Spectral Energy Distribution
	Planckian Radiator 5500°K	Ansco No. 11 Size 5 (sample b)	Ansco No. 11 Size 6 (sample b)	Wratten 85 Series VI	Planckian Radiator 3250°K
400	41.36	10.17	10.45	3.07	11.48
10	42.86	9.47	9.65	11.83	13.28
20	44.25	9.54	9.69	19.88	15.21
30	45.45	9.80	10.49	24.18	17.28
40	46.52	12.42	12.42	27.02	19.44
450	47.46	16.03	16.03	29.02	21.72
60	48.26	20.40	20.40	31.70	24.08
70	48.93	25.44	25.44	34.80	26.52
80	49.43	30.31	30.31	37.10	29.04
90	49.85	33.95	34.65	39.50	31.60
500	50.20	38.09	38.09	41.54	34.20
10	50.35	39.69	39.90	41.71	36.84
20	50.45	40.36	40.49	41.24	39.50
30	50.45	41.68	41.68	41.56	42.14
40	50.35	44.16	44.16	42.55	44.78
550	50.20	46.91	46.91	42.65	47.42
60	50.00	50.00	50.00	50.00	50.00
70	49.66	54.40	54.40	59.30	52.55
80	49.36	60.91	60.91	69.32	55.10
90	48.94	66.72	66.72	75.02	57.55
600	48.45	69.84	69.84	77.31	59.95
10	47.98	70.75	70.87	77.84	62.30
20	47.49	70.48	70.82	77.70	64.50
30	46.84	69.74	69.94	76.78	66.65
40	46.24	68.82	69.05	75.98	68.80
650	45.63	67.75	68.06	74.97	70.80
60	44.99	66.68	66.95	73.92	72.70
70	44.31	65.50	65.80	72.81	74.55
80	43.62	64.29	64.58	71.71	76.30
90	42.94	63.04	63.36	70.40	77.90
700	42.23	61.82	62.14	69.20	79.40
10	41.49	60.49	60.84	67.95	80.90
20	40.77	59.30	59.61	66.70	82.20

Table XI

Relative Spectral Energy Distribution of Light Sources Before and After Transmission by Color-Temperature-Conversion Filters. (Reduced to Equality at 560 mμ.)

Wave length mμ	Incident Spectral Energy Distribution	Relative Spectral Energy Distribution of Incident Radiant Energy after Transmission by:			Desired Spectral Energy Distribution
	Planckian Radiator 3250°K	Ansco No. 10 Size 5 (sample b)	Ansco No. 10 Size 6 (sample b)	Wratten 80A Series VI	Planckian Radiator 5500°K
400	11.48	17.42	18.25	33.59	41.36
10	13.28	21.20	21.97	42.71	42.86
20	15.21	24.99	26.00	51.66	44.25
30	17.28	28.69	29.83	59.39	45.45
40	19.44	32.03	33.25	65.46	46.52
450	21.72	34.99	36.18	70.45	47.46
60	24.08	37.53	38.71	73.41	48.26
70	26.52	39.33	40.34	74.75	48.93
80	29.04	38.78	39.49	74.15	49.43
90	31.60	37.46	37.39	71.24	49.85
500	34.20	36.99	36.44	67.67	50.20
10	36.84	35.04	33.77	62.68	50.35
20	39.50	27.95	26.27	58.54	50.45
30	42.14	21.95	19.64	54.76	50.45
40	44.78	25.52	22.98	52.36	50.35
550	47.42	38.74	37.66	50.24	50.20
60	50.00	50.00	50.00	50.00	50.00
70	52.55	52.67	53.89	51.47	49.66
80	55.10	51.91	52.82	54.34	49.36
90	57.55	49.96	50.90	58.87	48.94
600	59.95	44.90	45.64	61.84	48.45
10	62.30	38.00	38.32	61.56	47.98
20	64.50	30.93	30.89	57.53	47.49
30	66.65	28.75	28.54	50.76	46.84
40	68.80	32.21	31.72	45.78	46.24
650	70.80	33.78	33.22	43.39	45.63
60	72.70	30.47	30.54	42.72	44.99
70	74.55	26.28	26.18	42.27	44.31
80	76.30	22.72	22.32	40.12	43.62
90	77.90	30.05	29.25	37.58	42.94
700	79.40	54.94	52.82	38.48	42.23
10	80.90	79.08	77.84	47.50	41.49
20	82.20	93.95	96.11	69.26	40.77

XI. Summary

This report shows that measurements of spectral transmittance may be made of aerial- and hand-camera lenses on the General Electric recording spectrophotometer provided that the size of the optical elements of the cameras are larger than the dimensions of the light path of the instrument, and provided that the mounts of the camera lens do not block the comparison light beam of the instrument.

Figures 1 and 2 show that coating the optical elements of camera lenses with films that reduce reflection losses in the visible part of the spectrum may reduce the infrared transmittance of the lens below that of the uncoated lens and so make the lens less fit for use with "infrared film" [24].

The use of a system of color in transparent media may be useful for the colorimetric specification of photographic lenses and filters. In this report, in addition to the usual methods of expressing the data, use has been made of the Lovibond system of units of colored red, yellow, and blue glasses for the colorimetric specification of the lenses and filters.

An evaluation has been made of conversion filters of the types usually used in ordinary photography by comparing the spectral energy distributions of the converted sources with those of the sources which were intended to be duplicated.

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Appendix A

Set of the Ozalid prints of the 24 original recordings of the visible and the near infrared spectral transmittance (400 to 1080 millimicrons) made on a General Electric recording spectrophotometer for the aerial and hand camera lenses and photographic filters studied in this report. An index to the spectrophotometric curves of this set are listed in the following table, together with the dates of measurement.

