HOW TO USE

The Eastman Color Temperature Meter

EASTMAN KODAK COMPANY

ROCHESTER, N. Y.

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THE EASTMAN COLOR TEMPERATURE METER

The Eastman Color Temperature Meter is designed to enable the color photographer to measure the color quality of his illumination. It is important to be able to do this, because color films, such as Kodachrome, are made to give correct color rendering for a definite color of light. If the illumination is not of the quality for which the film is balanced, the finished picture will be too warm or too cold in general char-

acter. The Color Temperature Meter will enable the photographer to check his lamps for their color. If the readings show them to be different from that color for which the film is balanced, steps can be taken to compensate for this.

It is well known that the appearance of a colored object differs according to the kind of light by which it is viewed. For instance, the difference between daylight and artificial light in their effect on the apparent color of a piece of cloth is so marked that it is customary to use special daylight lamps in examining cloth. There are, however, differences between lamps which are more or less of the same kind, the extent of which depends on their type and wattage, their age, and the voltage at which they are operated. These differences cannot always be detected by the eye, because it has the power of compensating for them, so that the lamps might all look equally white.

Color films do not possess this power of

compensation, and if the color of one lamp differs from that of another as a result of one of the causes mentioned, it may readily show up in the film, even though the eye does not detect a difference.

COLOR TEMPERATURE

The color quality of a lamp or other source of light is conveniently described by its "color temperature." The effect of temperature on the color of a hot object is familiar to everybody. For instance, if a poker is put in a fire, as it becomes hotter, its color will first be dull red, then bright red, then yellowish white, and if it melts, the iron will be definitely white in color. Similarly, in the case of an ordinary electric lamp, if the voltage is much below that for which the lamp was made, the light will be yellowish, while if the voltage is raised above the rated value, the light will become bluish white, and eventually the filament will melt.

As the actual temperature of the filament is

increased by raising the voltage, the light becomes whiter, and the color temperature of the lamp increases. The color temperature is not quite the same as the actual temperature of the filament, but as the one increases, so does the other. In defining color temperature, the scientist takes as his standard a perfect source of radiation. The spectral distribution of this is precisely defined by its temperature. If the radiant energy from a lamp has the same visual color as that of a perfect source, the lamp is said to operate at a color temperature which is the same as the actual temperature of the perfect radiator of energy. A precise knowledge of the significance of this is not necessary for the successful application of color temperature values in practical photography.

Color temperatures are denoted in degrees Kelvin (°K). They are 273° higher than the same temperatures on the Centigrade scale. For instance, a temperature of 3,000°C. is the same as 3,273°K.

The following table shows the approximate color temperatures of some common light sources:

Color Temperature of Various Light Sources

Source	*Color Temperature, °K*
60-watt vacuum tungsten filament lamp	2,509
100-watt gas-filled tungsten filament lamp	2,865
500-watt gas-filled tungsten filament lamp	2,960
1,000-watt gas-filled tungsten filament lamp	2,990
500-watt projection lamp	3,190
G.E. Mazda Lamp 3200 °K	3,200
Mazda C.P. Lamps	3,380
1,000-watt Photoflood Lamp	3,415
250-watt Photoflood Lamp	3,444
Photoflash Lamp, No. 21	3,800
White flame carbon arc	5,000
Mean noon sunlight at Washington, D.C.	5,400
High intensity sun arc	5,500

The values in the table may be taken as an approximate guide. The actual values obtained in practice will depend on the age of the lamp, voltage, and other conditions of operation. The nature of the reflectors and diffusers employed

can exert a marked influence on the effective color temperature of the illumination. Values of color temperature can only be applied strictly to sources having an energy distribution resembling that of a perfect radiator. Tungsten filament lamps fall closely enough in this class. Some arc lamps, and other sources having discontinuous spectra should be said to have *equivalent* color temperatures, provided their color matches that of a perfect radiator. Discharge lamps, such as mercury, neon and sodium tubes, which have characteristic line spectra, cannot be said to have color temperatures.

