shows the distinguishable number of colored lights between white light and monochromatic light derived from the result illustrated in Figure 3.16.

Color specification by means of dominant wavelength and purity has been used frequently because it can be readily understood, but recently chromaticity coordinates have been preferred. In particular, colorimetric purity has a discontinuity in the purple region, and is therefore used less because of this inconvenience.

3.7 COLOR TEMPERATURE AND CORRELATED COLOR TEMPERATURE

As described above, a color stimulus can be specified in three dimensions by tristimulus values, and in two dimensions by chromaticity coordinates or by dominant wavelength and excitation purity. The variables for the methods are (X, Y, Z), (x, y) and (λ_d, p_e), respectively. Of course, the two-dimensional specifications can only distinguish among a restricted set of colors that all have the same luminance.

To go one step further, for stimuli with the spectral power distribution of an ideal black body (see Section 3.8), the absolute temperature and the spectral power distribution of the radiation (black-body radiation) are in 1 to 1 correspondence. (Absolute temperature is a temperature scale first introduced by Lord Kelvin in 1848 and thus is sometimes called 'Kelvin temperature'. Originally, the unit for this scale was the 'degree Kelvin' (abbreviated °K), but it is now known simply as the kelvin (abbreviated K). The lowest theoretically possible temperature (absolute zero) is set at 0 K, and the temperature (0.01°C) of the triple point of water (a state in which ice, water, and water vapor co-exist) is defined as 273.16 K. Thus the absolute temperature can be obtained by adding 273.15 to the Celsius temperature (°C) used in everyday life). Thus, the colors of these stimuli can be specified by only one variable (absolute temperature of the black body). The color specification based on this concept is called color temperature or correlated color temperature. Color temperature (usually denoted by T_c) expresses the chromaticity of a given radiation by the temperature of the black body having the same chromaticity as that of the radiation. For radiation whose chromaticity is not exactly equal to that of a black body, correlated color temperature T_{cp} is defined as the temperature of the black body whose chromaticity is nearest to that of the radiation. The absolute temperature scale (in kelvin) is used for expressing these temperatures.

Color temperature T_c indicates that the chromaticity of the given radiation corresponds to the chromaticity of the radiation from a black body of absolute temperature T_c. However, it does not necessarily indicate that the light source itself is heated to this temperature. This also applies to correlated color temperature T_{cp}. For example, some fluorescent lamps have a T_{cp} of 6000 K or more, but their actual temperature is not nearly so high. The value of T_{cp} signifies only that such a lamp radiates light having a color most resembling that of a black body heated to an absolute temperature of 6000 K.

The line connecting the chromaticity points of the series of absolute temperatures of black bodies is called the Planckian locus. The color temperature corresponding to these chromaticities can be obtained immediately as the corresponding absolute temperature on the Planckian locus. For chromaticities not on the Planckian locus, the correlated color temperature can be obtained on the CIE 1960 *uv* chromaticity diagram (see Section 4.1) by drawing a line from the chromaticity point of the radiation in such a manner that it crosses the Planckian locus at a right angle, and then determining the temperature corresponding to the cross point (Note 3.7).

A line crossing the Planckian locus at a right angle in the *uv* diagram is called an isotemperature line. These lines can be obtained for a series of correlated color temperatures and converted into *xy* coordinates. The results are shown in Figure 3.18. The correlated color temperature for a given radiation can be obtained

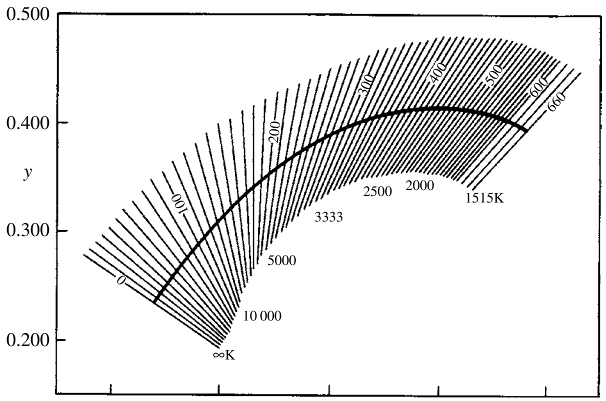

Figure 3.18 Planckian locus (thick line) and iso-temperature lines (fine lines) (numerals on upper side indicate reciprocal color temperature in units of MK^{-1})

geometrically from Figure 3.18. However, it is not appropriate to extend the isotemperature lines, and obtain, for example, a correlated color temperature of a saturated green light. The applicable chromaticity coordinates should be limited to a range of about 0.05 units on either side of the Planckian locus in the *uv* diagram. The correlated color temperature of light sources generally encountered in everyday life is given in Table 3.1.