Index to Appendix A

Object Number	Sample Designation	GE Graph Sheet Serial No., and Date Measured: Visible Spectrum	GE Graph Sheet Serial No., and Date Measured: Near Infrared Spectrum	Curve Number
(1)	Rear cell, B&L Metrogon lens, 6", f/6.3, Serial No. UF-6016	GE II-1415	GE II-1416	4
		March 17, 1954		
(2)	Assembled, B&L Metrogon lens, 6", f/6.3, Serial No. UF-6016	(No direct measurement made)		
(3)	Front cell, B&L lens, 12", f/4.5, Serial No. LF-8123	-1413	-1414	4
		March 17, 1954		
(4)	Rear cell, B&L lens, 12", f/4.5, Serial No. LF-8123	-1411	-1412	4
		March 16, 1954		
(5)	Assembled, B&L lens, 12", f/4.5, Serial No. LF-8123	(No direct measurement made)		
(6)	Yellow glass filter for use with Metrogon lens, filter only	-1417	-1418	4
		March 17, 1954		
(7)	Yellow glass filter for use with Metrogon lens, filter and anti-vignetting spot	-1417	-1418	5
		March 17, 1954		
(8)	Ansco Xenon lens, 50 mm, f/2, Serial No. 2563656	-1237	-1238	4
		June 4, 1953		
(9)	Kodak Ektar lens, 80 mm, f/2.8, Serial No. ET8144L	-1188	-1189	3 and 2
		April 20, 1953		
(10)	Leitz Elmar lens, 90 mm, f/4, Serial No. 720367	-1195	-1196	4 and 3
		April 23, 1953		
(11)	Leitz Summitar lens, 50 mm, f/2, Serial No. 603453	-1195	-1196	5 and 2
		April 23, 1953		
(12)	Ansco portrait lens, No. 30, plus 1, size 6	-1200	-1199	4
		April 24, 1953		
(13)	Ansco filter, Conversion 10, size 5 (sample a)	-1197	-1198	7
		April 23 and 24, 1953		

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Index to Appendix A (continued)

Object Number	Sample Designation	GE Graph Sheet Serial No., and Date Measured: Visible Spectrum	GE Graph Sheet Serial No., and Date Measured: Near Infrared Spectrum	Curve Number
(14)	Ansco filter, Conversion 11, size 5 (sample a)	GE II-1197	GE II-1198 April 23 and 24, 1953	8
(15)	Ansco filter, Conversion 10, size 6 (sample a)	-1200	-1199 April 24, 1953	8
(16)	Ansco filter, Conversion 11, size 6 (sample a)	-1200	-1199 April 24, 1953	9
(17)	Ansco filter, Conversion 10, size 5 (sample b)	-1398	-1399 March 1, 1954	4
(18)	Ansco filter, Conversion 11, size 5 (sample b)	-1398	-1399 March 1, 1954	5
(19)	Ansco filter, Conversion 10, size 6 (sample b)	-1398	-1399 March 1, 1954	6
(20)	Ansco filter, Conversion 11, size 6 (sample b)	-1398	-1399 March 1, 1954	7
(21)	Kodak Wratten filter 80A, series VI	-1400	-1401 March 3, 1954	4
(22)	Kodak Wratten filter 85, series VI	-1400	-1401 March 3, 1954	5
(23)	Ansco filter, UV-15, size 5	-1197	-1198 April 23 and 24, 1953	4
(24)	Ansco filter, UV-16, size 5	-1197	-1198 April 23 and 24, 1953	5
(25)	Ansco filter, UV-17, size 5	-1197	-1198 April 23 and 24, 1953	6
(26)	Ansco filter, UV-15, size 6	-1200	-1199 April 24, 1953	5
(27)	Ansco filter, UV-16, size 6	-1200	-1199 April 24, 1953	6

Index to Appendix A (continued)

Object Number	Sample Designation	GE Graph Sheet Serial No., and Date Measured: Visible Spectrum	Near Infrared Spectrum	Curve Number
(28)	Ansco filter, UV-17, size 6	GE II-1200	GE II-1199 April 24, 1953	7
(29)	Ansco filter, UV-16, size 7	-1190	-1191 April 20, 1953	10
(30)	Ansco filter, UV-17, size 7	-1190	-1191 April 20, 1953	9
(31)	Kodak Wratten filter A, series VII	-1190	-1191 April 20, 1953	4
(32)	Kodak Wratten filter B, series VII	-1190	-1191 April 20, 1953	6
(33)	Kodak Wratten filter C5, series VII	-1190	-1191 April 20, 1953	5
(34)	Kodak Wratten filter N, series VII	-1190	-1191 April 20, 1953	7
(35)	Kodak Wratten filter Aero 2, series VII	-1190	-1191 April 20, 1953	8

Appendix B

Tables of visible and near-infrared spectral-transmittance data (400 to 1080 millimicrons) of thirty-five components of lenses and of filters used with aerial and hand cameras. Values of spectral transmittance were read at 10 millimicron intervals from the 24 recordings in Appendix A. For the overlapping segments of the region 730 to 750 millimicrons, an average of both determinations in each case is reported.

Aerial-Camera Lens

Spectral Transmittance, T_λ, of the Rear Lens Cell, and of the Assembled Lens (Assuming the Front Lens Cell to have the same Spectral Transmittance, T_λ, as the Rear Lens Cell) of a Bausch & Lomb Metrogon Lens, 6 inch focal length, f/6.3, Serial No. UF-6016. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1415, -1416.)

Rear Lens Cell				Assembled Lens			
Wave Length mµ	T_λ	Wave Length mµ	T_λ	Wave Length mµ	T_λ	Wave Length mµ	T_λ
400	0.765	750	0.810	400	0.585	750	0.656
10	.790	60	.810	10	.624	60	.656
20	.804	70	.810	20	.646	70	.656
30	.812	80	.809	30	.659	80	.654
40	.815	90	.808	40	.664	90	.653
450	.818	800	.807	450	.669	800	.651
60	.822	10	.806	60	.676	10	.650
70	.825	20	.806	70	.681	20	.650
80	.826	30	.804	80	.682	30	.646
90	.828	40	.804	90	.686	40	.646
500	.828	850	.803	500	.686	850	.645
10	.828	60	.803	10	.686	60	.645
20	.828	70	.802	20	.686	70	.643
30	.828	80	.801	30	.686	80	.642
40	.828	90	.800	40	.686	90	.640
550	.828	900	.799	550	.686	900	.638
60	.827	10	.799	60	.684	10	.638
70	.826	20	.798	70	.682	20	.637
80	.825	30	.798	80	.681	30	.637
90	.824	40	.797	90	.679	40	.635
600	.823	950	.797	600	.677	950	.635
10	.821	60	.796	10	.674	60	.634
20	.820	70	.796	20	.672	70	.634
30	.819	80	.795	30	.671	80	.632
40	.818	90	.795	40	.669	90	.632
650	.817	1000	.794	650	.667	1000	.630
60	.816	10	.794	60	.666	10	.630
70	.816	20	.794	70	.666	20	.630
80	.815	30	.794	80	.664	30	.630
90	.815	40	.794	90	.664	40	.630
700	.814	1050	.794	700	.663	1050	.630
10	.813	60	.794	10	.661	60	.630
20	.813	70	.793	20	.661	70	.629
30	.812	80	.793	30	.659	80	.629
40	.811			40	.658		

Aerial-Camera Lens

Spectral Transmittance, T_λ, of the Front Lens Cell, the Rear Lens Cell, and of the Assembled Lens, of a Bausch & Lomb Lens, 12 inch focal length, f/4.5, Serial No. LF-8123. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1413, -1414.)