The color temperature of a studio lamp varies markedly with the voltage at which it is operated. As an approximate rule, it may be taken that the color temperature changes about 10°K. for each change of one volt.

NEED FOR COLOR TEMPERATURE MEASUREMENT IN PHOTOGRAPHY

Kodachrome Professional Film, Type B, is made to give correct color rendering when exposed to light at a color temperature of 3,200°K. This value was selected as representing the average quality of light in general use in commercial and professional studios. In practice, it is found that the line voltage may vary over a wide range. Although the electricity supply companies endeavor to maintain the line voltage constant, there are times of the day when the load is extremely high, or very low, and the actual voltage delivered will vary accordingly. This will produce corresponding changes in the color temperature of the light from the lamps. Similarly, lamps may be of various ages, and it is found that there may be a color temperature difference of several hundred degrees between a new lamp and the same type of lamp when it is about to be discarded.

If these differences in color temperature are big enough, they will produce changes in the color balance of the finished picture. If the lamps are operated at color temperatures below 3,200°K, the picture will appear warm in hue, while if they are run at higher values than 3,200°K, the results will be bluish, or cold in color.

The arguments which apply to Kodachrome Professional Film, Type B, are applicable also to other color films, and to three-color one-exposure cameras, if they are designed to give balance at a definite color temperature.

Kodachrome Professional Film, Daylight Type, is balanced to give correct rendering at a color temperature somewhat higher than that of average noon sunlight. Daylight will vary markedly in its effective color temperature according to the latitude, time of day, condition of the sky, and so on. It is less amenable to compensation than artificial light, but the principles to be described for artificial light may

be taken to apply in general to daylight.

Kodachrome Film, Type A, for miniature cameras, is balanced for use with the small Photoflood Lamps, which operate at a color temperature of over 3,400°K. Kodachrome Professional Film, Type B, exposed to these lamps, will be somewhat blue in color, while if Kodachrome Film, Type A, is exposed to lamps operated at 3,200°K, it will be yellowish in color.

In practice, it is found that a color temperature difference of about 100°K. can be picked up on Kodachrome Film.

USE OF THE EASTMAN COLOR TEMPERATURE METER

The Color Temperature Meter is intended to permit control of the quality of the illumination so that proper color balance is obtained in the final color photograph. It gives a direct measure of the color temperature of the light falling on the subject. If the readings are correctly made

and this temperature is the same as that for which the film is balanced, the exposure may be made with the knowledge the results will be satisfactory as far as the color quality of the actual illumination is concerned.

The Color Temperature Meter is *not* an exposure meter; it tells nothing about the brightness level of the illumination.

If the meter indicates a color temperature appreciably different from that for which the film is balanced, appropriate adjustment must be made. There are two methods by which this compensation may be effected:

In the first method, which is to be preferred, the voltage across the lamps is adjusted until the correct color temperature is attained. This can be done by the use of voltage control units, such as rheostats, or by other appropriate means usually available to photographers having their own generators. Provided the studio lamps do not differ too widely in wattage, age, and type, and the voltage drop is roughly equal

in all leads, it is sufficient to vary the voltage by a rheostat at the switchboard. In rare cases, it might be necessary to have individual rheostats in the lines to the lamps.

In the second method, which should be used in studios where voltage control is not possible, special compensating filters must be used over the camera lens. For this purpose, a new series of Eastman Color Compensating Filters has been designed.

OPERATION OF THE EASTMAN COLOR TEMPERATURE METER

The box containing the Eastman Color Temperature Meter and its case, includes also the following items:

One special candle, which burns with known spectral distribution.

One Accommodation Adjustment Filter.

Six sheets of white Eastman Color Temperature Test Paper.

