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MILITARY STANDARD

FILTERS, LIGHT, PHOTOGRAPHIC

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DEPARTMENT OF DEFENSE

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Filters, Light, Photographic

MIL-STD-1278

1. This standard is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to U.S. Army Electronics Command, Fort Monmouth, New Jersey 07703

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1. SCOPE

1.1 Purpose. This standard is issued to describe a general method of describing filters according to construction type, optical quality, and intended use, and to establish uniform definitions, general requirements (which includes the military filter designation system), detailed requirements, and test methods for filters used in military photographic work.

1.2 Classification. This standard covers photographic light filters classified as to the material from which they are constructed (type); as to optical quality (grade); and as to intended use (class).

1.2.1 Type. Filters are typed according to the material from which they are constructed.

Type I - Polymer sheet or film.
Type II - Polymer layer sandwiched between two sheets of glass.
Type III - Solid glass.
Type IV - Materials other than those used for types I, II, and III.

1.2.2 Grade. Filters are graded according to optical quality.

Grade B - High optical quality - to be used in the path of image-forming rays.
Grade C - Lower optical quality - not to be used in the path of image-forming rays.

1.2.3 Class. Filters are classed according to intended use.

Class B - Used with black and white film.
Class C - Used with color film.
Class P - Printing (color or black and white).
Class Z - Light polarizing (color or black and white photography).
Class S - Photographic safelights.
Class ND - Neutral density to cut down light uniformly across the spectrum (color or black and white photography).

2. REFERENCED DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

STANDARDS

MILITARY

MIL-STD-130 - Identification Marking of U.S. Military Property.
MIL-STD-150 - Photographic Lenses.

3. DEFINITIONS

3.1 Artificial daylight. Artificial illumination as used for photography, color matching, and colorimetry in which a light source is modified by means of filters to produce light simulating the combination of sunlight plus skylight.

3.2 Artificial light. Illumination provided by incandescent, flourescent, or flame sources as distinguished from natural light produced by solar radiation or self-luminous organisms.

3.3 Beauty defects. Beauty defects are those imperfections of components and elements of an optical system which do not affect the optical characteristics. They are undesirable but may be accepted if they do not cause a significant degradation of image quality or environmental stability. The various imperfections classified as beauty defects are as follows.

3.3.1 Material defects.

3.3.1.1 Bubbles. Bubbles are air or gaseous inclusions entrapped within the filter.

3.3.1.1.1 Seeds. Seeds are very small bubbles.

3.3.1.1.2 Air bells. Air bells are irregularly shaped bubbles.

3.3.1.2 Cracks. Cracks are shallow separations or breaks in the glass filter.

3.3.1.3 Feathers. Feathers are powdered surfaces folded into the glass in the pressing process.

3.3.1.4 Folds, or laps. Folds, or laps, are areas in which the glass has been folded upon itself but not fused.

3.3.1.5 Milkiness. Milkiness is cloudy or milky areas within the filter.

3.3.1.6 Stones. Stones are fragments of undissolved material in the filter.

3.3.1.7 Strain. Strain is tension within the filter caused by inadequate annealing or improper mounting. The tension alters the index of refraction of the material and causes it to become birefringent.

3.3.1.8 Striae. Striae are streaks or veins in the filter with the index of refraction differing from that of the body of the filter.

3.3.1.8.1 Reams. Reams are fine bands of striae.

3.3.1.8.2 Cords. Cords are streaks of very heavy striae.

3.3.2 Manufacturing defects.

3.3.2.1 Blisters. Blisters are bubbles in a cement layer.

3.3.2.2 Cement starts. Cement starts are spots where the components of a cemented filter have started to separate. They can be small irregular spots between the elements or run-ins at the edge, insufficient cement, or cement at the edge dissolved by a solvent.

3.3.2.2.1 Run-ins. Run-ins are cement separations at the edge of a cemented filter.

3.3.2.3 Chips. Chips are areas from which the filter material has been broken away from the surface, edge, or bevel of an optical element.

3.3.2.4 Cracks. Cracks are breaks in the filter.

3.3.2.5 Digs. Digs are breaks of the polished surface of a round, oval, square, etc., shape including pits, holes, and surface broken bubbles.

3.3.2.5.1 Dirt holes. Dirt holes are digs filled with rouge or other foreign material.

3.3.2.6 Dirt. Dirt consists of dust, lint, or other foreign matter on the surface or entrapped in a cement layer.

3.3.2.7 Orange peel. Orange peel is poorly polished surface, pock-marked with pits, having much the same surface appearance as the skin of an orange.

3.3.2.8 Poor polish. Poor polish pertains to polished surfaces containing minute pits of a gray or red color. They are gray grinding pits in the surface of the glass, or red grinding pits in which rouge has been so deeply embedded that it has to be removed by further polishing.

3.3.2.9 Scratches. Scratches are furrows or grooves in the surface of the filter caused by coarse grit, fragments of glass, sharp tools, etc., rubbed over the surface.

3.3.2.10 Smears, scum, water spots, etc. Smears, scum, water spots, etc., are residues of evaporated or unevaporated moisture. They are usually removable from other than Type I filters by "normal" cleaning.

3.3.2.11 Stain. Stain is a discoloration of the filter surface, usually brown, blue, or green, caused by the deposit of foreign matter, or changes produced on the surface of the filter by chemical action of some substance with the filter. It is usually not removable by "normal" cleaning.

3.4 Cement. An adhesive used to bond elements of Type II filters together.

3.5 Chromaticity. The quality of color expressible by dominant wavelength and purity taken together.

3.6 Chromaticity coordinates. Proportions of standard components required for color match, used as ordinate and abscissa to represent color in a chromaticity diagram.

3.7 Coating, anti-reflection. These coatings, known also as low reflecting films, are ordinarily used for reducing the reflectance and increasing the transmittance of glass surfaces.

3.8 Collimator. An optical device for artificially creating a target at infinite distance (a beam of parallel rays of light) used in testing and adjusting certain optical instruments. It usually consists of a converging lens and a target (a system of cross lines) placed at the principal focus of the lens.

3.9 Color. Characteristics of light other than spatial and temporal characteristics; light being that aspect of radiant energy of which a human observer is aware through the visual sensations which arise from the stimulation of the retina of the eye.

3.10 Color balance. The relationship between the three images composing a color negative or positive which provides accurate (or, more generally, the desired) reproduction of the natural colors.

3.11 Color Compensating Filter. A filter used to change the overall color balance of photographic results obtained with color films, and to compensate for deficiencies in the quality of the light when printing color films.

3.12 Color Contribution. The effect that an optical system has on changing the spectral characteristics of the light flux entering the system is termed "color contribution." This property of an optical system is specified and measured in terms of conventional spectral transmittance curves, wherein transmittance in percent is plotted against wavelength in millimicrons.

3.13 Color Specifications. Description of a color made in such a way that a color match for it may be set up. This description may take the form of a spectrophotometric curve, the amounts (tristimulus values) of three defined colors required for the match, or it may identify a material sample having the color intended.

3.14 Color Temperature. The temperature to which a blackbody radiator must be raised so that the light it emits may match a given light source in color. Usually expressed in degrees Kelvin (°K).

3.15 Colorants. Substances used to modify the colors of objects. Dyes, pigments, paints, inks, and all decorative coatings are colorants.

3.16 Colorimetric Calculation. Determination of color specifications by calculation from spectrophotometric data.

3.17 Complementary Wavelength (of a color). Wavelength of the spectrum color which must be mixed with the color to produce a match for a standard reference source (such as average daylight).

3.18 Contrast Filter. An optical filter used in photography to increase the contrast between one color and another that would otherwise be reproduced as similar gray densities.

3.19 Cyan. The preferred color name for the minus-red subtractive primary in three-color processes. Such a color has a rejection band in the region of 600 to 700 millimicrons and transmits (or reflects) light in the range of 400 to 600 millimicrons. Also called "blue," "blue-green," "sky blue," "turquoise."

3.20 Daylight. (1) Light consisting of a natural combination of sunlight and skylight. (2) The color quality of average daylight is said to match a blackbody at approximately 7000 degrees Kelvin.

3.21 Decamired. Related to mired by the expression

$$\text{Decamired Value} = \frac{\text{Mired Value}}{10}$$

3.22 Decamired System. A system of filters for color balancing and film type conversion used in color photography. Filter selection for a specific photograph is based on the color temperature of the light source and the color temperature response of the film being used.

3.23 Density, Optical. Logarithm to the base 10 of the reciprocal of transmittance.

3.24 Deviation. The angle through which a ray of light is bent as it passes through a filter.

3.25 Dominant Wavelength (of a color). Wavelength of the spectrum color which must be mixed with a standard reference source (such as average daylight) to produce a match for the color. Dominant wavelength correlates approximately with the hue perceived by an observer of normal color vision adapted to daylight, to belong to the color.

3.26 Effective Density. The effective density of a filter is the density measured with radiant energy extending over a finite wavelength region. It is a function of the transmittance of the filter, the sensitivity of the film, and the transmittance of a lens. It may also be a function of the spectral distribution of the illuminant.

3.27 Effective Transmittance. Effective transmittance (T_{eff}) is related to effective density (D_{eff}) by the expression

$$D_{eff} = -\log_{10} T_{eff}$$

3.28 Effective Wavelength. The effective wavelength of a light filter is the wavelength used in radiation formulas to calculate, at two different temperatures, a ratio of radiation intensities equal to the ratio of the luminosities of a blackbody observed or measured through the light filter.

3.29 Emulsion, Color Sensitive. A black and white emulsion having, in addition to the normal ultraviolet, violet, and blue sensitivity of the silver halide, added sensitivity to light of the longer wavelengths conferred by treatment with sensitizing dyes. Emulsions optically sensitized to yellow and green light are called orthochromatic. Those sensitized, in addition, to orange and red light are called panchromatic.

3.30 Emulsion Layer. In the anatomy of a photographic film, the emulsion layer is any coating which contains light sensitive materials as distinguished from the backing, base, substratum, or filter layers.

3.31 Fade-O-Meter. Trade name for a standard testing device simulating the effect of sunlight to determine the fading, yellowing, and other light aging characteristics of a material.

3.32 Film, Photographic, Color. Film used for the production of pictures in natural colors.

3.33 Film, Photographic, Infrared. Film coated with an emulsion especially sensitive to infrared light.

3.34 Filter, Color. An optical element such as a sheet of glass, gelatin, or plastic, dyed in a specific manner to selectively absorb light of certain colors. Also called ray filter and ray screen. Principal uses of color filters in photography are to emphasize or subdue certain colors (contrast filters), to improve the monochrome rendition of colored objects (correction filters), and to make color separations, all on black and white film.

3.35 Filter Factor. The number of times exposure must be increased to compensate for light absorbed by a filter.

3.36 Filter, Photographic. A layer of glass, gelatin, or other material used to selectively modify the transmitted light.

3.37 Filter, Neutral Density. A filter not selective for a certain portion of the spectrum but absorbing all colors equally, thus reducing the intensity of transmitted light without changing its chromaticity.

3.38 Filter Ratio. In color photography, the ratio of the exposure times used when blue, green, and red filters are used to make color separation negatives. The exposure time through the red filter is generally used as the basis for the ratio.

3.39 Filter, Polarizing. An optical device which converts natural or unpolarized light into polarized light. It is used to control the brightness of the sky and reflections from specular surfaces relative to the brightness of other parts of the scene.

3.40 Filter, Ultra-Violet. A light filter which (1) absorbs the ultra-violet but transmits visible light, or (2) absorbs visible light while transmitting some region in the ultra-violet. The latter is described as an ultra-violet cut-off filter.

3.41 Filters, tricolor. The particular color filters used for exposure of separation negatives in three-color photography.

3.42 Flux. A term used as an abbreviation for luminous flux or radiant flux.

3.42.1 Flux, luminous. The quantity that specifies the capacity of the radiant flux to produce the attribute of visual sensation known as brightness. Luminous flux is radiant flux evaluated with respect to its luminous efficiency of radiation. Unless otherwise stated, luminous flux pertains to the standard photopic observer.

3.42.2 Flux, radiant. Radiant energy transferred per unit time.

3.43 Homogeneity. The quality of a body in which the physical state of all minute portions are the same.

3.44 Illuminant C. A standard source defined by the Commission International de l'Eclairage (CIE). This source is often used to simulate average daylight.

3.45 Illumination. (1) Synonymous with flux density; stated in terms of units of luminous flux incident upon a unit area. If the flux is given in lumens and the area in square feet, the illumination is measured in foot-candles. (2) The lighting arrangement effective on a subject being photographed.

3.46 Infrared. Pertains to or designates those rays which lie beyond the red end of the visible spectrum (i.e., rays emitted by a hot body). Infrared rays are invisible and are detected by their thermal, photoelectric, and photographic effects. Their wavelengths are longer than those of visible light and shorter than those of radio waves.

3.47 Intensity (luminous). The solid angular flux density of a light source in a given direction. Hence, it is the luminous flux, on a surface normal to that direction, divided by the solid angle (in steradians) which the surface subtends at the source of light.