Front Lens Cell				Rear Lens Cell				Assembled Lens			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.759	750	0.899	400	0.786	750	0.911	400	0.597	750	0.819
10	.810	60	.898	10	.820	60	.907	10	.664	60	.814
20	.834	70	.895	20	.836	70	.905	20	.697	70	.810
30	.853	80	.891	30	.852	80	.903	30	.727	80	.805
40	.866	90	.888	40	.862	90	.900	40	.746	90	.799
450	.881	800	.885	450	.876	800	.898	450	.772	800	.795
60	.897	10	.882	60	.891	10	.895	60	.799	10	.789
70	.910	20	.880	70	.903	20	.892	70	.822	20	.785
80	.917	30	.876	80	.912	30	.890	80	.836	30	.780
90	.923	40	.874	90	.918	40	.887	90	.847	40	.775
500	.928	850	.870	500	.923	850	.884	500	.857	850	.769
10	.932	60	.868	10	.928	60	.882	10	.865	60	.766
20	.936	70	.865	20	.932	70	.879	20	.872	70	.760
30	.938	80	.862	30	.935	80	.877	30	.877	80	.756
40	.940	90	.860	40	.938	90	.874	40	.882	90	.752
550	.940	900	.857	550	.939	900	.872	550	.883	900	.747
60	.941	10	.855	60	.940	10	.870	60	.885	10	.744
70	.940	20	.853	70	.939	20	.867	70	.883	20	.740
80	.938	30	.851	80	.938	30	.866	80	.880	30	.737
90	.934	40	.850	90	.937	40	.864	90	.875	40	.734
600	.933	950	.848	600	.935	950	.862	600	.872	950	.731
10	.931	60	.846	10	.933	60	.859	10	.869	60	.727
20	.928	70	.844	20	.932	70	.857	20	.865	70	.723
30	.926	80	.842	30	.929	80	.856	30	.860	80	.721
40	.923	90	.841	40	.928	90	.856	40	.857	90	.720
650	.920	1000	.840	650	.926	1000	.854	650	.852	1000	.717
60	.917	10	.839	60	.924	10	.853	60	.847	10	.716
70	.916	20	.838	70	.924	20	.852	70	.846	20	.714
80	.916	30	.837	80	.924	30	.851	80	.846	30	.712
90	.914	40	.837	90	.923	40	.850	90	.844	40	.711
700	.912	1050	.836	700	.922	1050	.850	700	.841	1050	.711
10	.910	60	.836	10	.921	60	.849	10	.838	60	.710
20	.907	70	.835	20	.919	70	.848	20	.834	70	.708
30	.905	80	.833	30	.915	80	.846	30	.828	80	.705
40	.902			40	.913			40	.824		

Aerial-Camera Filter

Spectral Transmittance, T_λ, of a Yellow Glass Filter for use with the Bausch & Lomb Metrogon Lens. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1417, -1418.)

Filter Only

Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.000	750	0.800
10	.000	60	.795
20	.000	70	.789
30	.000	80	.783
40	.000	90	.777
450	.000	800	.771
60	.000	10	.765
70	.000	20	.760
80	.000	30	.754
90	.000	40	.750
500	.024	850	.744
10	.312	60	.739
20	.568	70	.734
30	.654	80	.729
40	.704	90	.724
550	.738	900	.720
60	.766	10	.716
70	.787	20	.712
80	.806	30	.709
90	.819	40	.706
600	.829	950	.703
10	.835	60	.700
20	.840	70	.698
30	.842	80	.696
40	.843	90	.694
650	.842	1000	.692
60	.841	10	.690
70	.839	20	.688
80	.836	30	.688
90	.831	40	.687
700	.827	1050	.686
10	.822	60	.686
20	.817	70	.685
30	.811	80	.684
40	.806		

Filter and Anti-Vignetting, Neutral-Density Film

Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.000	750	0.472*
10	.000	60	.469*
20	.000	70	.466*
30	.000	80	.463*
40	.000	90	.460*
450	.000	800	.458*
60	.000	10	.456*
70	.000	20	.453*
80	.000	30	.450*
90	.000	40	.448*
500	.014	850	.445*
10	.174	60	.444*
20	.315	70	.441*
30	.365	80	.439*
40	.393	90	.438*
550	.413	900	.437*
60	.430	10	.436*
70	.443	20	.434*
80	.454	30	--
90	.462	40	--
600	.467	950	--
10	.472	60	--
20	.475	70	--
30	.477	80	--
40	.479	90	--
650	.479	1000	--
60	.480	10	--
70	.481	20	--
80	.481	30	--
90	.479	40	--
700	.477	1050	--
10	.475	60	--
20	.474	70	--
30	.475*	80	--
40	.473*		

* Adjusted values.

Hand-Camera Lens

Spectral Transmittance, T_λ, of an Ansco Xenon Lens, 50 millimeter focal length, f/2, Serial No. 2563656. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1237, -1238.)

Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.685	750	0.782
10	.718	60	.779
20	.739	70	.777
30	.756	80	.774
40	.770	90	.771
450	.782	800	.768
60	.792	10	.766
70	.801	20	.763
80	.809	30	.761
90	.816	40	.758
500	.820	850	.756
10	.824	60	.753
20	.826	70	.751
30	.828	80	.750
40	.828	90	.748
550	.829	900	.747
60	.829	10	.747
70	.828	20	--
80	.825	30	--
90	.823	40	--
600	.821	950	--
10	.819	60	--
20	.817	70	--
30	.814	80	--
40	.811	90	--
650	.808	1000	--
60	.805	10	--
70	.804	20	--
80	.801	30	--
90	.799	40	--
700	.798	1050	--
10	.795	60	--
20	.792	70	--
30	.788	80	--
40	.784		

Hand-Camera Lens

Spectral Transmittance, T_λ, of an Eastman Kodak Ektar Lens, 80 millimeter focal length, f/2.8, Serial No. ET814L. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1188, -1189.)

Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.661	750	0.905
10	.709	60	.904
20	.741	70	.901
30	.767	80	.899
40	.785	90	.896
450	.805	800	.894
60	.825	10	.891
70	.841	20	.888
80	.855	30	.886
90	.868	40	.882
500	.880	850	.880
10	.890	60	.877
20	.898	70	.875
30	.904	80	.872
40	.910	90	.870
550	.914	900	.867
60	.916	10	.865
70	.919	20	.861
80	.920	30	.859
90	.921	40	.857
600	.923	950	.854
10	.924	60	.853
20	.924	70	.851
30	.924	80	.848
40	.923	90	.845
650	.922	1000	.843
60	.922	10	.842
70	.920	20	.840
80	.918	30	.839
90	.918	40	.835
700	.915	1050	.835
10	.914	60	.833
20	.911	70	.832
30	.910	80	.831
40	.907		

Hand-Camera Lens

Spectral Transmittance, T_λ, of an E. Leitz Elmar Lens, 90 millimeter focal length, f/4, Serial No. 720367, and an E. Leitz Summitar Lens, 50 millimeter focal length, f/2, Serial No. 603453. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1195, -1196.)

Elmar Lens				Summitar Lens			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.674	750	0.903	400	0.627	750	0.827
10	.704	60	.903	10	.676	60	.826
20	.724	70	.902	20	.709	70	.824
30	.740	80	.901	30	.734	80	.820
40	.754	90	.900	40	.754	90	.818
450	.770	800	.899	450	.770	800	.814
60	.785	10	.897	60	.785	10	.812
70	.797	20	.896	70	.799	20	.809
80	.808	30	.895	80	.812	30	.806
90	.819	40	.893	90	.822	40	.804
500	.830	850	.891	500	.830	850	.800
10	.838	60	.890	10	.838	60	.798
20	.848	70	.888	20	.844	70	.795
30	.854	80	.886	30	.848	80	.792
40	.861	90	.886	40	.851	90	.789
550	.868	900	.884	550	.854	900	.788
60	.874	10	.882	60	.856	10	.785
70	.879	20	.880	70	.857	20	.782
80	.882	30	.878	80	.857	30	.780
90	.886	40	.877	90	.856	40	.779
600	.889	950	.875	600	.855	950	.777
10	.892	60	.873	10	.854	60	.774
20	.895	70	.871	20	.853	70	.771
30	.896	80	.870	30	.850	80	.769
40	.899	90	.868	40	.850	90	.767
650	.900	1000	.867	650	.848	1000	.766
60	.901	10	.865	60	.846	10	.764
70	.904	20	.864	70	.844	20	.762
80	.904	30	.863	80	.842	30	.761
90	.905	40	.860	90	.840	40	.759
700	.905	1050	.858	700	.838	1050	.758
10	.906	60	.857	10	.836	60	.757
20	.906	70	.856	20	.834	70	.756
30	.906	80	.855	30	.832	80	.754
40	.904			40	.830		

Hand-Camera Supplementary Lens

Spectral Transmittance, T_λ, of an Ansco No. 30 Portrait Lens, Plus 1, Size 6. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1200, -1199.)

No. 30 Portrait Lens
Plus 1, Size 6

Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.912	750	0.912
10	.912	60	.912
20	.912	70	.912
30	.914	80	.911
40	.914	90	.911
450	.915	800	.911
60	.916	10	.910
70	.918	20	.910
80	.918	30	.910
90	.918	40	.910
500	.918	850	.909
10	.918	60	.909
20	.918	70	.908
30	.918	80	.908
40	.918	90	.907
550	.918	900	.907
60	.918	10	.906
70	.918	20	.906
80	.918	30	.906
90	.918	40	.906
600	.917	950	.906
10	.916	60	.906
20	.916	70	.906
30	.915	80	.906
40	.915	90	.906
650	.915	1000	.906
60	.914	10	.907
70	.914	20	.907
80	.914	30	.907
90	.913	40	.907
700	.913	1050	.907
10	.914	60	.907
20	.913	70	.907
30	.912	80	.907
40	.912		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, Conversion 10, Size 5 (sample a), and an Ansco Filter, Conversion 11, Size 5 (sample a). (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1197, -1198.)

Conversion 10 Size 5 (sample a)				Conversion 11 Size 5 (sample a)			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.683	750	0.701	400	0.150	750	0.856
10	.717	60	.763	10	.133	60	.851
20	.740	70	.800	20	.130	70	.849
30	.747	80	.822	30	.141	80	.846
40	.742	90	.831	40	.164	90	.843
450	.726	800	.835	450	.202	800	.840
60	.707	10	.835	60	.255	10	.837
70	.667	20	.834	70	.314	20	.834
80	.602	30	.831	80	.369	30	.831
90	.533	40	.830	90	.420	40	.830
500	.485	850	.827	500	.456	850	.827
10	.424	60	.826	10	.474	60	.826
20	.318	70	.824	20	.482	70	.824
30	.236	80	.821	30	.495	80	.821
40	.251	90	.820	40	.525	90	.819
550	.360	900	.820	550	.558	900	.817
60	.445	10	.819	60	.595	10	.815
70	.450	20	.817	70	.649	20	.814
80	.423	30	.816	80	.728	30	.812
90	.391	40	.815	90	.804	40	.811
600	.340	950	.814	600	.852	950	.810
10	.276	60	.813	10	.875	60	.810
20	.216	70	.811	20	.883	70	.809
30	.192	80	.810	30	.885	80	.807
40	.210	90	.810	40	.883	90	.807
650	.214	1000	.809	650	.883	1000	.806
60	.189	10	.809	60	.880	10	.805
70	.159	20	.809	70	.879	20	.805
80	.131	30	.808	80	.876	30	.805
90	.172	40	.808	90	.874	40	.804
700	.309	1050	.808	700	.870	1050	.803
10	.435	60	.807	10	.869	60	.803
20	.510	70	.807	20	.865	70	.802
30	.573	80	.807	30	.861	80	.802
40	.634			40	.858		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, Conversion 10, Size 6 (sample a), and an Ansco Filter, Conversion 11, Size 6 (sample a). (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1200, -1199.)