In order to familiarize the user with its operation, the meter should be held with the knob towards the face and pointed at a lamp of moderate wattage so that the field seen through the eyepiece is at its brightest. The field will be seen to be circular, and divided by a vertical line. The part to the right of the line appears yellow, and that to the left will be red or green, depending on the color temperature of the lamp and the position of the dial on the instrument. The eyepiece should be rotated until the dividing line is in sharp focus. Still pointing the meter at the lamp, the knob is rotated until both halves of the field appear yellow and match in color; then if the knob is rotated in one direction, one half of the field will gradually become green in color, or if it is turned in the opposite direction, the same part of the field will gradually become red. Between these two positions at the point where both halves of the field are yellow and match in color and brightness, the index line on the body of the meter points to

the color temperature of the lamp indicated on the movable scale. The operation should be repeated a number of times, and the readings averaged.

It may be found that the readings obtained differ somewhat from each other. This is because many people find it difficult at first to obtain consistent matching. It will, in general, need some practice for the user to obtain the consistent results required. This is common in all optical instruments which employ photometric matching fields to make readings.

In order that the figures on the dial can be printed to a fairly large size, they are abbreviated by omission of the final two zeros. Thus, a dial reading of 28, represents a color temperature of 2,800°; one of 34, a temperature of 3,400°, and so on. The scale is so divided that up to a color temperature of 4,000°, the main divisions represent intervals of 200°, and the subdivisions steps of 50°. From 4,000° to 6,000°, the main divisions are at intervals of 500°, and

the subdivisions are steps of 100° from 4,000° to 5,000°, and of 250° from 5,000° to 6,000°. Above 6,000°, the scale closes in, and the divisions represent progressively greater steps, as will be evident from inspection of the scale. When the line on the body is between two divisions on the scale, the actual reading must be found by interpolation.

In reading the instrument, it is always good practice to make a number of determinations, say, at least five, and take the average. With experience, it is possible to read the color temperature of studio lamps to an accuracy of less than fifty degrees, which is amply high for practical use, since a difference of this value cannot be detected in the color of the picture.

SETTING THE ACCOMMODATION SCALE

The use of the instrument presupposes normal color vision. *Color blind people will not be able to use the meter, and neither will those who have certain abnormalities in their color vision.* There is much

difference in the color accommodation between different people and sometimes between the two eyes of the same person. It is, therefore, necessary to set each instrument for the individual eye before putting the meter into use. Once this has been done, the meter will be satisfactory for that individual, and will not have to be readjusted unless the setting is changed for some reason. If the instrument is used by other people, each will have to set the accommodation scale to suit himself.

The most desirable way of setting the scale is to employ a standard lamp, operated at a known color temperature. Such sources are not readily available to most photographers, but are to be found in many electrical testing or optical laboratories. In order to permit the photographer to effect the calibration himself, the special candle and blue Accommodation Adjustment Filter are provided. The adjustment is effected in the following manner:

When viewed through the blue filter, the

flame of the lighted candle has an effective color temperature equal to that marked on the filter mount. The candle should be lighted and set up in a dark place free from drafts. Hold the filter over the objective of the meter, and sight on the candle flame through it, so that the field is at its brightest all over. About four inches distance is sufficient. First set the color temperature scale to the temperature indicated on the filter mount. Hold the meter in the left hand, and with the thumb, press down firmly on the temperature scale to hold it in a fixed position as the knob is rotated. Now sight on the candle flame, holding the Accommodation Adjustment Filter with the first and second fingers of the left hand over the objective of the meter and obtain the best possible color match by rotating the knob alone. This will give a setting of the accommodation scale at the base of the knob. Several readings should be taken until consistent values are obtained, say within one small division on the accommodation scale; this will

give the proper personal accommodation factor. This setting should be used with this particular meter. Conditions of fatigue and eye strain make it important that the accommodation setting be redetermined occasionally.

The candle should be burned for a minute or two before a reading is made, to enable the flame to come to temperature equilibrium. The top of the candle should contain a full puddle of wax. If a glowing red tip forms on the end of the wick, the tip should be cut off, trimming the wick to about $\frac{3}{8}$ inch long.