3.48 Kelvin, degrees. Kelvin refers to measurement of the color of light in degrees. Kelvin temperature (°K) is equal to Centigrade temperature plus 273.

3.49 Laminate. Material consisting of two or more layers pressed together, usually with an adhesive.

3.50 Light. The aspect of radiant energy of which a human observer is aware through the visual sensations which arise from the stimulation of the retina of the eye.

3.51 Light, polarized. Light in which the electric vector of the wave vibrates on one plane rather than all planes as it does in ordinary (unpolarized) light. Light may become polarized by reflection or by passing through optical devices or sheets known as "polarizers."

3.52 Magenta. The color name for the minus-green subtractive primary used in three-color processes. Such a color has an rejection band in the 500- to 600- millimicron range. Its transmission (or reflection) is in the 400- to 500- and 600- to 700- millimicron range.

3.53 Military filter designation system (MFDS). This system is a three-item code referring to usage, color, and filter designation currently in common use. Each filter has a specific code designation.

3.54 Millimicron. A unit of length in the metric system equal to 0.001 micron. It is equivalent to 10 angstroms and is now frequently called nanometer (nm).

3.55 Mired. A contraction for micro-reciprocal degrees. It is used as a convenient alternative to the designation of color quality by color temperature. Thus, a color temperature of 3000°K may be expressed as $10^6/3000$ mireds or 333.3 mireds.

3.56 Mired filter. A filter which raises or lowers the color temperature of a light source. The mired value or mired shift value of a filter is given by $(1/T_1 - 1/T_2)\ 10^6$, where T_1 is the color temperature in degrees Kelvin of the light source and T_2 is the apparent color temperature in degrees Kelvin of the light source viewed through the filter.

3.57 Mired shift value. See mired filter.

3.58 Objective. In telescopes and microscopes, it is the optical component which receives light from the object and forms the first or primary image. The image thus formed is magnified by use of an eyepiece.

3.59 Optical axis. The line formed by the coinciding principal axes of a series of optical elements comprising an optical system; in other words, an imaginary line passing through the centers of curvature of the optical elements of a system.

3.60 Optical characteristics. Those properties of a filter which affect its optical performance (e.g., aberration, deviation, and resolution).

3.61 Parallelism. The absence of a finite angle between the front and rear optical surfaces of the filter.

3.62 Photicity. Photicity is a measure of the actinic effectiveness of an illuminant and can be obtained as the product of the spectral sensitivity of the emulsion, the spectral energy distribution of an illuminant, and the spectral transmittance distribution of an intervening absorber.

3.63 Photography, infrared. The rendering of images by the photographic action of infrared radiation on infrared sensitized films or plates, as distinguished from imagery produced by thermal action of infrared radiation on thermal sensing devices.

3.64 Polariscope. A combination of polarizer and analyzer used to detect birefringence in materials placed between them or to detect rotation in the plane of polarization caused by such materials.

3.65 Polarizer. An optical device for converting unpolarized or natural light into polarized light.

3.66 Resolution chart. A carefully prepared card with vertical and horizontal lines inscribed at various spacings. It is used to test the resolving power of an optical system.

3.67 Resolving power. The degree to which an optical system is able to define the details of an image. This is expressed as the maximum number of black lines, with equal white interspaces per millimeter, discernible in the image.

3.68 Reticle. A scale, indicator, or pattern placed in one of the focal planes of an optical instrument so that it appears to the observer to be superimposed upon the field of view. Reticles are used to determine the center of the field or to assist in gaging distance, determining leads, or measurements.

3.69 Safelight. A darkroom light source shielded by filters which pass only such parts of the spectrum that will not expose or fog sensitized materials within time limits dictated by practical consideration.

3.70 Saturation. The degree of purity of color or freedom from dilution by black or white.

3.71 Selected ordinate method. Numerical integration using unequal intervals of integration variable, so as to eliminate multiplications in determination of contribution of each interval.

3.72 Sensitivity. The degree to which an emulsion reacts by the formation of a image under given exposure conditions, especially as this relates to exposure by different wavelengths (colors) of light.

3.73 Skylight. Light from the sun which reaches the observer indirectly by scattering and reflection in the upper air.

3.74 Spectral. Pertains to the electromagnetic spectrum; i.e., a quantity measured with respect to a narrow wavelength interval, as spectral transmittance or spectral reflectance.

3.75 Spectral Sensitivity. The response of a sensitized material to radiant energy in a narrow wavelength interval, often expressed as the reciprocal of the exposure required to produce a given density under specified conditions.

3.76 Spectral Sensitivity Distribution. The spectral sensitivity for various wavelengths, usually displayed as a smooth curve of sensitivity vs. wavelength.

3.77 Spectrophotometer. An instrument which measures the reflectance or transmittance of a sample to monochromatic light whose wavelength can be varied progressively over some specified range.

3.78 Spectrum. (1) A pattern formed by radiation when it is angularly dispersed by refraction or diffraction, or a band or series of juxtaposed images of a line-source of radiant energy produced upon a screen by refraction or diffraction of the radiant energy at angles depending upon the wavelength. When the range of wavelength is confined to the limits perceptible by the eye, the pattern will take the form of a bank of light with progressively varying color ranging from red at one end to violet at the other. If the radiation arises in an incandescent solid, all wavelengths of light are 'present' and the spectrum will be continuous. If it arises in an incandescent gas, certain wavelengths will be absent and the spectrum will consist of a number of bright lines with dark spaces between them, each line having a different color from all the others. (2) The word "spectrum" is often used to designate some range of wavelengths of electromagnetic radiation, such as "the visible spectrum," "the ultraviolet spectrum," etc. (3) Analogously, the term "spectrum" may be used to designate a range of sound frequencies or wavelengths.

3.79 Spectrum Locus. A curve connecting points in chromaticity diagram that represent various wavelengths of the spectrum.

3.80 Specular. Like a mirror, reflecting in a regular manner so that clear images may be formed, non-diffusing. The meaning is extended to include regular (non-diffusing) transmission as well as reflection, e.g., specular density as contrasted to diffuse density.

3.81 Sunlight. Light reaching the observer directly from the sun. Such light may be altered by absorption in passing through the earth's atmosphere but it must not include light reaching the observer indirectly by refraction (e.g. rainbow) or by reflection. Washington, D.C., mean noon sunlight has a color temperature in the neighborhood of 5,600 degrees Kelvin. Distinguished from: Skylight, Daylight.

3.82 Transmittance. The ratio of the flux transmitted by an object to the incident flux. This term and its specializations are applied to radiant and luminous flux. Unless qualified, the term applies to regular (specular) transmission.

3.83 Transmittance, Spectral. Transmittance evaluated over a narrow wavelength interval.

3.84 Ultraviolet. Those rays which lie just beyond the violet end of the visible spectrum. Ultraviolet wavelengths are comparatively short (about 100 to 390 millimicrons).

3.85 Visible Spectrum. The portion of the electromagnetic spectrum to which the retina is sensitive and by which we see. Extends from about 400 to about 750 millimicrons in wavelength of the radiation.

3.86 Wavelength Centroid. Alternative name for spectral centroid. Spectral Centroid - average wavelength, weighted by transmittance.

4. GENERAL REQUIREMENTS

4.1 Military Filter Designation System. The Military Filter Designation System (MFDS) consists of a three-item code referring to usage, color, and filter designation in common use.

4.1.1 Item One (Usage). Item One in the MFDS code is a class letter which designates the Class of the filter, as follows:

Class letter	Filter use
B	For camera use with black and white film
C	For camera use with color film
P	In printing processes
Z	Polarizing filter
S	Safelight filter
ND	Neutral density filter

4.1.2 Item Two (Color). Item Two in the MFDS code is a color number which indicates the color of the filter. The color number is based upon the location of the dominant wavelength of the filter within the spectrum band, as follows:

Color Number	Color	Spectrum band (Wavelength in Millimicrons)
0	Ultraviolet	360-399
1	Blue	400-484
2	Yellow	560-589
3	Green	495-559
4	Magenta	490-570 complementary
5	Red	590-699
6	Cyan	485-494
7	Infrared	700 and above

4.1.2.1 Dominant wavelength. The dominant wavelength of a filter is determined with the use of a chromaticity diagram.

4.1.2.1.1 Chromaticity diagram. The chromaticity diagram is constructed by plotting values of x horizontally, increasing towards the right, and plotting values of y vertically, increasing upward according to the same linear scale as x.

4.1.2.1.1.1 The values of the x and y coordinates for certain wavelengths of the spectrum are given in Table I. They form the spectrum locus where these points are connected by a smooth curve.

Table I[1]

Trichromatic Coordinates of the Spectrum

Wave-length (mμ)	x	y	z	Wave-length (mμ)	x	y	z
380	0.1741	0.0050	0.8209	580	0.5125	0.4866	0.0009
385	0.1740	0.0050	0.8210	585	0.5448	0.4544	0.0008
390	0.1738	0.0049	0.8213	590	0.5752	0.4242	0.0006
395	0.1736	0.0049	0.8215	595	0.6029	0.3965	0.0006
400	0.1733	0.0048	0.8219	600	0.6270	0.3725	0.0005
405	0.1730	0.0048	0.8222	605	0.6482	0.3514	0.0004
410	0.1726	0.0048	0.8226	610	0.6658	0.3340	0.0002
415	0.1721	0.0048	0.8231	615	0.6801	0.3197	0.0002
420	0.1714	0.0051	0.8235	620	0.6915	0.3083	0.0002
425	0.1703	0.0058	0.8239	625	0.7006	0.2993	0.0001
430	0.1689	0.0069	0.8242	630	0.7079	0.2920	0.0001
435	0.1669	0.0086	0.8245	635	0.7140	0.2859	0.0001
440	0.1644	0.0109	0.8247	640	0.7190	0.2809	0.0001
445	0.1611	0.0138	0.8251	645	0.7230	0.2770	0.0000
450	0.1566	0.0177	0.8257	650	0.7260	0.2740	0.0000
455	0.1510	0.0227	0.8263	655	0.7283	0.2717	0.0000
460	0.1440	0.0297	0.8263	660	0.7300	0.2700	0.0000
465	0.1355	0.0399	0.8246	665	0.7311	0.2689	0.0000
470	0.1241	0.0578	0.8181	670	0.7320	0.2680	0.0000
475	0.1096	0.0868	0.8036	675	0.7327	0.2673	0.0000
480	0.0913	0.1327	0.7760	680	0.7334	0.2666	0.0000
485	0.0687	0.2007	0.7306	685	0.7340	0.2660	0.0000
490	0.0454	0.2950	0.6596	690	0.7344	0.2656	0.0000
495	0.0235	0.4127	0.5638	695	0.7346	0.2654	0.0000
500	0.0082	0.5384	0.4534	700	0.7347	0.2653	0.0000
505	0.0039	0.6548	0.3413	705	0.7347	0.2653	0.0000
510	0.0139	0.7502	0.2359	710	0.7347	0.2653	0.0000
515	0.0389	0.8120	0.1491	715	0.7347	0.2653	0.0000
520	0.0743	0.8338	0.0919	720	0.7347	0.2653	0.0000
525	0.1142	0.8262	0.0596	725	0.7347	0.2653	0.0000
530	0.1547	0.8059	0.0394	730	0.7347	0.2653	0.0000
535	0.1929	0.7816	0.0255	735	0.7347	0.2653	0.0000
540	0.2296	0.7543	0.0161	740	0.7347	0.2653	0.0000
545	0.2658	0.7243	0.0099	745	0.7347	0.2653	0.0000
550	0.3016	0.6923	0.0061	750	0.7347	0.2653	0.0000
555	0.3373	0.6589	0.0038	755	0.7347	0.2653	0.0000
560	0.3731	0.6245	0.0024	760	0.7347	0.2653	0.0000
565	0.4087	0.5896	0.0017	765	0.7347	0.2653	0.0000
570	0.4441	0.5547	0.0012	770	0.7347	0.2653	0.0000
575	0.4788	0.5202	0.0010	775	0.7347	0.2653	0.0000
				780	0.7347	0.2653	0.0000

[1] American Standard Z58.7.2-1951.

4.1.2.1.2 Determination of the chromaticity coordinates of the filter by the selected ordinates method. "Selected ordinates" refers to the ordinates of the transmission versus wavelength curve of the filter that has been selected for performing a simple integration, which is required for finding the chromaticity coordinates. Thirty wavelengths are used for each integration. They are listed in Table II. The transmittance values at these wavelengths are measured, or read from a curve based on measurements at other wavelengths. The average of all values for the wavelengths listed under X' is multiplied by 0.9804 and called X. The average of the Y' column is used without modification, and called Y. The average of the Z' column is multiplied by 1.1810 and called Z.