Conversion 10 Size 6 (sample a)				Conversion 11 Size 6 (sample a)			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.676	750	0.695	400	0.141	750	0.854
10	.708	60	.757	10	.126	60	.850
20	.727	70	.791	20	.125	70	.846
30	.735	80	.810	30	.135	80	.844
40	.730	90	.817	40	.158	90	.840
450	.711	800	.821	450	.199	800	.837
60	.686	10	.821	60	.250	10	.834
70	.650	20	.819	70	.305	20	.831
80	.585	30	.817	80	.360	30	.828
90	.506	40	.815	90	.411	40	.825
500	.454	850	.812	500	.449	850	.823
10	.391	60	.810	10	.467	60	.821
20	.282	70	.808	20	.474	70	.817
30	.199	80	.805	30	.488	80	.815
40	.216	90	.804	40	.516	90	.813
550	.331	900	.801	550	.551	900	.810
60	.425	10	.800	60	.588	10	.809
70	.438	20	.797	70	.643	20	.807
80	.412	30	.796	80	.723	30	.806
90	.382	40	.796	90	.802	40	.805
600	.331	950	.795	600	.853	950	.804
10	.266	60	.794	10	.875	60	.802
20	.207	70	.792	20	.882	70	.802
30	.181	80	.791	30	.883	80	.801
40	.197	90	.790	40	.883	90	.800
650	.202	1000	.790	650	.883	1000	.800
60	.180	10	.789	60	.879	10	.799
70	.151	20	.788	70	.879	20	.798
80	.122	30	.787	80	.876	30	.797
90	.159	40	.787	90	.873	40	.797
700	.286	1050	.787	700	.869	1050	.796
10	.407	60	.787	10	.868	60	.796
20	.493	70	.788	20	.866	70	.796
30	.569	80	.790	30	.861	80	.796
40	.633			40	.859		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, Conversion 10, Size 5 (sample b), and an Ansco Filter, Conversion 11, Size 5 (sample b). (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1398, -1399.)

Conversion 10 Size 5 (sample b)				Conversion 11 Size 5 (sample b)			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.681	750	0.707	400	0.150	750	0.858
10	.717	60	.761	10	.133	60	.855
20	.738	70	.800	20	.130	70	.852
30	.746	80	.823	30	.137	80	.850
40	.740	90	.833	40	.158	90	.846
450	.723	800	.837	450	.200	800	.844
60	.700	10	.837	60	.250	10	.841
70	.666	20	.837	70	.308	20	.838
80	.600	30	.835	80	.363	30	.835
90	.532	40	.833	90	.412	40	.832
500	.486	850	.831	500	.450	850	.831
10	.427	60	.828	10	.470	60	.828
20	.318	70	.827	20	.476	70	.826
30	.234	80	.826	30	.490	80	.825
40	.256	90	.824	40	.520	90	.822
550	.367	900	.822	550	.554	900	.820
60	.449	10	.820	60	.592	10	.819
70	.450	20	.818	70	.649	20	.817
80	.423	30	.816	80	.731	30	.816
90	.390	40	.815	90	.808	40	.815
600	.336	950	.814	600	.854	950	.814
10	.274	60	.814	10	.875	60	.813
20	.215	70	.813	20	.884	70	.812
30	.194	80	.813	30	.885	80	.811
40	.210	90	.812	40	.885	90	.810
650	.214	1000	.812	650	.884	1000	.810
60	.188	10	.812	60	.882	10	.809
70	.158	20	.810	70	.880	20	.809
80	.134	30	.810	80	.877	30	.809
90	.173	40	.810	90	.874	40	.809
700	.311	1050	.810	700	.872	1050	.809
10	.439	60	.810	10	.869	60	.809
20	.513	70	.810	20	.866	70	.809
30	.574	80	.810	30	.864	80	.809
40	.635			40	.862		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, Conversion 10, Size 6 (sample b), and an Ansco Filter, Conversion 11, Size 6 (sample b). (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1398, -1399.)

Conversion 10 Size 6 (sample b)				Conversion 11 Size 6 (sample b)			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.678	750	0.707	400	0.146	750	0.853
10	.706	60	.761	10	.131	60	.851
20	.729	70	.793	20	.128	70	.848
30	.736	80	.813	30	.137	80	.846
40	.730	90	.820	40	.158	90	.842
450	.711	800	.822	450	.200	800	.838
60	.686	10	.822	60	.250	10	.835
70	.649	20	.821	70	.308	20	.832
80	.580	30	.817	80	.363	30	.829
90	.505	40	.816	90	.412	40	.826
500	.454	850	.814	500	.450	850	.824
10	.391	60	.811	10	.467	60	.821
20	.284	70	.810	20	.474	70	.819
30	.199	80	.807	30	.490	80	.817
40	.219	90	.805	40	.520	90	.815
550	.339	900	.804	550	.554	900	.813
60	.426	10	.801	60	.592	10	.811
70	.438	20	.799	70	.649	20	.810
80	.409	30	.799	80	.731	30	.809
90	.377	40	.796	90	.808	40	.807
600	.325	950	.795	600	.854	950	.805
10	.262	60	.794	10	.874	60	.805
20	.204	70	.794	20	.880	70	.804
30	.183	80	.793	30	.882	80	.803
40	.197	90	.792	40	.882	90	.802
650	.200	1000	.791	650	.880	1000	.801
60	.179	10	.790	60	.878	10	.800
70	.150	20	.790	70	.876	20	.800
80	.125	30	.789	80	.873	30	.800
90	.160	40	.789	90	.870	40	.800
700	.284	1050	.790	700	.867	1050	.800
10	.410	60	.790	10	.864	60	.800
20	.499	70	.790	20	.862	70	.800
30	.574	80	.791	30	.860	80	.800
40	.634			40	.856		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Eastman Kodak Filter, Wratten 80A, Series VI, and an Eastman Kodak Filter, Wratten 85, Series VI. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1400, -1401.)