READING THE COLOR TEMPERATURE

In order to read the color temperature of a lamp, it is only necessary to point the meter in the direction of the lamp so that the field is at its brightest, and turn the knob until a color match is obtained. The lamp itself will not be visible in the meter. In measuring the color temperature of very strong light sources such as studio lamps, the field may be too bright to permit an accurate reading. For this purpose

the Eastman Color Temperature Test Paper is provided with the meter. Hold a sheet of this special paper in the full beam of the light and then direct the Color Temperature Meter toward it, and read the reflected light. The white paper supplied for this purpose is so chosen that the color quality of the light reflected from it differs only slightly from the color quality of the light falling upon it. When the paper is used, 75° should be subtracted from the meter reading in order to obtain the color temperature of the source itself.* *Ordinary white paper and other white objects will by no means be satisfactory for this purpose.*

*The value 75° applies only to color temperatures about 3,000°K. The actual deduction to be made will depend on the color temperature indicated by the meter. At about 4,000°K. the deduction will be 130°, at about 5,000°K. the deduction will be 200°. Deductions for intermediate color temperatures should be roughly proportional.

The Eastman Color Temperature Test Paper may be used either to measure the color

temperature of individual lamps or it may be placed on the scene to be photographed so as to measure the color temperature of the entire illumination. When placed on the colored set, it should be placed in such a position so that no light reflected from a strongly colored object in the set falls upon it; this would cause incorrect readings to be obtained. If there is a bright light, or strongly illuminated colored subject behind the white paper, light may be transmitted by the paper and so affect the reading obtained. In such circumstances, the white paper should be backed by a piece of photographic black paper.

Important: When a sheet of test paper shows any discoloration, or if it should be soiled, it must be discarded and a new sheet used.

In using Kodachrome Professional Film, Type B, if the color temperature of the illumination is found to be appreciably different from 3200°K, that is, more than 100° higher or lower, it is necessary to introduce compensa-

tion. Either the voltage of the lamps must be changed so that the color temperature is correct for Kodachrome, or one of the Eastman Color Compensating Filters should be used.

USE OF THE EASTMAN COLOR COMPENSATING FILTERS

The Eastman Color Compensating Filters have been designed in order that the photographer may adjust his light quality to the correct value for proper color rendering. These filters are supplied in sets of seven: four bluish and three yellowish. They are designated by the letters CC. Filters CC3 to CC6 are bluish, and CC13 to CC15 are yellowish in color. The bluish filters are for the purpose of raising the effective color temperature when the quality of light emitted is somewhat lower than that from a source operating at 3200°K, and the yellowish filters are for lowering the effective temperature of lamps operating higher than 3200°K.

To select the proper filter for Kodachrome

Professional Film, Type B, set the scale of the Color Temperature Meter at 3200°K and test the quality of illumination on the set. If the field of the meter is not in color balance, maintain the 3200°K setting and select from the set of compensators by trial and error the filter which restores the balance; holding the filter over the objective of the meter. When the temperature is lower than 3200°K, a bluish filter will be required. When the temperature is higher than 3200°K, a yellowish filter is required. The filter which restores the balance in the meter is the one which should be used over the lens of the camera when making an exposure in order that the color rendering in the photograph shall be correct. In some extreme cases it may be necessary to combine two or more of the compensating filters to secure correct exposure conditions. This procedure is not recommended, however, except in an emergency. When more than one filter is required, the troublesome lamp should be

replaced with a new one.

The same method should be employed when films balanced for other color temperatures are used, such as Kodachrome Film, Type A. The filters may also be used to give some correction for variations in daylight when using Kodachrome Professional Film, Daylight Type.

Note: The Eastman Color Compensating Filters are not calibrated with the precision of the filters of the Wratten series. Although every attempt will be made to maintain them uniform in manufacture, no guarantee can be given to match any particular filter with a duplicate. Since the same filter is used over the meter and the lens of the camera, and since filter factors are negligible, there is no need for strict interchangeability as in the case of Wratten Filters.