The value obtained by dividing color temperature or correlated color temperature into 10^6 is called reciprocal color temperature or reciprocal correlated color temperature. Originally, the unit for these values was called the 'mired', an abbreviation of 'micro-reciprocal-degree'. Recently, it has been proposed to use 'mirek' (for micro-reciprocal-kelvin) instead of 'mired', but this name has not been widely accepted. The correct SI unit is the reciprocal megakelvin (MK^{-1}). One advantage of using this reciprocal scale is that color temperatures or correlated color temperatures are discriminable by the human eye if there is a difference of about $5.5\,\mathrm{MK}^{-1}$, regardless of the value of T_c or T_{cp}.

Reciprocal color temperature is widely used to express the performance of a color temperature conversion filter (a filter that converts color temperature from one value to another). Such filters are often used in color photography. For example, a filter of $35\,\mathrm{MK}^{-1}$ converts

Table 3.1 Color temperature of light sources (Yamazaki 1979). Reproduced by permission of Sougen Sha

Color temperature (K)	Specific examples of colored light
800	Red nichrome wire
1000	Yellow fire in furnace
1200	White fire in furnace
1900	Flame of paraffin candle or kerosene lamp
2400	20 W light bulb, acetylene lamp
2740	40 W gas-filled light bulb
2860	100 W gas-filled light bulb
2920	500 W gas-filled light bulb
3200	200 W or higher light bulb for movie cameras, flash bulbs
3700	Carbon arc, acetylene oxygen flame
3800	Medium-size flash bulb
4100	Full moon
4400	Sun observed 2 h after sun rise
5300	Light from the sun on a slightly cloudy day
6000	Light in the middle of a fine day with clear air
20000–25000	Light from blue sky on a fine day

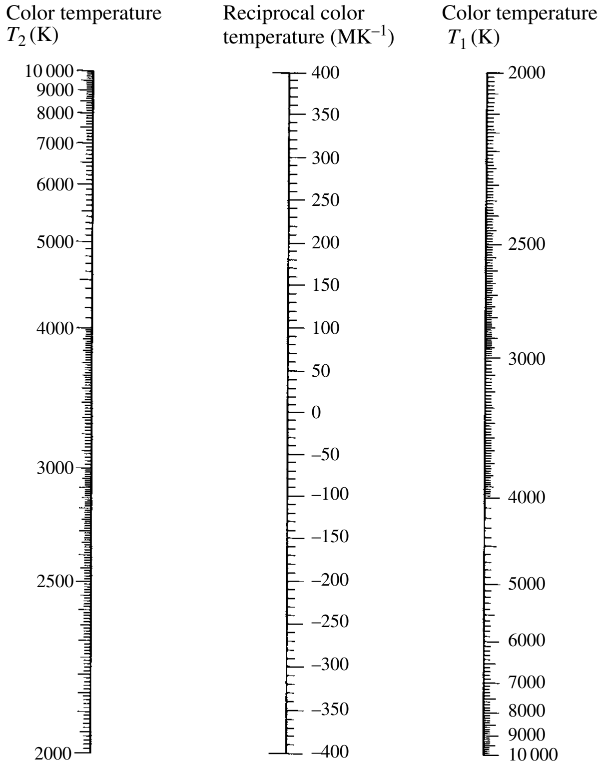

Figure 3.19 Conversion from color temperature T_1 to T_2 using a color temperature conversion filter

the light of an incandescent lamp of 2856 K to a light of 3200 K. The filter is effective with any type of illuminating light, and it can also convert a light of 6500 K to a light of 8400 K (See Note 3.8). Figure 3.19 is a useful conversion chart for obtaining the converted color temperature when such a filter is used. The color temperature T_2 of the converted illuminant can be obtained by connecting the color temperature T_1 of the unfiltered illuminant with the value (MK^{-1}) of the reciprocal color temperature of the filter, and then reading out the value on the extended line.

3.8 ILLUMINANTS AND LIGHT SOURCES

Light sources used for illumination in daily life include natural light sources such as the sun and artificial light sources such as incandescent lamps. People have used sunlight from ancient times, and,