Wratten 80A Series VI				Wratten 85 Series VI			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.639	750	0.549	400	0.041	750	0.896
10	.702	60	.660	10	.152	60	.896
20	.742	70	.735	20	.247	70	.895
30	.751	80	.790	30	.292	80	.893
40	.736	90	.827	40	.319	90	.892
450	.709	800	.847	450	.336	800	.891
60	.666	10	.858	60	.361	10	.890
70	.616	20	.866	70	.390	20	.889
80	.558	30	.868	80	.412	30	.888
90	.492	40	.871	90	.435	40	.887
500	.432	850	.871	500	.454	850	.886
10	.372	60	.872	10	.455	60	.885
20	.324	70	.873	20	.449	70	.884
30	.284	80	.873	30	.452	80	.884
40	.256	90	.873	40	.464	90	.884
550	.232	900	.873	550	.486	900	.882
60	.218	10	.872	60	.549	10	.882
70	.214	20	.872	70	.656	20	.881
80	.216	30	.872	80	.771	30	.880
90	.224	40	.872	90	.842	40	.880
600	.225	950	.872	600	.876	950	.880
10	.216	60	.872	10	.891	60	.880
20	.195	70	.871	20	.899	70	.879
30	.166	80	.871	30	.900	80	.879
40	.145	90	.870	40	.902	90	.878
650	.134	1000	.870	650	.902	1000	.877
60	.128	10	.870	60	.902	10	.877
70	.124	20	.869	70	.902	20	.876
80	.115	30	.869	80	.903	30	.876
90	.105	40	.868	90	.900	40	.876
700	.106	1050	.870	700	.900	1050	.877
10	.128	60	.870	10	.899	60	.877
20	.184	70	.871	20	.898	70	.877
30	.296	80	.871	30	.898	80	.877
40	.421			40	.897		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, UV-15, Size 5, of an Ansco Filter, UV-16, Size 5, and of an Ansco Filter, UV-17, Size 5. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1197, -1198.)

UV-15 Size 5				UV-16 Size 5				UV-17 Size 5			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.658	750	0.850	400	0.365	750	0.850	400	0.197	750	0.856
10	.662	60	.846	10	.546	60	.846	10	.397	60	.851
20	.679	70	.844	20	.686	70	.844	20	.601	70	.849
30	.708	80	.840	30	.765	80	.840	30	.725	80	.846
40	.734	90	.837	40	.806	90	.837	40	.792	90	.843
450	.770	800	.834	450	.836	800	.834	450	.831	800	.840
60	.805	10	.831	60	.855	10	.831	60	.855	10	.837
70	.835	20	.826	70	.869	20	.826	70	.869	20	.834
80	.857	30	.824	80	.878	30	.824	80	.878	30	.831
90	.872	40	.822	90	.884	40	.822	90	.884	40	.830
500	.883	850	.819	500	.890	850	.819	500	.890	850	.827
10	.891	60	.816	10	.895	60	.816	10	.895	60	.826
20	.895	70	.814	20	.896	70	.814	20	.896	70	.824
30	.898	80	.811	30	.898	80	.811	30	.898	80	.821
40	.899	90	.809	40	.899	90	.809	40	.899	90	.819
550	.900	900	.808	550	.900	900	.808	550	.900	900	.817
60	.900	10	.805	60	.900	10	.805	60	.900	10	.815
70	.898	20	.805	70	.898	20	.805	70	.898	20	.814
80	.897	30	.803	80	.897	30	.803	80	.897	30	.812
90	.895	40	.801	90	.895	40	.801	90	.895	40	.811
600	.893	950	.800	600	.893	950	.800	600	.893	950	.810
10	.891	60	.800	10	.891	60	.800	10	.891	60	.810
20	.887	70	.798	20	.888	70	.798	20	.890	70	.809
30	.884	80	.797	30	.885	80	.797	30	.886	80	.807
40	.881	90	.796	40	.883	90	.796	40	.884	90	.807
650	.879	1000	.796	650	.880	1000	.796	650	.883	1000	.806
60	.876	10	.795	60	.878	10	.795	60	.880	10	.805
70	.874	20	.794	70	.875	20	.794	70	.879	20	.805
80	.871	30	.794	80	.872	30	.794	80	.876	30	.805
90	.868	40	.793	90	.869	40	.793	90	.874	40	.804
700	.865	1050	.793	700	.866	1050	.793	700	.870	1050	.803
10	.863	60	.793	10	.863	60	.793	10	.869	60	.803
20	.860	70	.792	20	.860	70	.792	20	.865	70	.802
30	.856	80	.792	30	.856	80	.792	30	.861	80	.802
40	.855			40	.855			40	.858		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, UV-15, Size 6, of an Ansco Filter, UV-16, Size 6, and of an Ansco Filter, UV-17, Size 6. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1200, -1199.)

UV-15 Size 6				UV-16 Size 6				UV-17 Size 6			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.697	750	0.851	400	0.285	750	0.855	400	0.210	750	0.855
10	.706	60	.848	10	.474	60	.851	10	.401	60	.852
20	.719	70	.844	20	.636	70	.847	20	.591	70	.848
30	.740	80	.841	30	.735	80	.844	30	.717	80	.846
40	.760	90	.837	40	.785	90	.840	40	.785	90	.842
450	.781	800	.833	450	.824	800	.837	450	.824	800	.839
60	.816	10	.831	60	.848	10	.834	60	.850	10	.836
70	.838	20	.828	70	.862	20	.831	70	.866	20	.833
80	.856	30	.825	80	.874	30	.828	80	.875	30	.831
90	.869	40	.822	90	.881	40	.825	90	.884	40	.828
500	.879	850	.820	500	.887	850	.823	500	.889	850	.826
10	.886	60	.817	10	.893	60	.821	10	.893	60	.823
20	.891	70	.815	20	.897	70	.817	20	.897	70	.821
30	.895	80	.812	30	.899	80	.815	30	.899	80	.818
40	.898	90	.810	40	.901	90	.813	40	.901	90	.816
550	.900	900	.807	550	.902	900	.810	550	.902	900	.814
60	.901	10	.806	60	.902	10	.809	60	.902	10	.812
70	.900	20	.804	70	.901	20	.807	70	.902	20	.811
80	.899	30	.804	80	.899	30	.806	80	.902	30	.810
90	.897	40	.802	90	.897	40	.805	90	.899	40	.808
600	.895	950	.801	600	.895	950	.804	600	.898	950	.808
10	.892	60	.800	10	.892	60	.802	10	.895	60	.807
20	.889	70	.798	20	.889	70	.802	20	.892	70	.806
30	.887	80	.797	30	.887	80	.801	30	.889	80	.804
40	.883	90	.796	40	.883	90	.800	40	.886	90	.804
650	.883	1000	.796	650	.883	1000	.800	650	.885	1000	.803
60	.879	10	.795	60	.879	10	.799	60	.882	10	.803
70	.878	20	.795	70	.879	20	.798	70	.881	20	.801
80	.874	30	.794	80	.876	30	.797	80	.877	30	.801
90	.871	40	.794	90	.873	40	.797	90	.875	40	.801
700	.868	1050	.794	700	.869	1050	.796	700	.871	1050	.801
10	.867	60	.794	10	.868	60	.796	10	.870	60	.801
20	.862	70	.791	20	.866	70	.796	20	.866	70	.801
30	.858	80	.790	30	.861	80	.796	30	.861	80	.801
40	.854			40	.858			40	.858		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Ansco Filter, UV-16, Size 7, and of an Ansco Filter, UV-17, Size 7. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1190, -1191.)