4.1.2.1.2.1 The chromaticity coordinates, i.e., the coordinates on the chromaticity diagram that represent the test filter, are found by the use of the formulas:

$$x = \frac{X}{X + Y + Z} \qquad y = \frac{Y}{X + Y + Z}$$

4.1.2.1.2.2 The coordinates of Standard Source C on the chromaticity diagram are given as $x = 0.3101$ and $y = 0.3163$.

4.1.2.1.2.3 The dominant wavelength of the test filter is determined by a line drawn from the point on the chromaticity diagram representing Standard Source C, through the point on the diagram representing the test filter, and extending to the curve of the spectrum locus defined by Table I. The exact value of the dominant wavelength can then be found by interpolation.

4.1.2.1.3 Complementary wavelength. Where the line extended from the coordinates of Standard Source C through the test filter point does not intercept the curve of the spectrum locus, reverse the direction of the line so as to intercept the spectrum locus. This intercept point is the complementary wavelength. A complementary wavelength is that wavelength interpolated on the spectrum locus for the intersection of that curve with the straight line drawn from the point xy, representing the sample through the point $x_o = 0.3101$, $y_o = 0.3163$ representing the standard quality of illumination, and extending to the spectrum locus.

4.1.2.2 Wavelength centroid. For those filters which have transmission bands beyond the visible spectrum, the wavelength centroid or spectral centroid may be employed in place of the dominant wavelength. The spectral centroid of a filter is the average wavelength transmitted by the filter and is computed by weighting each wavelength by the transmittance of the filter. The spectral centroid may be evaluated using the following formula:

$$\lambda_{ctd} = \frac{\Sigma \lambda t}{\Sigma t}$$

Table II[2]

Selected Ordinates for Standard Source, C

Ordinate Number	X' (mμ)	Y' (mμ)	Z' (mμ)
1	424.4	465.9	414.1
2	435.5	489.4	422.2
3	443.9	500.4	426.3
4	452.1	508.7	429.4
5	461.2	515.1	432.0
6	474.0	520.6	434.3
7	531.2	525.4	436.5
8	544.3	529.8	438.6
9	552.4	533.9	440.6
10	558.7	537.7	442.5
11	564.1	541.4	444.4
12	568.9	544.9	446.3
13	573.2	548.4	448.2
14	577.3	551.8	450.1
15	581.3	555.1	452.1
16	585.0	558.5	454.0
17	588.7	561.9	455.9
18	592.4	565.3	457.9
19	596.0	568.9	459.9
20	599.6	572.5	462.0
21	603.3	576.4	464.1
22	607.0	580.5	466.3
23	610.9	584.8	468.7
24	615.0	589.6	471.4
25	619.4	594.8	474.3
26	624.2	600.8	477.7
27	629.8	607.7	481.8
28	636.6	616.1	487.2
29	645.9	627.3	495.2
30	663.0	647.4	511.2

[2] American Standard Z.58.7.2.

where: λ_{ctd} is the wavelength centroid when the evaluation is carried out at 10 mu intervals or less.

λ is the wavelength.

t is the transmittance at λ.

4.1.3 Item Three (Filter designation in common use). Item Three in the MFDS code is a number (or number and letter) which refers to the filter designation in common commercial use.

4.1.3.1 Decamired filters. Item Three for decamired filters will consist of the letters DR or DB (indicating the respective positive or negative decamired values) followed by the decamired value number. Where a commercial filter number exists, it appears in parenthesis after the decamired value number, e.g., (81), (81A), (81B), (81C), (81D), (81EF), (82), (82A), (82B), or (82C). Filters with decamired values other than those of the 81 and 82 series will have no commercial filter number.

4.1.4 Neutral density filters. Neutral density filters are designated by three items, as follows: Class letter - nominal filter density - filter factor.

4.1.4.1 Filter factors for neutral density filters are given by the number whose log is the density value. For example, for filter nominal densities of 2.0 and .50, the filter factors are 100 and 3.2, respectively.

4.1.5 Color compensating and color printing filters. The color compensating and color printing filters are designated by three items, as follows: Class letter - color number - commercial color density.

4.1.6 Varigam and polycontrast printing filters. The military designations for the corresponding commercial filters are shown in Table III.

Table III

Military Designations for Commercial Varigam and Polycontrast Printing Filters

Commercial Name	MFD	Commercial Name	MFD
Varigam 1	P-2-1V	Polycontrast 1	P-2-1P
Varigam 2	P-2-2V	Polycontrast 1-1/2	P-2-1.5P
Varigam 3	P-2-3V	Polycontrast 2	P-4-2P
Varigam 4	P-2-4V	Polycontrast 2-1/2	P-4-2.5P
Varigam 5	P-5-5V	Polycontrast 3	P-4-3P
Varigam 6	P-4-6V	Polycontrast 3-1/2	P-4-3.5P
Varigam 7	P-4-7V	Polycontrast 4	P-4-4P
Varigam 8	P-4-8V		
Varigam 9	P-1-9V		
Varigam 10	P-4-10V		

4.1.7 Examples of Military filter designation system.

Class Letter (B) Black and white film photography (para. 4.1.1)
Color Number (5) Red (para. 4.1.2)
Commercial designation (para. 4.1.3)

B - 5 - 25

Class Letter (P) Printing
Color Number (1) Blue
Commercial designation

P - 1 - 05B

Class letter (C) Color film photography

Color number (2) Yellow

Decamired (See para. 4.1.3.1) i.e. positive decamired value 4

Commercial designation

C -2 -DR4-81D

4.2 Marking of Filter Packages and Filters.

4.2.1 Filter packages. In addition to any existing commercial markings, all filter packages shall be marked with the following information:

a. Military filter designation
b. Filter type
c. Filter grade
d. Filter size
e. Manufacturer's name
f. Method of mounting (should be specified as slip on, screw-on, bayonet, etc.)

4.2.2 Markings on filters. All markings shall be permanent, legible, and in accordance with MIL-STD-130.

4.2.2.1 Type I filters. No markings are required on the filter. Filters may be marked with the commercial filter designation and/or the military filter designation.

4.2.2.2 Banded Type II and Type III filters. In addition to any existing commercial markings, the military filter designation shall be marked on the band.

4.2.2.3 Unbanded Type II and Type III filters disks. No markings are required on these filters.

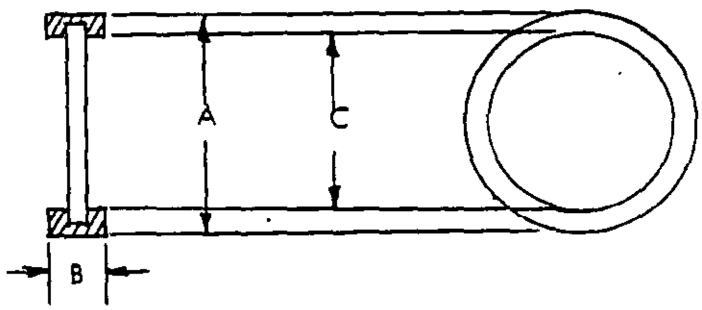
4.2.2.4 Unbanded Type II and Type III filter squares. In addition to any existing commercial markings, the military filter designation shall be marked on the filter. All markings shall extend no more than 0.20 inch from the edge of the filter.

4.3 Filter Bands. Protective bands shall conform to the dimensional requirements specified in 4.6. They shall not tarnish during the course of specified environmental tests.

4.4 Mounting. The method by which the filter is to be mounted shall be specified. Some filter bands are threaded on the outside to permit them to thread into a lens hood or filter adapter. Others are designed to be mounted by a snap-on, or a bayonet-type mounting. Where mounting is other than slip-on, the detailed band required shall be specified.

4.5 Reflection-Reducing Coatings. Reflection-reducing coatings are not required on Type II and Type III filters. Unless otherwise specified, filters will be acceptable with or without reflection-reducing coating.

4.6 Filter Dimensions. Unless otherwise specified the dimensions of the filters shall conform to Figures 1 through 7 inclusive.



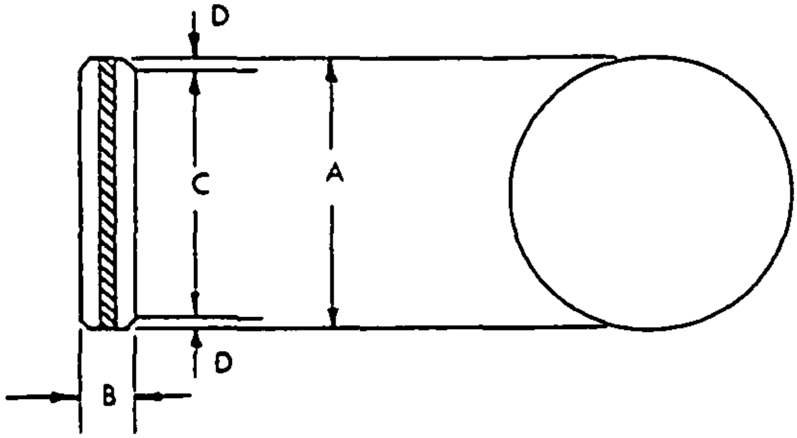
Filter Size Designation	A-Outside Diameter	B Thickness	C-Full Aperture (minimum)
IV (13/16)	0.813	0.160	0.688
V (1-3/16)	1.188	0.170	1.062
VI (1-5/8)	1.625	0.190	1.500
VII (2)	2.000	0.210	1.875
VIII (2-1/2)	2.500	0.220	2.375
IX (3-1/4)	3.240	0.220	3.125

Notes: 1. All dimensions are given in inches.

2. Tolerance on diameter A is ± 0.008 inch.

3. Tolerance on thickness B is ± 0.010 inch.

Figure 1. Type II and Type III Filter Disk (Banded).



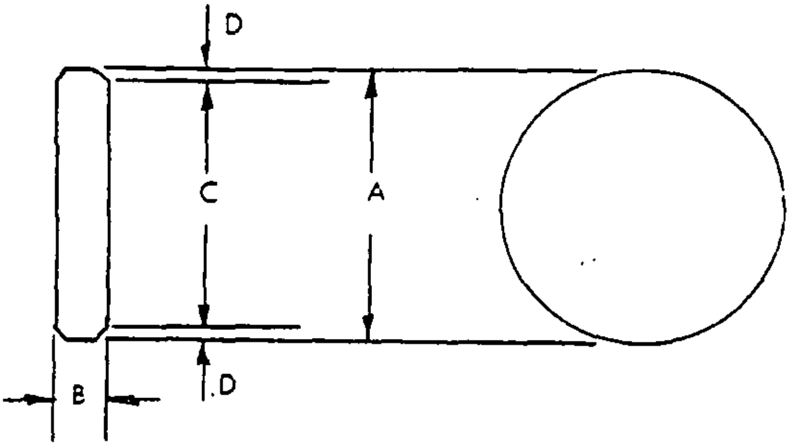
Filter Size Designation	A-Outside Diameter	B Thickness	D Beveled Edge
3/4	0.750	0.115	
1	1.000	0.115	This shall be
1-1/4	1.250	0.130	of such a dimen-
1-1/2	1.500	0.130	sion that:
1-3/4	1.750	0.130	$2D = A-C \leq 0.020$
2	2.000	0.155	
3	3.000	0.187	
4	4.000	0.187	
5	5.000	0.187	

Notes: 1. All dimensions are given in inches.

2. Tolerance on diameter A is +0 -0.016 inch.

3. Tolerance on thickness B is ±0.010 inch.

Figure 2. Type II Filter Disk (Unbonded).



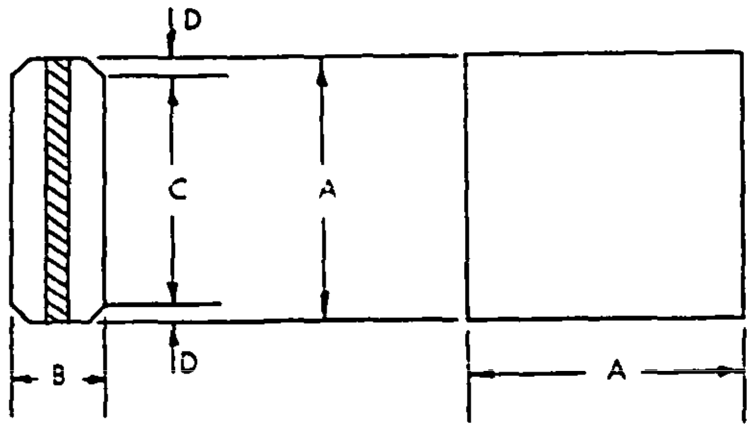
Filter Size Designation (millimeters)	A-Outside Diameter	B Thickness	D Beveled Edge
19.0	0.748	0.040 to 0.200	
21.5	0.846	0.040 to 0.200	This shall be
25.0	0.984	0.040 to 0.200	of such a
26.5	1.043	0.040 to 0.200	dimension that
31.5	1.240	0.040 to 0.200	2D = A-C $\leq$ 0.020
33.0	1.299	0.040 to 0.200	
39.0	1.535	0.040 to 0.200	

Notes: 1. All dimensions are given in inches unless otherwise noted.

2. Tolerance on diameter A is +0 -0.016 inch.

3. Thickness B is based on the glass characteristics and color specifications. Nominal thickness should be as indicated if possible.