VARIATION OF COLOR OF DAYLIGHT

When reading outdoor light conditions with the Color Temperature Meter it is necessary that

the test paper be used. It should be held to reflect the strongest light toward the meter.

In balancing Kodachrome Professional Film, Daylight Type, a color temperature somewhat higher than that of mean noon sunlight at Washington, D.C. was taken as standard. However, the color of daylight is extremely variable. Photographs made on Kodachrome Professional Film, Daylight Type, show a predominance of warm sunlight values if they were made early or late in the day, in high latitudes, or in the winter time in moderate latitudes. On the other hand, they are frequently bluish if made in the shade, or with an overcast sky.

The Eastman Color Temperature Meter can be used to give an approximate measure of the departure of the color of daylight from that corresponding to the color temperature for which the film is balanced. The Eastman Color Compensating Filters may be used to effect some compensation for such departure, but the possible variation in effective color temperature of

daylight is so wide that these filters may not be entirely adequate. Wratten Filters of the Photometric series can also be used for correction purposes. No specific recommendations can be made, since conditions vary so much, and often rapidly. The photographer is advised to make trials to suit the particular conditions, it is suggested, however, to set the meter at 6000°K. as a basis for applying the compensating filters. The Photometric Filters of the 78 Series (see "Wratten Light Filters" book) are bluish in color, and are for increasing color temperature. They might be useful if the light is pronouncedly yellow in color. The Photometric Filters of the 86 series are yellowish in color, and are for decreasing color temperature, and certain of them should be found useful if the light is definitely bluish. These filters are actually made for visual, and not photographic correction, but it is possible that adequate photographic compensation may be obtained in extreme cases.

Some idea of the possible variation in the

effective color temperature of daylight is given in the following:

Mean noon sunlight at Washington	5,400°K.
Direct sunlight about noon in mid-summer may rise to	5,800°K.
Sunlight plus light from clear sky about noon will be still higher, perhaps to	6,500°K.
Light from a totally overcast sky may be as high as	6,800°K.
Light from a hazy or smoky sky may range from	7,500 to 8,400°K.
Light from the clear blue sky	12,000 to 27,000 °K.
Direct sunlight early or late in the day in winter may drop to below	5,000°K.

(Data from A. H. Taylor, Trans. III. Eng. Soc., 1930, 25, 154-160)

WARNING

It must be emphasized that people who are color blind will not be able to use the meter, and that some others who have certain abnormalities in their color vision will not be able to use it.

Care must be exercised in the use of the meter. Consistently good results will only come with experience and care. Constant viewing conditions should always be employed.

Useful results will not be obtained with light sources such as gaseous discharge lamps, which do not have continuous spectra resembling that of a perfect radiator.

Reflectors, diffusers, colored backgrounds, colored spot-light condensers, and other colored objects may markedly influence the color of the light so that true color temperature readings are not obtained.

The meter must be adjusted for the accommodation of the individual user, as described on pages 15 to 18.

The Eastman Color Compensating Filters are not calibrated, and cannot necessarily be duplicated exactly.

If the light is measured as reflected from a white surface instead of directly from the lamps, the white Eastman Color Temperature

Test Paper supplied must be used, and the proper correction applied.

The meter should not be put in a hot place, such as on a radiator, or in hot show cases or windows, in fact the color wedge inside the meter will be damaged by heat in excess of 118° Fahr. It should be accorded the same care given to Wratten Light Filters.

If the owner of an Eastman Color Temperature Meter has reason to believe it may have been subjected to excessive temperature, or if for any reason it is felt that the accuracy of the meter should be checked, it may be sent to Rochester to the attention of the Service Department with a letter of explanation. If after checking, adjustments or replacement of parts is necessary, a reasonable charge will be made. If requested, an estimate for such charges will be sent the owner for confirmation.

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