UV-16 Size 7				UV-17 Size 7			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.298	750	0.809	400	0.150	750	0.818
10	.496	60	.802	10	.349	60	.811
20	.671	70	.797	20	.573	70	.806
30	.764	80	.791	30	.713	80	.801
40	.812	90	.787	40	.784	90	.796
450	.844	800	.782	450	.825	800	.791
60	.861	10	.776	60	.850	10	.786
70	.873	20	.772	70	.865	20	.782
80	.881	30	.767	80	.875	30	.777
90	.886	40	.763	90	.881	40	.773
500	.890	850	.760	500	.885	850	.770
10	.892	60	.756	10	.888	60	.766
20	.893	70	.752	20	.890	70	.763
30	.893	80	.748	30	.891	80	.760
40	.893	90	.746	40	.893	90	.757
550	.893	900	.743	550	.893	900	.754
60	.892	10	.740	60	.893	10	.751
70	.891	20	.738	70	.893	20	.748
80	.888	30	.736	80	.892	30	.747
90	.884	40	.733	90	.890	40	.745
600	.881	950	.732	600	.886	950	.742
10	.878	60	.730	10	.883	60	.741
20	.875	70	.728	20	.879	70	.741
30	.869	80	.726	30	.876	80	.740
40	.864	90	.726	40	.871	90	.737
650	.859	1000	.725	650	.866	1000	.737
60	.855	10	.724	60	.861	10	.736
70	.851	20	.724	70	.859	20	.736
80	.847	30	.724	80	.855	30	.736
90	.842	40	.722	90	.850	40	.734
700	.836	1050	.721	700	.844	1050	.734
10	.831	60	.720	10	.839	60	.731
20	.826	70	.719	20	.832	70	.731
30	.819	80	.719	30	.827	80	.731
40	.814			40	.822		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Eastman Kodak Filter, Wratten A, Series VII, of an Eastman Kodak Filter, Wratten B, Series VII, and of an Eastman Kodak Filter, Wratten C5, Series VII. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1190, -1191.)

Wratten A Series VII				Wratten B Series VII				Wratten C5 Series VII			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.000	750	0.860	400	0.000	750	0.362	400	0.073	750	0.071
10	.000	60	.858	10	.000	60	.533	10	.181	60	.198
20	.000	70	.856	20	.000	70	.652	20	.354	70	.343
30	.000	80	.855	30	.000	80	.728	30	.460	80	.484
40	.000	90	.853	40	.000	90	.782	40	.488	90	.608
450	.000	800	.850	450	.000	800	.816	450	.470	800	.692
60	.000	10	.848	60	.000	10	.841	60	.421	10	.752
70	.000	20	.846	70	.000	20	.856	70	.337	20	.790
80	.000	30	.846	80	.010	30	.866	80	.272	30	.816
90	.000	40	.843	90	.055	40	.871	90	.188	40	.832
500	.000	850	.842	500	.205	850	.876	500	.112	850	.843
10	.000	60	.840	10	.428	60	.877	10	.052	60	.850
20	.000	70	.837	20	.551	70	.880	20	.018	70	.854
30	.000	80	.836	30	.554	80	.880	30	.002	80	.859
40	.000	90	.835	40	.486	90	.881	40	.000	90	.861
550	.000	900	.834	550	.386	900	.881	550	.000	900	.862
60	.000	10	.832	60	.279	10	.881	60	.000	10	.864
70	.000	20	.831	70	.179	20	.881	70	.000	20	.865
80	.000	30	.831	80	.090	30	.882	80	.000	30	.866
90	.115	40	.830	90	.034	40	.882	90	.000	40	.866
600	.536	950	.829	600	.010	950	.882	600	.000	950	.867
10	.760	60	.828	10	.000	60	.882	10	.000	60	.867
20	.821	70	.827	20	.000	70	.882	20	.000	70	.867
30	.841	80	.826	30	.000	80	.882	30	.000	80	.867
40	.850	90	.826	40	.000	90	.882	40	.000	90	.867
650	.855	1000	.825	650	.000	1000	.882	650	.000	1000	.867
60	.859	10	.825	60	.000	10	.882	60	.000	10	.867
70	.862	20	.825	70	.000	20	.882	70	.000	20	.867
80	.864	30	.825	80	.000	30	.882	80	.000	30	.867
90	.864	40	.825	90	.000	40	.881	90	.000	40	.867
700	.864	1050	.824	700	.000	1050	.881	700	.000	1050	.867
10	.864	60	.822	10	.000	60	.881	10	.000	60	.867
20	.862	70	.819	20	.019	70	.880	20	.000	70	.867
30	.862	80	.819	30	.097	80	.880	30	.004	80	.867
40	.861			40	.221			40	.024		

Hand-Camera Filters

Spectral Transmittance, T_λ, of an Eastman Kodak Filter, Wratten N, Series VII, and of an Eastman Kodak Filter, Wratten Aero 2, Series VII. (See Index to Appendix A, and GE Graph Sheets Serial No. GE II - 1190, -1191.)