Figure 3. Type III Filter Disk (Unbanded).



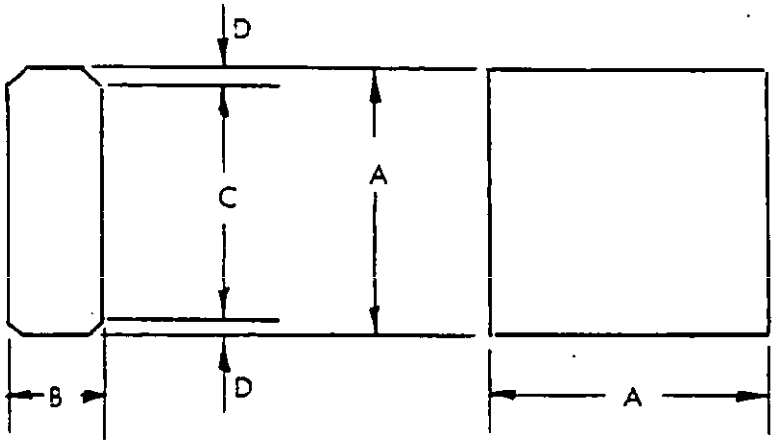
Filter Size Designation	A Width	B Thickness	D Beveled Edge
2	2.000	0.183	This shall be of
3	3.000	0.183	such a dimension
4	4.000	0.183	that:
5	5.000	0.183	$2D = A-C \leq 0.020$

Notes: 1. All dimensions are given in inches.

2. Tolerance on width A is +0 -0.016 inch.

3. Tolerance on thickness B is ±0.010 inch.

Figure 4. Type II Filter Square (Unbanded).



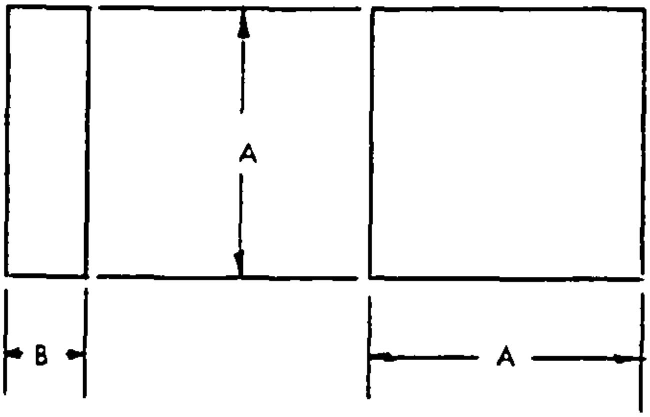
Filter Size Designation	A Width	B Thickness	D Beveled Edge
2	2.000	0.100 to 0.500	This shall be
3	3.000	0.100 to 0.500	of such a
4	4.000	0.100 to 0.500	dimension that:
5	5.000	0.100 to 0.500	$2D = A-C \leq 0.020$

Notes: 1. All dimensions are given in inches.

2. Tolerance on width A is +0 -0.016 inch.

3. Thickness B is based on the glass characteristics and color specifications. Nominal thickness should be as indicated if possible.

Figure 5. Type III Filter Square (Unbanded).

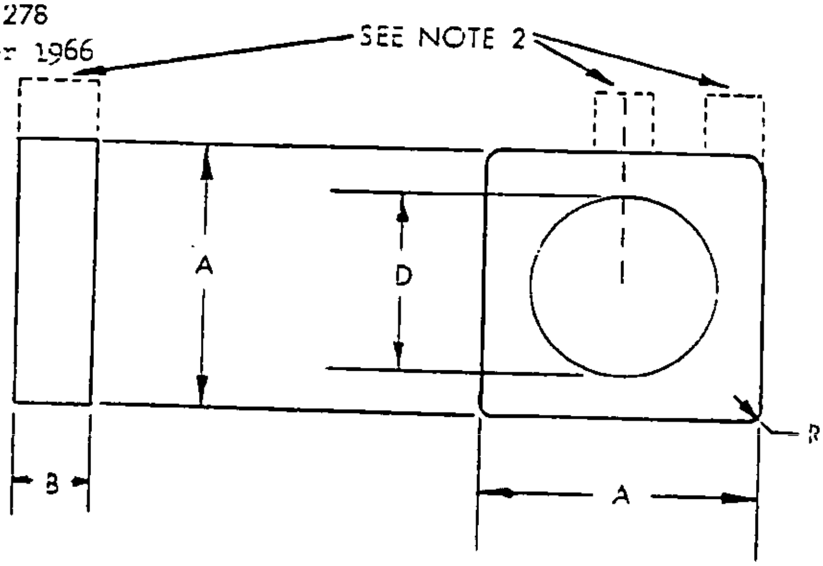


Filter Size Designation	A Width	B Thickness
2	2.000	≤ 0.008
3	3.000	≤ 0.008
4	4.000	≤ 0.008
5	5.000	≤ 0.008

Notes: 1. All dimensions are given in inches.

2. Tolerance on width A is +0 -0.070 inch.

Figure 6. Type I Filter, Polymer Film.



Filter Size Designation	A Width	B Thickness (max)	D Diameter (min.)	R Radius of Curvature (max.)
2	2.50 ± .01	0.250	2.000	1.000

Notes: 1. All dimensions are given in inches.

2. A protrusion from one edge is permissible. It may extend from any part of the filter edge.

Figure 7. Type I Filter, bonded Polymer Sheet.

5. DETAIL REQUIREMENTS

5.1 Methods of Test and Measurement. This section deals with methods of testing and measuring properties related to photographic light filters. When this standard is used in reference to the procurement of photographic light filters, only those tests specifically designated shall be used in the examination of the product. The procurement shall also clearly state which tests apply to 100 percent inspection and which tests are to be used only for the examination of samples.

5.2 Measurement of Spectral Transmittance.

5.2.1 Test conditions. The following conditions shall apply to the measurement of the spectral transmittance of filters:

(a) Filter transmittance shall be measured at wavelengths between 360 mμ and 700 mμ unless otherwise specified.

(b) The filter shall be perpendicular to the light beam between the monochromator and the photo detector.

(c) The nominal spectral bandwidth of the spectrophotometer shall be no greater than 10 mμ within the spectrum from 360 mμ to 700 mμ.

(d) The nominal wavelength for any setting of the monochromator shall be within 0.50 mμ of the spectral centroid of the transmitted band as evaluated by the radiation detector used in the spectrophotometer.

(e) The photometric scale of spectral transmittance shall be accurate to within 0.005 of full scale.

5.2.2 Method I, spectrum subdivision. For the purposes herein described, the spectrum shall be divided into four subdivisions, as follows:

Ultraviolet - from 360 mμ to 400 mμ
Blue - from 400 mμ to 500 mμ
Green - from 500 mμ to 600 mμ
Red - from 600 mμ to 700 mμ

The averaged transmittance for any subdivision shall be derived by averaging the transmittance values to 10 mu intervals throughout that subdivision. By this method, the averaged value in the ultraviolet segment is equal to:

$$1/4 \left[\frac{(t_1 + t_2)}{2} + \frac{(t_2 + t_3)}{2} + \frac{(t_3 + t_4)}{2} + \frac{(t_4 + t_5)}{2} \right]$$

where: t_1 is transmittance at wavelength 360 mμ
t_2 is transmittance at wavelength 370 mμ
t_3 is transmittance at wavelength 380 mμ
t_4 is transmittance at wavelength 390 mμ
t_5 is transmittance at wavelength 400 mμ

5.2.3 Method II, spectral centroid. Where the wavelength of the spectral centroid (λ_c) is specified, it shall be determined by the summation at 10 mu intervals,

$$\lambda_c = \frac{\Sigma \lambda t}{\Sigma t}$$

where: λ_c is the wavelength of the spectral centroid when the evaluation is carried out at intervals of 10 mμ or less.
λ is the wavelength.
t is the transmittance at wavelength λ.

5.2.4 Method III, infrared filter transmittance. The spectrum from 700 to 1000 millimicrons is subdivided into divisions of 100 millimicrons. The average transmittance within a subdivision is determined by:

$$T_{av} = 1/2 \left[1/2 t_1 + t_2 + 1/2 t_3 \right]$$

where: t_1 is the transmittance at the beginning of the spectrum subdivision.
t_2 is the transmittance at the middle of the spectrum subdivision.
t_3 is the transmittance at the end of the subdivision.
T_{av} is the average transmittance of the spectrum subdivision.

For example, in determining the average transmittance for the subdivision from 700 to 800 mμ, t_1 shall be the transmittance at 700 mμ, t_2 the transmittance at 750 mμ, and t_3 the transmittance at 800 mμ.

5.2.5 Method IV, analysis of light balancing filter transmittance. The photicity of each emulsion layer of the Average Color Film is determined for the spectral energy distribution which is desired (the reference distribution). For example, for the C-2-85 filter, the reference distribution is that of daylight. These reference photicities are then normalized to an assigned value of 100 for the green sensitive emulsion layer photicity.

5.2.5.1 Calculation of reference photicity values. The reference photicity values are calculated as follows:

$$P'_b = \Sigma E_\lambda S_{b\lambda} t'_\lambda$$

$$P'_g = \Sigma E_\lambda S_{g\lambda} t'_\lambda$$

$$P'_r = \Sigma E_\lambda S_{r\lambda} t'_\lambda$$

where: E_λ is the desired relative spectral energy at wavelength λ.

t'_λ is the transmittance of the average photographic lens at wavelength λ.

$S_{b\lambda}$ is the sensitivity of the blue sensitive layer of the Average Color Film at wavelength λ.

$S_{g\lambda}$ is the sensitivity of the green sensitive layer of the Average Color Film at wavelength λ.

$S_{r\lambda}$ is the sensitivity of the average red sensitive color film layer.

P'_b, P'_g, P'_r are the respective photicities of the blue, green, and red sensitive layers of the Average Color Film.

Notes:

1. Summations are to be carried out at 10 millimicron intervals.
2. The relative sensitivity values for the three layers of the Average Color Film are given in Table IV.
3. The transmittance of the adopted photographic lens is given in Table V.
4. The appropriate desired spectral energy distribution (reference distribution) for the filter being evaluated is listed below and the distribution data given in the column of Table VI indicated below.

Filters	Source description	Table VI, column
C-1-80B	Daylight	2
C-1-80C	Daylight	2
C-2-85	Photoflood (3450°K)	4
C-2-85B	3200°K	3
C-2-85C	3800°K	5

5.2.5.1.1 The photicities of the three layers of the Average Color Film are determined for the spectral energy distribution which is to be altered (for C-2-85, this is 3450°K lamp) with the transmittance of the filter applied to the calculation.

5.2.5.1.2 The photicity values for the Average Color Film exposed through the filter being evaluated and the source being "balanced" is determined as follows:

$$P_b = \Sigma E_\lambda S_{b\lambda} t'_\lambda t_\lambda$$

$$P_g = \Sigma E_\lambda S_{g\lambda} t'_\lambda t_\lambda$$

$$P_r = \Sigma E_\lambda S_{r\lambda} t'_\lambda t_\lambda$$

where: E_λ is the relative energy at wavelength λ of the source being balanced.

t'_λ is the transmittance of the adopted photographic lens at wavelength λ.

t_λ is the transmittance of the light balancing filter at wavelength λ.

$S_{b\lambda}$, $S_{g\lambda}$, $S_{r\lambda}$ are the respective sensitivities of the blue, green, and red sensitive emulsion layers of the Average Color Film.

P_b, P_g, P_r are the respective photicities of the blue, green, and red sensitive layers of the Average Color Film.

Notes:

1. Summations are to be carried out at 10 millimicron intervals.
2. The relative sensitivity values for the three layers of the Average Color Film are given in Table IV.

3. The transmittance of the adopted photographic lens is given in Table V.

4. The appropriate spectral energy distribution for the filter being evaluated is listed below and referenced to Table VI.

Filters	Source description	Reference Table VI, column
C-1-80B	Photoflood (345°K)	4
C-1-80C	3800°K	5
C-2-85	Daylight	2
C-2-85B	Daylight	2
C-2-85C	Daylight	2

5.2.5.1.3 The photicity values are normalized by assigning P'_g a value of 100 and multiplying P'_r and P'_b each by $100/P'_g$. P_g is given a normalized value of 100 and P_r and P_b each are multiplied by $100/P_g$.

5.2.6 Method V, analysis of mired filters transmittance.

5.2.6.1 At 10 millimicron intervals, from 360 mμ to 700 mμ, the relative spectral densities of a reference filter of the same mired shift value assigned to the real filter is calculated with the formula:

$$D = \frac{6.245\ (10^{-3})\ (M)}{\lambda}$$

where: D is the density at wavelength
λ is the wavelength in microns
M is the mired shift value

The relative spectral density data are converted to special transmittances.

5.2.6.2 A negative value for M in the formula specified in 5.2.6.1 will produce negative density values for D. To normalize so that all values of densities are positive, add a quantity D' to each D such that the D which greatest negatively is reduced to zero and the other values of D are consequently positive quantities. The formula then applying is $D_t = D + D' = \frac{6.245(10^{-3})M}{\lambda} - D'$ where D_t is the normalized density. The relative spectral transmittance data are then used to determine the effective transmittances of the reference filter weighted by the sensitivity of the Average Color Film, as follows:

$$T'_b = \frac{\Sigma\, S_{b\lambda}\, t'_\lambda\, t''_\lambda}{\Sigma\, S_{b\lambda}\, t'_\lambda}$$

$$T'_g = \frac{\Sigma\, S_{g\lambda}\, t'_\lambda\, t''_\lambda}{\Sigma\, S_{g\lambda}\, t'_\lambda}$$

$$T'_r = \frac{\Sigma\, S_{r\lambda}\, t'_\lambda\, t''_\lambda}{\Sigma\, S_{r\lambda}\, t'_\lambda}$$

where:

T'_b is the effective transmittance of the reference filter with respect to the blue sensitive layer.

T'_g is the effective transmittance of the reference filter with respect to the green sensitive layer..

T'_r is the effective transmittance of the reference filter with respect to the red sensitive layer.

$S_{b\lambda}$ is the sensitivity of the average color film blue sensitive layer as listed in Table V.

$S_{g\lambda}$ is the sensitivity of the average color film green sensitive layer as listed in Table V.

$S_{r\lambda}$ is the sensitivity of the average color film red sensitive layer as listed in Table V.

t'_λ is the transmittance of the adopted lens as indicated in Table VI.

t''_λ is the transmittance of the reference filter.

5.2.6.3 T'_b, T'_g, and T'_r are converted to density values and the neutral density component is subtracted to give the color contribution. For example:

	Blue	Green	Red
T'	.75	.85	.90
D	.12	.07	.05
Color contribution	.07	.02	.00

Table IV

Average Color-Film Sensitivity
(Relative Sensitivity-Equal Energy Source-
Arithmetic Scale)

Wavelength in mμ	Blue	Green	Red
360	42.7		
370	60.0		
380	77.4		
390	90.0		
400	97.1		
410	98.5		
420	94.7		
430	86.6		
440	75.5		
450	64.2	0.2	
460	51.5	0.6	
470	38.3	2.7	
480	25.9	5.8	
490	15.2	11.8	
500	7.5	21.7	
510	3.2	35.4	
520	0.9	46.3	0.1
530	0.2	53.2	0.2
540		66.9	0.5
550		73.5	0.9
560		64.8	1.8
570		53.0	4.2
580		30.0	6.9
590		8.3	11.0
600		2.4	14.4
610		0.6	24.0
620		0.2	33.8
630			51.0
640			72.8
650			89.0
660			61.6
670			17.8
680			6.3
690			0.2
700			0.1

Table V

Adopted Lens Transmittance

Wavelength mμ (Col 1)	Adopted lens transmittance (Col 3)
360	0.425
370	0.600
380	0.720
390	0.800
400	0.855
410	0.895
420	0.925
430	0.945
440	0.956
450	0.964
460	0.968
470	0.971
480	0.975
490	0.977
500	0.980
510	0.983
520	0.985
530	0.987
540	0.989
550	0.990
560	0.992
570	0.994
580	0.996
590	0.998
600	1.000
610	1.000
620	1.000
630	1.000
640	1.000
650	1.000
660	1.000
670	1.000
680	1.000
690	1.000
700	1.000
710	1.000
720	1.000

Table VI

Relative Spectral-Energy Distribution of Several Light Sources

Wavelength mμ (Col 1)	Daylight Taylor-Kerr Distribution; Relative Energy (Col 2)	3,200-K Relative Energy Distribution ** (Col 3)	3,450-K Relative Energy Distribution ** (Col 4)	3,800-K Photoflash (Col 5)
360	46 *	10.55	14.57	23
370	49 *	12.89	17.37	26
380	53 *	15.53	20.45	31
390	57 *	18.47	23.79	37
400	65	21.70	27.38	42
410	79	25.23	31.20	47
420	87	29.03	35.23	52
430	89	33.10	39.46	57
440	94	37.42	43.84	60
450	102	41.96	48.36	64
460	108	46.71	52.99	66
470	109	51.64	57.71	68
480	109	56.73	62.49	68
490	107	61.94	67.30	69
500	105	67.27	72.12	72
510	103	72.67	76.92	76
520	100	78.12	81.69	60
530	99	83.61	86.40	85
540	100	89.10	91.03	90
550	101	94.57	95.57	93
560	101	100.00	100.00	98
570	98	105.37	104.31	101
580	95	110.67	108.48	104
590	92	115.87	112.50	106
600	90	120.95	116.37	108
610	90	125.92	120.08	109
620	88	130.74	123.62	110
630	87	135.41	126.98	99
640	85	139.93	130.16	97
650	83	144.28	133.17	95
660	83	148.45	135.99	93
670	83	152.45	138.64	91
680	83	156.26	141.10	90
690	81	159.88	143.38	90
700	79	163.31	145.49	89
710	76 *	166.55	147.41	-
720	74 *	169.60	149.17	-

* Extrapolated by use of other natural radiation data.

** Spectral-energy distributions are relative to 100.00 at 560 mμ.

5.2.6.4 The effective transmittance of the real decamired filter, weighted by the sensitivity of the Average Color Film, is determined as follows:

$$T_b = \frac{\Sigma S_{b\lambda} t'_\lambda t_\lambda}{\Sigma S_{b\lambda} t'_\lambda}$$

$$T_g = \frac{\Sigma S_{g\lambda} t'_\lambda t_\lambda}{\Sigma S_{g\lambda} t'_\lambda}$$

$$T_r = \frac{\Sigma S_{r\lambda} t'_\lambda t_\lambda}{\Sigma S_{r\lambda} t'_\lambda}$$

where: T_b is the effective transmittance of the real filter with respect to the blue sensitive color film layer.

T_g is the effective transmittance of the real filter with respect to the green sensitive color film layer.

T_r is the effective transmittance of the real filter with respect to the red sensitive color film layer.

t_λ is the transmittance of the real filter at wavelength λ.

$S_{b\lambda}$ is the sensitivity of the average color film blue sensitive layer as listed in Table V.

$S_{g\lambda}$ is the sensitivity of the average color film green sensitive layer as listed in Table V.

$S_{r\lambda}$ is the sensitivity of the average color film red sensitive layer as listed in Table V.

t'_λ is the transmittance of the adopted lens as indicated in Table VI.

5.2.6.5 T_b, T_g, and T_r are converted to density values and the neutral density component is subtracted to give the color contribution as in 5.2.6.3.

5.2.7 <u>Method VI, analysis of spectral transmittance of color compensating and color printing filters.</u>

5.2.7.1 The effective transmittance of a color compensating filter is determined as follows:

$$T_b = \frac{\Sigma S_{b\lambda} t'_\lambda t_\lambda}{\Sigma S_{b\lambda} t'_\lambda}$$

$$T_g = \frac{\Sigma S_{g\lambda} t'_\lambda t_\lambda}{\Sigma S_{g\lambda} t'_\lambda}$$

$$T_r = \frac{\Sigma S_{r\lambda} t'_\lambda t_\lambda}{\Sigma S_{r\lambda} t'_\lambda}$$

where:

T_b is the effective transmittance of the filter with respect to the blue sensitive average color film layer.

T_g is the effective transmittance of the filter with respect to the green sensitive average color film layer.

T_r is the effective transmittance of the filter with respect to the red sensitive average color film layer.

t'_λ is the transmittance of the adopted lens as indicated in Table IX.

t_λ is the transmittance of the real filter at wavelength

$S_{b\lambda}$ is the sensitivity of the average color film blue sensitive layer as listed in Table V.

$S_{g\lambda}$ is the sensitivity of the average color film green sensitive layer as listed in Table V.

$S_{r\lambda}$ is the sensitivity of the average color film red sensitive layer as listed in Table V.

5.2.7.2 Three effective transmittances are converted to the corresponding effective densities. The neutral component common to the three effective densities is then subtracted for each effective density (D') to give the following color contribution:

	Blue	Green	Red
T	.90	.84	.62
D'	.05	.08	.21
Color contribution	0.00	0.03	0.16

5.3 Tests for Resolution. Two methods of testing for resolution are used. One method is visual (telescopic) and the other method is photographic. In cases where the filter does not transmit enough light for convenient visual observation, the photographic method must be used; ultraviolet and infrared filters are tested using a photographic method.

5.3.1 Criterion of resolution. In all tests the resolution is determined by observation of a pattern of lines. The criterion of resolution to be used by the observer is as follows: a pattern is considered resolved if all six of the lines of the pattern can be individually distinguished and counted.

5.3.1.1 When specifying or measuring resolution the following factors shall be considered:

a. whether the visual (telescopic) or photographic method shall be used.

b. the illumination of the target.

c. type of film and the method of processing when film is used.

d. kind of telescope when one is used.

e. magnification at which the resolution patterns shall be read.

5.3.1.2 For reading resolution, a magnification of the lowest power which permits convenient viewing will give the highest resolution readings. A useful approximation is that the numerical value of the magnification equals the number of lines per millimeter expected to be resolved.

5.3.1.3 Vibration, such as that caused by vehicular traffic outside the building, must be damped to minimize its effect on a test. The telescope or camera, the filter under test, the target, and the light source should be rigidly supported to prevent vibration. Unless so specified, the shutter of a camera used in a resolution test will not be used to control exposure. This will prevent vibration due to operation of the shutter.

5.3.2 Test target.

5.3.2.1 The target used for all resolution tests shall consist of transparent, clear lines on an opaque background. The target shall have high contrast, with a density difference between the transparent lines and the opaque background of at least 2.0. The target shall consist of a series of patterns decreasing in size as the sixth root of two. The range of patterns shall exceed the resolution capabilities of the test system. A resolution element shall consist of two patterns (two sets of lines) at right angles to each other. Each pattern shall consist of three lines separated by spaces of equal width. Each line shall be five times as long as it is wide.

5.3.2.2 The USAF target of 1951* is designed according to the specification indicated in paragraph 5.3.2.1. The target has ten groups. Each group has six elements. Each element consists of three horizontal and three vertical lines. Each pattern on the target can be identified by its group and element number.

*Available commercially from Buckbee-Mears and Co., St. Paul, Minn., or W. and L. E. Gurley, Inc., Troy, N.Y.

5.3.3 Method VII, visual (telescopic) resolution test.

5.3.3.1 Equipment. The following equipment is required for this test:

5.3.3.1.1 A telescope with a focal length from 11 to 13 inches with an effective aperture between 1.5 and 2 inches and an angular resolving power of less than five seconds. Means should be provided to mount the test filter in front of the objective and in a plane perpendicular to the optical axis of the telescope.

5.3.3.1.2 A source of white light to illuminate uniformly the test target from the rear.

5.3.3.1.3 A means of modulating the intensity of the illumination; i.e., diaphragm or neutral density filters between the light source and the target.

5.3.3.2 Procedure. The test is performed as follows:

5.3.3.2.1 Center the target on the optical axis of the telescope in a plane perpendicular to the axis. The target should be at such a distance that at least the ten largest target elements shall be resolved, but several of the smallest elements shall be left unresolved.

5.3.3.2.2 Illuminate the target evenly so that there are no hot spots, and establish a convenient level of brightness.

5.3.3.2.3 With the filter holder on the telescope, sight through the telescope and focus on the target; identify the group and element number of the smallest pattern that can be resolved. Increase the illumination and note the pattern resolved. Continue to increase the illumination until there is no increase in resolution. Note the smallest element that is resolved. There should be no additional adjustment in focus during the test.

5.3.3.2.4 Place the filter in the filter holder in front of the telescope objective. The filter holder should allow only light passing through the filter to enter the telescope. Increase the illumination until no further change in illumination can effect an increase in resolution. Note the smallest resolution element which can be resolved.

5.3.3.2.5 Note the number of resolution elements lost due to the presence of the filter.

5.3.4 Method VIII, photographic resolution test.

5.3.4.1 Equipment. This test requires the following equipment:

5.3.4.1.1 A 35mm camera with a 50mm focal length lens. The camera lens, when tested by Method 11 or Method 12 of Mil-Std-150A, shall have an on-axis resolving power of at least 120 lines per millimeter at the lens apertures at which it is to be used for testing filters.

5.3.4.1.2 A filter adapter to hold the filter in front of the camera in a plane perpendicular to the optical axis and centered on it.

5.3.4.1.3 High contrast resolution target as indicated in 5.3.2.

5.3.4.1.4 An electronic photoflash unit rated at 100 watt-seconds or more and auxiliary diaphragm or neutral density filters which can be used to modulate exposure intensity.

5.3.4.1.5 A panchromatic emulsion capable of resolving 150 lines/millimeter should be used to test filters which transmit radiation between 360 and 640 millimicrons. Filters which transmit only in the infrared should be tested with the infrared emulsion specified.

5.3.4.2 Procedure. The test shall be performed as follows:

5.3.4.2.1 The camera and test target should be mounted firmly in place in such manner so as to eliminate the vibration of the camera due to any extraneous source.

5.3.4.2.2 The target should be centered on the optical axis of the camera in a plane perpendicular to the axis and at least 20 focal lengths away from the camera.

5.3.4.2.3 Provision should be made for uniform illumination of the target from the rear by the light source. A diaphragm or neutral density filter(s) placed between the light source and the target should be used to modulate exposures (dependent upon the transmittance of the test filters).

5.3.4.2.4 Select an aperture of at least f/4 for filters with a diameter of 1.5 inches or greater. For filters with diameters less than 1.5 inches the ratio of filter diameter to the effective diameter of the lens aperture should be no greater than 3:1. The selected aperture should not be altered during the test.

5.3.4.2.5 Use the rangefinder to focus the camera on the target. Then make several photographs to determine the correct level of illumination.

5.3.4.2.6 Locate the target position of best focus. This is the distance at which the highest resolution can be obtained. It is found by changing the target position used in 5.3.4.2.5. The target is moved through a series of equal positive and negative distance increments (towards and away from the camera). Exposures are made at each distance setting. A plot of resolving power vs. distance is made to determine the distance interval within which the position of best focus is located. The above procedure is repeated until the resolution cannot be increased by a change in target distance when the increment used is 1/4 the size of the smallest increment which effected a change in resolution.

5.3.4.2.7 Exposure time is controlled by the light source. All illumination and stray light should be eliminated before making an exposure. Then the shutter is opened, the electronic flash fired, and the shutter closed.

5.3.4.2.8 A control exposure is made in the manner described above with the target at the position of best focus and best illumination; i.e., giving the highest resolving power. The filter adapter, which will be used to hold the test filter, should be mounted in position.

5.3.4.2.9 A test exposure is made in the same manner as the control exposure except that a filter being tested is mounted over the lens in a plane perpendicular to the optical axis and with the filter center essentially at the optical axis. Exposure adjustment (to compensate for filter density) should be with a light source diaphragm or neutral density filters between the light source and the target.

5.3.4.2.10 A minimum of one control exposure should be made for every ten test exposures.

5.3.4.2.11 Develop the test film according to manufacturer's instructions.

5.3.4.2.12 Note the number of resolution elements lost due to the presence of the filter.

5.3.4.2.13 It is possible that the resolution with a filter may be greater than that obtained without it. The lens may have a noticeable amount of longitudinal chromatic aberration resulting in color fringes in the selected focal plane. A filter transmitting a narrow region of the spectrum may reduce the color fringes and thus increase resolution.

5.4 Tests for homogeneity. The homogeneity tests (shadowgraph and polariscope) may be applied to all types filters when such tests are specified. Homogeneity refers to the uniformity among area elements of a filter. Poor distribution of colorant will show up in the shadowgraph test by causing certain areas to appear darker than others. The presence of striae (streaks or veins) will also be revealed. Unequally distributed stresses within a filter may be due to improper annealing of the filter and poor mounting or clamping. These stresses can be observed in the polariscope test.

5.4.1 Method IX, shadowgraph test. This test is performed using a shadowgraph, which includes a concentrated light source, consisting of a 2-watt concentrated arc lamp and an associated power supply, a 20-inch by 20-inch ground glass screen (medium texture), and a means of holding the filter between the light source and screen. The test shall be performed in a darkened room so that the only illumination that falls on the screen is from the light source via the filter. Examine the color projected on the screen for any irregularities or lack of evenness.

5.4.1.1 Set up the equipment with the filter holder between the light source and the screen with a distance of two meters between the arc and the screen. Place the filter normal to the optical axis of the system in such a position that the image fills the screen.

5.4.1.2 The image of the filter should be inspected for a lack of homogeneity; i.e., a difference in color or transmittance over any area of the filter, not due to an air bell or an inclusion. Inspection also should be made for delamination or cracks.

5.4.2 Method X, polariscope test. The polariscope consists of a light source and two linear polarizers. The light source illuminates one polarizer. The second polarizer, parallel to the first, is illuminated by light passing through the first. A filter to be tested for stress is placed between the two polariscope polarizers in a position parallel to them. A filter with no stresses will appear uniformly light or dark. A filter with stresses will have light and dark areas or striations. There should be no change in the transmission of the filter as it is rotated nor should any striations appear. The transmission of polarizing filters when so tested will change with the angle of rotation of the filter, but no striations should appear.

5.5 Method XI, Test for Deviation. Deviation is measured by the angle through which a ray of light is deflected as it passes through a filter. Deviation is due to wedging; i.e., the non-parallelism of the two surfaces of the filter. Acceptable deviation limits are related to the size of filters with larger limits permissible for larger filters.

5.5.1 Equipment. The equipment required for this test is as follows:

5.5.1.1 A telescope with a dot or cross line reticle. The telescope should have an adapter to hold the filter in front of the telescope objective in a plane perpendicular to the optical axis.

5.5.1.2 A target with two concentric circles and a dot or crossline at the center of the circles. The radius of the outer circle should be 1.5 times that of the inner circle.

5.5.1.3 A light source to illuminate the target.

5.5.2 Procedure. Perform test as follows:

5.5.2.1 Place the target at a distance from the telescope objective where the radius of the inner circle subtends an angle of five minutes. (The ratio of the radius of the inner circle to the distance from the center of the target to the objective is 0.00145.)

5.5.2.2 Sight through the telescope at the target, and align the system so that the dot in the center of the target is superimposed on the junction of the horizontal and vertical lines of the telescope reticle.

5.5.2.3 Place the filter in the filter adapter mounted in front of the telescope objective and note the amount by which the center of the telescope reticle is displaced as a result of the presence of the filter.

5.6 Method XII, Test for Actinic Radiation Stability.

5.6.1 Equipment. The equipment required for the radiation test is commercially available. It consists of the following:

5.6.1.1 A carbon arc lamp surrounded by a No. 9200PX pyrex glass bulb. The arc is to be run at a current between 11 and 13 amperes DC or 15 to 17 amperes AC (60 cps).

5.6.1.2 A provision for holding the filter under test at a distance of 10 inches from the arc, and capable of rotating the filter around the arc at a rate between two and four times per minute. The filter under test shall be within ±4 inches of a horizontal plane passing through the arc.

5.6.1.3 A black panel with an attached thermometer, capable of being mounted in the same position as the filters under test. The black panel shall be a sheet of metal approximately 2-3/4 x 5-7/8 inches in size, with the sensitive portion of the stem of a bimetallic dial-type thermometer mounted in the center. The panel and the thermometer stem shall have been sprayed with two coats of a baked non-reflecting light-resistant black enamel. During the test, the black panel shall be maintained at a temperature of 125 ±5 degrees F, using the temperature-control mechanism.

5.6.2 Calibration of equipment. The equipment shall be checked before use for possible wear of the carbon arc, for deterioration of the black coating on the black panel, for cleanliness of the pyrex glass, and for proper operation of the temperature control mechanism. In addition, the device shall be calibrated using standard fading strips obtainable from the National Bureau of Standards, Washington 25, D.C. The strips are contained in a book, together with light-sensitive paper, and are calibrated by exposure to the Bureau's Master Fading Lamp. Perform the calibration as follows:

5.6.2.1 Place the light-sensitive paper in the holder for the filter without any backing, and expose it for 20 hours.

5.6.2.2 Remove the paper and let it stand for two hours in the dark at room temperature.

5.6.2.3 Compare the paper with the standard fading strips to determine the exposure in Standard Fading Hours required to duplicate the fading of the test piece. In performing the comparison, avoid soiling the surfaces of the strips being compared, and place the strips side by side, trimming off any rough edges, if present. Use a daylight source or a fluorescent lamp with a daylight color for this comparison.

5.6.2.4 Derive a conversion factor that relates the number of hours of exposure to the number of Standard Fading Hours. Adjust the arc lamp to produce an approximate one-to-one relationship. The factor should not be higher than 1.1 since this results in too high a fading rate.

5.6.2.5 During the performance of the test, place several pieces of the light-sensitive paper in the sample holders so that the fading operation may be monitored. During the test, remove strips at various times and compare them with the standard fading strips using the method indicated in 5.6.2.3. In this manner verify that the lamp is maintaining proper intensity during the test.

5.6.3 Procedure. Perform test as follows:

5.6.3.1 Place the filter under test in the holder. Position the black panel and light sensitive paper in sample holders.

5.6.3.2 Perform the test for 24 Standard Fading Hours using the fading strips and calibration procedure described in paragraph 5.6.2.

5.6.3.3 After the fading test, the filter shall be tested in a spectrophotometer and the transmission characteristics compared with those measured prior to the test.

5.7 Temperature and Humidity Tests. After each environmental test described in paragraphs 5.7.1 through 5.7.1.3 (Type I filters)and 5.7.2 through 5.7.2.3 (Type II filters), grade B filters shall be inspected to determine their compliance with resolution, deviation, and homogeneity requirements. Filter bonds, when present, should not be affected by the tests. Filter spectral transmittance shall be within the specified requirements after environmental tests. Grade C filters shall be inspected for homogeneity and deterioration at the filter edge. Filter spectral transmittance shall be within the specified requirements after environmental tests.

5.7.1 Type I filters. Unless otherwise specified, tests on Type I filters shall be performed with the filters in their individual wrapping and packaging as delivered by the manufacturer. When testing without packaging is specified, filters in test chambers shall be supported, at their edges, by non-corrossive metals or plastics which are not affected bythe test conditions.

5.7.1.1 Method XIII, high-temperature test. Test samples shall be placed within a test chamber at room temperature. The temperature shall be raised to 120°F within a one-half to two hour period. This temperature shall be maintained for six hours. The filters then shall be allowed to reach room temperature before inspection as specified in 5.7.

5.7.1.2 Method XIV, low-temperature test. Filters shall be placed within the test chamber at room temperature. The temperature shall be lowered to -65°F. This temperature shall be maintained for six hours. The filters then shall be allowed to reach room temperature before inspection as specified in 5.7.

5.7.1.3 Method XV, humidity test. The test chamber shall be brought to a temperature of 96°F and 86 percent relative humidity. The test samples shall then be placed in the test chamber. At least five sides of each filter package shall be in contact with the atmosphere of the test chamber. The filters shall be maintained at 96°F and 86 percent relative humidity for 48 hours. The filters then shall be brought to room temperature and humidity before inspection as specified in 5.7.

5.7.2 Type II and Type III filters. Tests on Type II and Type III filters shall be performed with the filters in their individual packages unless otherwise specified. In all tests, the filter packages shall be exposed at least on five sides to the atmosphere of the test chamber. When testing without packaging is specified, the test filters shall be supported at their edges by non-corrosive metals or a plastic which is not affected by the test conditions.

5.7.2.1 Method XVI, high-temperature test. Test samples shall be placed in the test chamber at room temperature. The temperature should be raised to 160°F. This temperature shall be maintained for six hours. The samples then shall be allowed to reach room temperature before inspection as specified in 5.7.

5.7.2.2 Method XVII, low-temperature test. The test samples shall be placed with the test chamber at room temperature. The temperature shall be lowered to -65°F and this temperature maintained for six hours. The test samples then shall be brought to room temperature before inspection as specified in 5.7.

5.7.2.3 Method XVIII, humidity test. The humidity chamber shall be brought to a temperature of 145°F and 90 percent relative humidity. The test samples shall then be placed in the test chamber. At least five sides of each filter package shall be in contact with the atmosphere of the test chamber. The filters shall be maintained at the specified conditions for 48 hours. The filters then shall be brought to room temperature before inspection as specified in 5.7.

Custodians
Army - EL
Navy - AS
Air Force - 70

Review Activities
Navy - AS
Air Force - 70
Other - NSA

User Activities
Army - MI, MO

Preparing Activity
Army -EL
Coordination Method Code - C
Project No. 6760-0327

APPENDIX

10. REFERENCE MATERIAL

10.1 General. The material covered in this appendix does not form a part of this standard. It is provided, primarily, to describe the applications of filters and as reference material. A reference list intended for use by those preparing specifications and procurement documents is also provided.

10.2 Applications of Filters.

10.2.1 General. This section describes the applications or design functions of photographic filters.

10.2.1.1 Two groups of filters may be distinguished by their design functions. There are those filters which have specific design functions, such as the C-1-80B which is designed to convert the spectral energy distribution of a photoflood lamp to that of daylight. Another group of filters have design functions which cannot be rigidly defined because their use is dependent upon the photographer's analysis of the subject and his desired interpretation of it. The B-2-6, which is designed to give more accurate rendition to outdoor photographs, is typical of this group. Red and blue objects would photograph as identical greys if the products of their spectral reflected intensity and their emulsion spectral sensitivity were equal. To make them distinguishable in the photograph, a photographer could use a yellow filter. This would result in a photograph with lighter grey representing the red portion and a darker grey representing the blue portion.

10.2.1.2 The choice between the applications of filters such as B-2-6, B-2-8, and B-2-9, which may be described respectively as designed for partial correction outdoors, full correction outdoors, and moderate correction outdoors, is ultimately dependent upon the photographer's analysis of all aspects of the photograhic scene, his ability to visualize how the photographic emulsion will reproduce the scene, and how different filters will modify that reproduction to give him the desired result.

10.2.1.3 Those filters whose proper application is determined by the photographer's evaluation of the photographic set, are best described by their transmittance properties. These filters are used to enhance the contrast of certain colors or to reduce their contrast. For example, yellow stains on a document being copied can be eliminated or their effect on contrast reduced by the use of a yellow filter. The general rule is that to reduce the contrast of an object being photographed, use a filter which transmits the same color and to increase its contrast, use a filter which absorbs the color of the object.

10.2.1.4 The information which is presented here is intended to serve as a general guide in the selection of the filter transmittance desired for a particular photographic situation.

10.2.2 Light scattering.

10.2.2.1 The photographic effect of light scattered due to atmospheric haze can be greatly reduced by filters which absorb in the short wavelength region of the photographic spectrum. The scattering of light in the atmosphere is a function of the wavelength of the light; the amount of scattering increases with decreasing wavelength.

10.2.2.2 As the subject-to-camera distance increases, the light scattering also increases due to the greater volume of haze between the subject and camera.

10.2.2.3 All filters used to reduce haze should absorb in the ultraviolet. To eliminate haze, extremely distant scenes should be photographed through filters transmitting only wavelengths above 600 mu. As the distance between the photographer and the photographed subject decreases, filters transmitting shorter wavelengths become suitable.

10.2.3 Detail in dark colored object. To enhance the detail in a dark colored object, use a filter of the same color.

10.2.4 Polarized light. Normal light may be assumed to consist of vibrations in all planes which are at right angles to the direction of propagation. A polarizer transmits light vibrating in only one plane and absorbs the other components of the light. It has little or no affect on the color of the light.

10.2.4.1. When a ray of light which is polarized is incident upon a polarizing filter, it may be transmitted, partially absorbed, or completely absorbed, depending on the angle of rotation of the filter. This property of polarizing filters can be put to use in photography wherever polarized light is encountered.

10.2.4.2 Polarized light is usually present in the glossy specular reflection from non-metallic surfaces, water, snow, glass, etc. These objectional reflections can be subdued or eliminated by the proper rotation of a polarizing filter.

10.2.4.3 Skylight traveling at right angles to the sun is polarized. Thus, the saturation of the blue color of the sky in color photographs can be varied with a polarizing filter, or the sky darkened when photographing with both black and white, and color film.

10.2.5 Correction of black and white photographs.

10.2.5.1 The human eye is most sensitive to radiation in the vicinity of 555 mu. This is shown graphically in Figure A. A panchromatic emulsion whose sensitivity curve duplicated the luminosity curve of the eye would interpret colors in densities as a function of their visual luminosity.

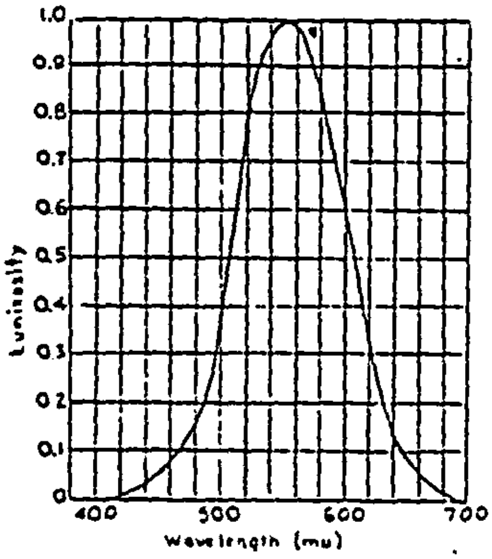


Figure A . Luminosity Functions

10.2.5.2 This is usually what is desired in the use of correction filters (B-2-8, B-2-11, B-2-13). Panchromatic emulsions are ordinarily too sensitive to ultraviolet and blue, and objects primarily reflecting this radiation will have too great a relative luminosity in the photograph. Similarly, panchromatic emulsions may have too high a sensitivity to red light and some control in this region is desirable.

10.2.6 Safelight filters. Safelight filters should only be used in accordance with manufacturer's recommendations. Table A presents only a general statement of filter utility.

10.2.7 Primary applications. Table B presents a list of filters with their applications.

Table A

Safelight Filters

Filter No.	Application
S-2-OA	Contact printing and enlarging papers.
S-2-OC	High-speed enlarging papers, including Kodak Polycontrast papers.
S-2-OO	Flash exposure technique with Kodak Magenta Contact Screens.
S-5-1	Blue-sensitive films and plates, such as Kodak Commercial film and Kodak Lantern Slide Plates; Kodagraph Projection paper; and Kodak Electrocardiograph 797 paper.
S-5-1A	Kodalith materials, Kodagraph Contact papers, Kodak Electrocardiograph film.
S-5-2	Orthochromatic films and plates, Kodagraph Fast Projection paper, and green-sensitive film for photoradiography.
S-3-3	Panchromatic films and plates.
S-5-6B	X-ray film blue-sensitive film for photoradiography, Kodak Electrocardiograph 553 paper, and Kodak Electrocardiograph film.
S-3-7	Infrared-sensitive films and plates and Kodak Ektacolor Print film. Not safe for orthochromatic materials.
S-5-8	Eastman Color Print Film, Type 5385.
S-5-10	For use with Kodak Color Print Material, Types C and R; Kodak Panalure paper.
S-5-S55	For use with high speed printing papers.

Table B

Filters With Specific Applications

Filter	Application
B-0-18A	Ultraviolet photography. Filter absorbs visible spectrum; transmits ultraviolet.
B-1-47	Direct blue color separation from color negative film.
B-1-47B	Direct blue color separation from transparencies and color negative materials.
B-1-98	Blue filter for tricolor exposure of color paper. Equivalent to B-1-47B and P-2-2B.
B-2-0	Filter used to compensate for a filter of equivalent optical path.
B-2-6	Partial correction of blue for daylight panchromatic shots.
B-2-8	Full correction for daylight panchromatic shots with Type B film (higher sensitivity to green than Type C film).
B-2-13	Corrects Type C panchromatic film exposed by tungsten lights.
B-2-90	Nonchromatic viewing filter.
B-3-11	Corrects Type B panchromatic materials exposed with tungsten light. Corrects Type C materials outdoors.
B-3-40	Two-color photography (tungsten).
B-3-57	Two-color photography (daylight).
B-3-58	Tricolor for direct green separation.
B-3-66	Contrast effects in medical photography.
B-3-93	Densitometric measurement of color films and papers.

Table 8 (Cont'd)

Filters With Specific Applications

Filter	Application
B-3-99	For use in controlling green exposure of color papers exposed through color negative materials. Equivalent to B-3-61 and B-2-16.
B-4-34A	Blue separation in Kodak Fluorescence process.
B-5-25	Tricolor red for direct color separation.
B-5-29	Tricolor red for direct color separation from transparencies and in Kodak Fluorescence.
B-5-70	Printing red color on color sensitive paper with color negatives.
B-5-92	Densitometric measurement of red on color films and papers.
C-4-1A	Reduces excess blue and ultraviolet in color photograph in shade under a clear blue sky.
P-2-2B	Absorbs objectionable ultraviolet in tungsten lamps used in color printing.

10.3 Reference Material.

10.3.1 General. The material covered in this appendix does not form a part of this standard. It is provided primarily as reference material. A reference list intended for use by those preparing specifications and procurement documents is also provided.

10.3.2 The energy distribution of daylight.

10.3.2.1 The most widely used light source in photography is daylight. This light source is usually described by a color temperature. However, detailed studies have indicated that daylight varies considerably in color quality depending upon the location, time of day, and atmospheric conditions.

10.3.2.2 Filters which are designed to convert the spectral energy distribution of daylight to that of a known artificial source can only be accurate when the daylight distribution is approximately equal to that distribution for which the filter was designed.

10.3.2.3 When the sky is cloudy, the atmosphere is hazy, or it contains appreciable amounts of smoke, the color temperature may be expected to be lower than for that temperature for which filters are designed. This follows from the fact that light of shorter wavelengths will be scattered more than light of longer wavelengths.

10.3.2.4 In Table C, data for average spectral energy distributions of five phases of daylight are shown. This data was reported by Taylor and Kerr[1] in the vicinity of Cleveland, Ohio between the hours of 9:30 A.M. and 3:30 P.M.

10.3.3 The mired system.

10.3.3.1 General. Blackbody type illuminants (incandescent radiators) are usually described by an assigned color temperature (degrees Kelvin). This color temperature is the temperature of an ideal black body with the same chromaticity as the incandescent source being rated.

10.3.3.2 In the mired system chromaticity of light sources are described by the microreciprocal of the color temperature in degrees Kelvin.

10.3.3.3 The advantages obtained by using this system are as follows:

10.3.3.3.1 A small interval in reciprocal temperature represents an approximately equal difference in chromaticity, regardless of the color temperature. Thus, when color temperature is specified, it is impossible to perceive that at 20,000°K a difference of 100°K represents a color shift equivalent to 1° at 2,000°K. However, a difference of 1 mired represents an approximately equal color shift for a 50- or 500- mired source.

10.3.3.3.2 A filter with a mired value will shift that same mired value in a variety of color temperatures, for example:

[1]Taylor, A.H. and Kerr, G.P., "The Distribution of Energy in the Visible Spectrum of Daylight," J.O.S.A., 31, 3 (1941).

Color temperature of source	Mired value of source	Mired value of source modified by +40 mired filter
2800	384	424
3000	333	373
3200	313	353
3400	294	334
4000	250	290
5500	182	222
6500	154	194

10.3.3.4 Filters which lower the color temperature of a source have positive mired shift values and, are usually yellow in color. Filters that raise the apparent color temperature of a source have negative mired shift values and are blue in color.

10.3.3.5 Mired values are usually applied to color temperatures ranging from 2,000°K to 20,000°K.

10.3.4 <u>Theoretical basis and limitations of mired systems</u>.

10.3.4.1 Wien's equation for a radiator of temperature t and wavelength λ is

$$(1)\quad J\lambda_t = C_1\lambda^{-5} \; e^{-c^2/\lambda t}$$

Where: J is radiant energy
t is temperature
λ is wavelength

10.3.4.2 The ratio of the expression at two temperatures gives the transmittance of an ideal conversion filter as a function of wavelength.

$$(2)\quad \frac{J_{\lambda t2}}{J_{\lambda t1}} = 1 - (C_2/\lambda)\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$$

Table C

Relative Spectral Energy Distribution of Five Phases of National Daylight (Averages).

Wave-length (angstroms)	Direct sunlight	Sun plus sky, horizontal plane	Overcast sky	North skylight on 45° plane	Zenith sky
			Relative Energy		
4000	49	63	59	105	165
4100	62	76	81	133	162
4200	69	84	94	142	159
4300	74	86	98	136	153
4400	78	91	97	128	158
4500	83	98	101	138	162
4600	90	104	110	149	161
4700	94	105	112	146	156
4800	96	105	112	139	148
4900	96	103	110	132	138
5000	96	101	108	123	127
5100	93	99	104	117	120
5200	90	96	100	107	112
5300	94	95	98	103	108
5400	98	96	97	101	103
5500	98	97	96	98	98
5600	96	97	94	93	92
5700	96	94	92	88	85
5800	94	92	89	84	81
5900	93	89	87	79	76
6000	92	87	85	75	71
6100	90	87	83	72	67
6200	89	85	82	70	64
6300	87	84	82	68	60
6400	85	82	86	65	57
6500	84	80	84	62	54
6600	83	80	83	59	52
6700	84	80	82	59	50
6800	88	80	83	58	47
6900	87	78	86	57	45
7000	85	76	86	54	42
		Trilinear coordinates, I.C.I. Colorimetry system			
x	0.336	0.322	0.313	0.278	0.263
y	.350	.335	.328	.294	.279
z	.342	.343	.359	.429	.458
		Color temperature			
	5335°K	6000°K	6500°K	10000°K	13700°K

10.3.4.3 As can be seen from equation (2), one filter will satisfy all cases for which $\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$ is a constant.

10.3.4.4 Since $\frac{J_{\lambda t_2}}{J_{\lambda t_1}}$ in equation (2) is the transmittance, this equation may be expressed in logarithmic form as (3)

$$D = -\left(\frac{C_2 \log e}{\lambda}\right)\left(\frac{1}{t_2} - \frac{1}{t_1}\right)$$

10.3.4.5 Since equation (3) has been derived from Wien's law, it will be subject to the inaccuracy of this law at long wavelengths and high temperatures. The description of the chromaticity of ideal black bodies by the I.C.I. standard observer and coordinate system is facilitated by the isotemperature lines[2] by which color points slightly off the Planckian locus can be assigned appropriate color temperatures. Table D correlates color temperatures based upon these two formulas.

[2] Judd., D.B., "Estimation of Chromaticity Differences and Nearest Color Temperature on the Standard 1931 I.C.I. Colormatic Coordinate System," J.O.S.A. 421 (1936).

Table D[3]

Correlation of Wien and Planck Color Temperatures

Color temperature, °K			Reciprocal temperature, mireds		
Wien	Planck	Difference	1/Wien	1/Planck	Difference
4000	4006	6	250	249.6	0.4
5000	5028	28	200	198.9	1.1
6000	6075	75	166.7	164.6	2.1
7000	7158	158	142.9	139.7	3.2
8000	8293	293	125.0	120.6	4.4
9000	9512	512	111.1	105.1	6.0
10000	10840	840	100.0	92.2	7.8
11000	12310	1310	90.9	81.2	9.7
12000	13950	1950	83.3	71.7	11.6
13000	15770	2770	76.9	63.4	13.5
14000	17845	3845	71.4	56.0	15.4
15000	20240	5240	66.7	49.4	17.3
16000	22880	6880	62.5	43.7	18.8
17000	25770	8770	58.5	38.8	20.0
18000	28740	10740	55.6	34.8	20.0

[3] Estey, R.S. "The Correlation of Color Temperatures Based on the Wien and the Planck Radiation Formulas," J.O.S.A., 28, 293 (1938).

10.3.5 Errors caused by filters[4]. The use of a plane-parallel glass plate (such as a filter) in the optical path of a camera will introduce the following errors:

Displacement of the focal plane
Image distortion
Aberrations affecting lens definition

10.3.5.1 Displacement of the focal plane. The insertion of a filter between lens and focal plane displaces the focal plane away from the lens, the amount along the axis being about 1/3 the thickness of the filter. This axial displacement is expressed as

$$\text{displacement} = T - \frac{T}{N}$$

in which T = filter thickness and N = filter index of refraction. The index of refraction for most filters is approximately 1.52. The above expression is not absolutely correct for off-axis rays, in that the filter introduces curvature of field. This causes images of points near the edge of the field to have a greater displacement than the image of an axial point. Thus the field of best imagery is convex toward the lens and the curvature (measured parallel to the axis) can be computed from the equation

$$\text{curvature} = \frac{T}{2N}\left(1 - \frac{\cos^2 B}{\cos B'}\right)$$

in which B and B' (see Figure B) are connected by the relation

$$\frac{\sin B}{\sin B'} = N$$

in which B is the angle of incidence and B' is the angle of refraction. For example, the curvature introduced by a filter 4 millimeters thick and with an index of refraction of 1.52 is 0.58 millimeters at a point 45 degrees off the axis. If the image field of a photographic lens is concave the use of a filter will help to flatten the field.

[4] American Society of Photogrammetry, "Manual of Photogrammetry," Second Edition, page 44 (1952).

10.3.5.2 Image distortion.

10.3.5.2.1 The radial distortion introduced by insertion of a filter into the optical system results in a radial displacement of an image point toward or away from the center of the field, depending on whether the filter is between lens and image or between lens and object, respectively (see Figure B). The magnitude of distortion is shown in Table E which gives distortion error (expressed as a decimal part of filter thickness) for rays at angular distances (in degrees) from the center of the field. The distortion varies with the index of refraction (N) of the glass. The index used in computing the table is 1.52, approximately the same as for most filters. Changes in distortion due to change of index are negligible. For index values between 1.48 and 1.56, the table values are correct to 3 in the fourth place for angles up to 25 degrees, and 6 in the fourth place for angles between 25 and 50 degrees.

10.3.5.2.2 Note the following when computing distortion error: (1) A filter located anywhere between lens and object causes a radial displacement of an image point away from (sign assumed +) the center of the field, the magnitude being equal to the value in the table multiplied by filter thickness and scale ratio. The scale ratio (image to object size) is very small, approximately 1:20,000, in the case of an aerial camera. For the purpose of distortion computation it may be considered to be zero, hence the image distortion caused by a filter in front of a camera lens will be zero. That is, when the object is essentially at infinity, the light rays striking the filter are parallel and therefore, there is no image distortion. (2) A filter located anywhere between lens and image causes a radial displacement of an image point toward the center of the image field equal to the value in the table multiplied by filter thickness only.

10.3.5.3 Aberrations affecting lens definition. The aberrations in a well designed lens have been balanced to the point where their effects will not adversely affect picture quality. It is most important therefore, that a filter located in the optical path of the lens does not cause that balance to deteriorate. The effect of curvature of field error (discussed under displacement of the focal plane, 10.3.5.1) may be reduced by reducing the size of the lens opening. Such error reduction is due to an increase in depth of field. It should be noted, however, that this procedure is not always possible because it decreases the amount of light reaching the film. Distortion error (previously discussed) is not reduced by reducing the size of the lens opening.

10.3.6 References.

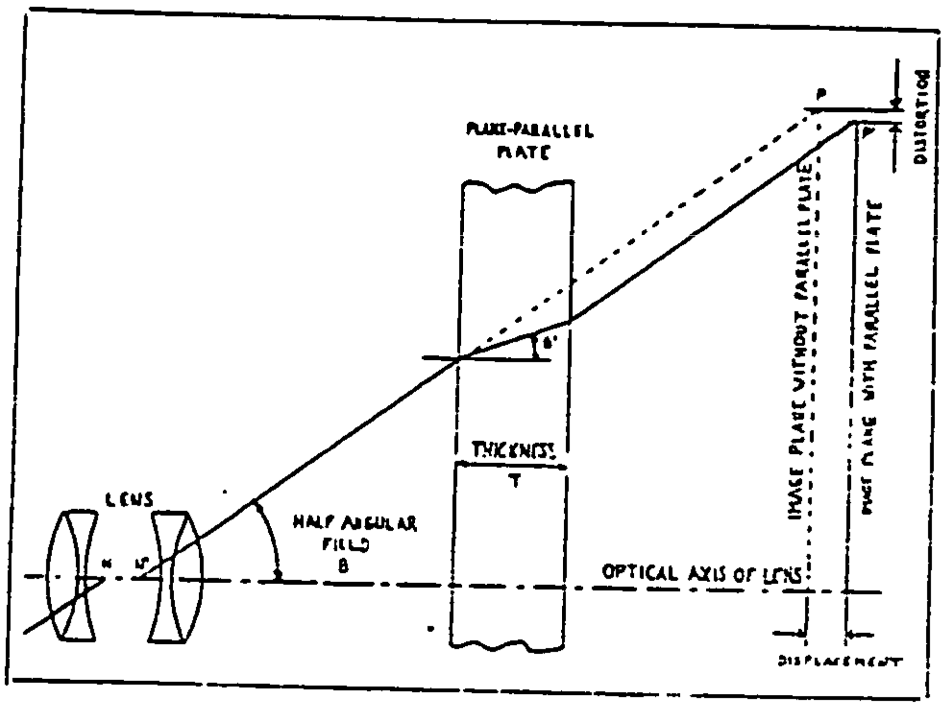


Figure 8. Image Distortion and Displacement
Caused by the Insertion of
a Plane-Parallel Plate.

Table E

Distortion Introduced by a Plane-Parallel Plate
Expressed as a Decimal Part of the Plate Thickness

(B) Half angular field (degrees)	Distortion N = 1.52	(B) Half angular field (degrees)	Distortion N = 1.52
1	0.0000	26	0.0197
2	0.0000	27	0.0222
3	0.0000	28	0.0251
4	0.0001	29	0.0281
5	0.0001	30	0.0315
6	0.0002	31	0.0352
7	0.0003	32	0.0391
8	0.0005	33	0.0434
9	0.0007	34	0.0481
10	0.0010	35	0.0532
11	0.0014	36	0.0587
12	0.0018	37	0.0646
13	0.0022	38	0.0710
14	0.0028	39	0.0779
15	0.0035	40	0.0854
16	0.0043	41	0.0934
17	0.0051	42	0.1021
18	0.0061	43	0.1114
19	0.0073	44	0.1215
20	0.0085	45	0.1324
21	0.0099	46	0.1441
22	0.0115	47	0.1566
23	0.0133	48	0.1702
24	0.0152	49	0.1848
25	0.0173	50	0.2006

10.3.6.1 List of non-mandatory references. The following lists are for information only and are not to be considered applicable to this standard in any other sense. These documents will not be supplied by the procuring activity.

10.3.6.1.1 American Standards Association.

PH2.11-1958	- Daylight Type Color Films.
PH2.20-1960	- Sensitometric Exposure of Artificial Light Color Films, Method for.
PH3.17-1958	- Photographic Filter Sizes.
PH3.37-1961	- Selective Transmission of a Photographic Lens, Test Method for.
Z58.1.2-1952	- Nomenclature and Definition in the Field of Colorimetry.
Z58-7.2.3.1951	- Methods of Measuring and Specifying Color.

10.3.6.1.2 Journal of the Optical Society of America.

A Proposed Scale for Use in Specifying the Chromaticity of Incandescent Illuminants and Various Phases of Daylight, I. G. Priest - 23. 41 (1933).

Approximate Spectral Energy Distribution of Skylight, K.S. Gibson - 30,88 (1940).

Color Designations for Lights, K. L. Kelly - 33, 627 (1943).

Colorimetric Specifications of Wratten Light Filters, David L. MacAdam - Vol 35, 10 (Oct. 1945).

Criteria and the Intensity-Epoch Slope, B. P. Ramsay, E. L. Cleveland, C. T. Koppius - Vol. 31 (Jan. 1941).

Improvement of Photographic Color Rendering by Correction Filters, A. Van Kreveld - Vol. 36, 7 (July 1946).

Resolving Power of Photographic Emulsions, P. Hariharan Vol. 46, 5 (May 1956).

Spectral Energy Distribution of the International Commission on Illumination Light Sources, Raymond Davis, Kasson S. Gibson, and Geraldine Walker Haupt - Vol 43, (March, 1953) pp. 172-176.

The Correlation of Color Temperatures Based on the Wien and the Planck Radiation Formulas, R. S. Estey - 28, 293 (1938).

The Distribution of Energy in the Visible Spectrum of Daylight, A. H. Taylor and G. P. Kerr - 31, 3 (1941).

The Optical Properties of Light Filters, C.E.K. Mees - (Dec. 1916).

10.3.6.1.3 Books.

Color Photography in the Studio: Eastman Kodak Co. Publication No. E-76 (1957).

Filter Manual, Carl Bakel: Camera Craft Publishing Co. San Francisco 5, Calif. (1953).

Infrared and Ultraviolet Photography: Eastman Kodak Co., Publication No. M-3 (1959).

Kodak Color Dataguide: Eastman Kodak Co., Publication No. R-19 (1960).

Kodak Color Films: Eastman Kodak Co., Publication No. E-77 (1959).

Kodak Films: Eastman Kodak Co., Publication No. F-1 (1958).

Kodak Filters and Pola-Screens: Eastman Kodak Co., Publication No. B-1 (1961).

Kodak Wratten Filters: Eastman Kodak Co., Publication No. B-3 (1960).

Manual of Photogrammetry: American Society of Photogrammetry, Washington, D.C. (1944, 1952).

Method for Determining the Resolving Power of Photographic Lenses: NBA Circular 533, 20 May 1962, United States Department of Commerce, National Bureau of Standards.

Military Standard Photographic Lenses, MIL-STD-150A: 12 May 1959, United States Department of Defense.

Military Standarization Handbook Glossary of Photographic Terms (including Document Reproduction), MIL-HDBK-25: 20 February 1961, Department of the Army Technical Manual.

Photo-Lab-Index: Morgan and Morgan, Inc., 1962.

Precision Measurement and Calibration, Optics, Metrology and Radiation-Handbook 77, Vol. III; February 1, 1961, United States Department of Commerce - National Bureau of Standards.

Principles of Color Photography, Evans, Hanson and Brewer: John Wiley and Sons, Inc. (1953).

The Science of Color: Committee on Colorimetry Optical Society of America; Thomas Y. Cromwell Co., New York (Jan 1953, 1954).

The Theory of the Photographic Process, C. E. Kenneth Mees, D. SC. FRS: The MacMillan Co., New York (rev. ed., Copyright 1954).

10.3.6.1.4 Miscellaneous.

A Correlated Color Temperature for Illuminants, R. Davis: Bureau of Standards, Journal of Research, 7, 659, (1931).

Daylight Color Variations and Color Photography, R. H. Bingham and H. Hoerlin: Photographic Science and Technique (April 1951).

Filters for Artificial Daylight, Their Grading and Use, H. P. Gage and N. Macbeth: Transactions of the Illuminating Engineering Society, 31, 195 (1936).

Proposed Standard Solar-Radiation Curves for Engineering Use, P. Moon: Journal of the Franklin Institute, 230, 583, (1940).

Spectral Distribution of Solar Radiant Energy, H.P.Gage: Transactions of the Illuminating Engineering Society, Vol. 34, 316 (1939).

The Colour Temperature of Light Sources, H.G.W. Harding: National Physical Laboratory.

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