Wratten N Series VII				Wratten Aero 2 Series VII			
Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ	Wave Length mμ	T_λ
400	0.000	750	0.102	400	0.000	750	0.865
10	.000	60	.250	10	.000	60	.862
20	.000	70	.384	20	.000	70	.861
30	.000	80	.497	30	.000	80	.859
40	.000	90	.590	40	.000	90	.857
450	.000	800	.655	450	.000	800	.855
60	.000	10	.705	60	.000	10	.852
70	.000	20	.727	70	.020	20	.851
80	.006	30	.746	80	.131	30	.850
90	.060	40	.756	90	.340	40	.847
500	.205	850	.759	500	.545	850	.847
10	.360	60	.768	10	.674	60	.844
20	.436	70	.771	20	.742	70	.842
30	.432	80	.772	30	.779	80	.841
40	.370	90	.772	40	.804	90	.840
550	.284	900	.772	550	.821	900	.838
60	.190	10	.772	60	.836	10	.837
70	.107	20	.772	70	.848	20	.836
80	.050	30	.772	80	.857	30	.836
90	.018	40	.772	90	.864	40	.835
600	.001	950	.771	600	.868	950	.835
10	.000	60	.771	10	.872	60	.833
20	.000	70	.771	20	.874	70	.832
30	.000	80	.771	30	.875	80	.831
40	.000	90	.770	40	.874	90	.831
650	.000	1000	.770	650	.874	1000	.831
60	.000	10	.770	60	.875	10	.831
70	.000	20	.770	70	.875	20	.830
80	.000	30	.769	80	.875	30	.829
90	.000	40	.769	90	.873	40	.829
700	.000	1050	.767	700	.872	1050	.828
10	.000	60	.767	10	.871	60	.828
20	.000	70	.767	20	.870	70	.827
30	.004	80	.767	30	.868	80	.827
40	.034			40	.866		

Appendix C

Copies of the four requests authorizing the studies on the aerial- and hand-camera lenses and filters herein reported are included in this appendix together with other information on the disposition of the data. It will be noted that some of the camera lenses, both aerial and hand, could not be measured on the presently unmodified General Electric recording spectrophotometer. The unsuitable size of the optical elements or of the mounts of the camera lenses interfered with either the optical path of the light beam through the sample or with the comparison light beam of the instrument.

The following are copies of the original work requests received from Dr. O'Neill for hand-camera lenses and filters. Also included are copies of the WADC telegram requesting measurements of the aerial-camera lenses and filters, together with the NBS answer, and NBS notes on both of these matters.

* * * * *

Serial Number 2.1 WADC-17/53 (A) April 20, 1953

"Spectrophotometric curves of filters, lenses, etc. for use with Hasselblad, Karomat, Speedex, Viking and other cameras".

* * * * *

Serial Number 2.1 WADC-17/53 (B) July 13, 1953

"Spectrophotometric curves of the filters accompanying Fr. Dutilly's Hasselblad camera on clear Ozachrome cellulose acetate. These filters are: UV 16, UV 17, Aero 2 (yellow), Wratten A (red), Green B, Green N, Blue C-5. Also on Ozachrome cellulose acetate clear, a considerable number of spectrophotometric curves which you have already determined and which are of sufficient importance to justify making duplicates on this transparent medium for the purpose of comparison on a light-table".

"This request may be considered as duplicating a previous request. It is sent to make clearer what we need, if such clarification is necessary. If not, this request should be destroyed".

* * * * *

Note JCS to HJK September 16, 1953

"One set of each of the single and the double Ozachromes given to Dr. O'Neill. Dr. O'Neill also has four sets of double Ozalids of two double sheets of lenses and filters, GE II-1188, - 1189, -1190, and -1191".

* * * * *

Serial Number 2.1 WADC-17/53 (C) February 25, 1954

"Please determine the spectrophotometric curves of the following filters which will be used in experimental photography for WADC in the near future: Two conversion filters No. 10 Ansco, Series V and VI; and two conversion filters No. 11 Ansco, Series V and VI. These are herewith. They are for using Ansco Color Daylight film in tungsten-light illumination and Ansco Color tungsten-light film used in daylight. As these conversion filters differ very notably even to the eye, from similar conversion filters for Eastman's Kodachrome, we also wish to have similarly studied the Kodak

conversion filters which we will deliver next week but in size Series VI only. It is believed the curves resulting from these studies will enable us to understand the different results obtained when using the two corresponding films, at least to some extent".

* * * * *

Telegram March 11, 1954 152PM

"FM COM WADC Wright Patterson AFB Ohio. To National Bureau of Standards. From WCLFP-1 For Mr. Harry J. Keegan, Spectrophotometry Section".

"Capt. Robert Fisher and T/Sgt Stephen Ujhelyi expect to arrive National Bureau of Standards on 16 March 1954 with four aerial camera lenses, two 24-inch, one 12-inch and one 6-inch to be tested for spectral transmittance characteristics. Please advise if this date not suitable. Photographic Reconnaissance Laboratory WADC."

* * * * *

Telegram March 11, 1954 332P
"175 CI WBS /C-NBS/ Washington 3-11-54 332P
Commanding General /WCLFP/
Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Retel. We shall expect Captain Robert Fisher and Sergeant Stephen Ujhelyi on 16 March 1954. Can measure spectral transmission of 6-inch aerial camera lens. Will try to measure spectral transmission of 12 and 24-inch lenses.

Harry J. Keegan, National Bureau of Standards

16 1954 6 12 24
JG 334P"

* * * * *

Note JCS to HJK March 17, 1954

"Tracings of visible and near infrared spectral transmittance curves given to Captain Robert Fisher of the following: (1) the rear cell of a Metrogon lens, B & L 6" f/6.3; (2) the front and rear cells of a B & L 12" f/4.5 lens; and (3) a yellow glass filter used with the B & L Metrogon lens, showing the spectral transmittance of the glass filter and the anti-vignetting neutral density spot of the glass filter".

* * * * *

Note JCS to HJK April 15, 1955

"Given to Dr. O'Neill, copies of the following: (1) double Ozachromes. GE graph sheet Nos. GE II-1190-1191, 1197-1198, 1200-1199, 1237-1238, 1188-1189; (2) single Ozachromes. GE graph sheet Nos. GE II-1188, 1189, 1190, 1191, 1197, 1198, 1199, 1200, 1237, and 1238".

* * * * *

THE NATIONAL BUREAU OF STANDARDS

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The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

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The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS