●Measurement

Specific precautions are required for measuring the CCFL, because, in addition to electrical features related to high voltage and high frequency, optical features of the very small and non-planar (cylindrical) area peculiar to CCFLs are involved. Precautions and suggestions for the measurement of CCFLs are described below for your reference.

1 Measuring Equipment

The measuring equipment (including power supply, measuring instruments, etc.) is introduced below.

1-1 Power Supply and Electrical Measuring Instruments

1-1-1 Power Supply

A power supply generating 40 to 60 kHz frequency close to sine waves is generally used for CCFL measurement. Sanken uses a DC stabilized power supply combined with an inverter adapted to the customer specification or a specially designed integrated power supply (NF Corporation Model AS114 cold cathode discharge characteristics testing system). The output voltages of either power supply are variable and measurement is performed after confirming that there is no variation which may affect the measurement.

1-1-2 Measuring Instruments

The AC measuring instruments as well as instruments built-in in the power supply indicate the results of measurement in the effective values. The standard instruments used at Sanken are listed below for your reference.

Current measurement:

Yokogawa Electric YEW Model 2016 high-frequency AC ammeter

Voltage measurement:

NF Corporation Model AS114 cold cathode discharge characteristics test system

1-1-3 Circuitry

The measuring circuit is described below.

(1) Figs. 14 and 15 show examples of the electrical characteristics measuring circuits used at Sanken.

Fig. 14 Combined DC Stabilized Power Supply and Inverter

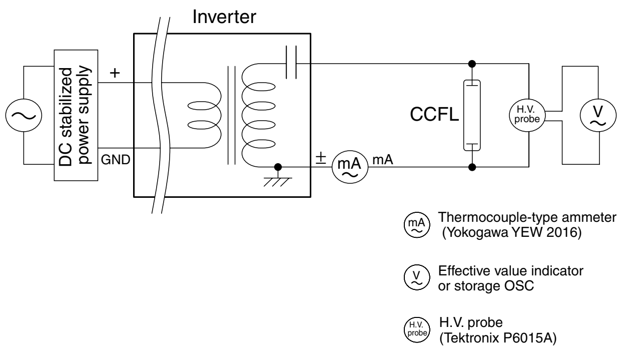
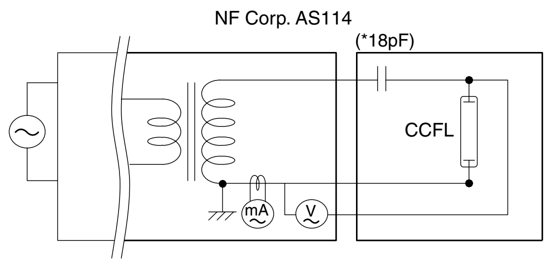


Fig. 15 Dedicated Power Supply



(2) The circuit diagram shall indicate the manufacturer name and the type number of measuring instruments in use. When a dedicated power supply is used, the manufacturer name and the type number shall be also indicated.

(3) Cables connecting the instruments to the lamp shall conform to the relevant standards for cables (pressure withstand, etc.). The cable length must be as short as possible to prevent leakage current generated by high frequency and high voltage.

1-2 Optical Measuring Equipment

1-2-1 Place for Measurement

The measurement shall take place at a place where the lamp surface is not affected by wind and the conductive object should not be located near the lamp to prevent leakage current. Ambient temperature of the place of measurement shall be 25±2°C, unless a particular environmental temperature is specified by the customer (lighting start voltage, etc.). The place of measurement must be free from wind and vibration that may affect measurement. The measuring system must be free from the effects of reflected radiations from nearby objects or the effects must be negligible.

1-2-2 Instruments

A spectroradiometer or a luminance colorimeter is used to measure luminance and chromaticity. The spectroradiometer is controlled by the calibration system traceable to the national standard. The luminance colorimeter is so calibrated as to reproduce the values of the master CCFL measured by the calibrated spectroradiometer.

Sanken uses the Topcon Model SR3 spectroradiometer, which is deemed as the de facto industry standard. The Topcon Model BM7 luminance colorimeter has been used in the LCD industry as the standard measuring instrument. Sanken has made a comprehensive investigation into instrumental error, accuracy and other features of the equipment and recommends Model SR3 spectroradiometer for measuring luminance and chromaticity of CCFLs.

The accuracy of measurement is compared in the table below for your reference.

Instrument	Accuracy of luminance *1	Accuracy of chromaticity *1	Accuracy of chromaticity *2
Spectroradiometer SR3	±2%	Within ±0.002	Within ±0.005
Luminance colorimeter BM7	±4%	Within ±0.002	Within ±0.03

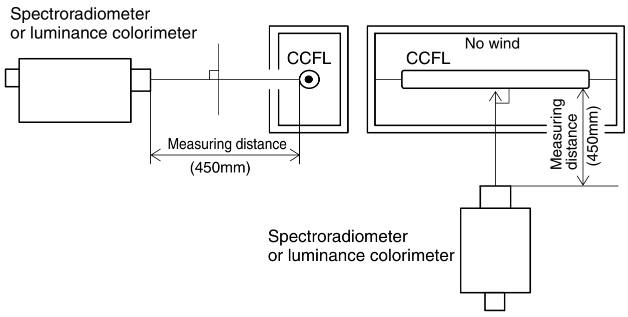
*1: When measuring Std A Light Source
*2: For radiations equivalent to CCFL (reference only)

1-2-3 Measurement Diagram

The following conditions must be satisfied when measuring optical characteristics:

(1) Optical characteristics shall be measured as shown in Fig. 16.
(2) The measurement diagram shall indicate the supplier's name and the type number of the instruments in use.
(3) The measuring diagram shall indicate the dark box, fixing method and the measuring distance.

Fig. 16 Illustration of Optical Characteristics Measurement



Conditions
- Set a lamp horizontally. Measure at right angles with the lamp axis.
- Measuring distance 450±45 mm.
- Ambient temp 25±2°C

2 Measuring Method

This section describes the actual measuring methods and precautions.

2-1 Measurement of Electrical Characteristics (Lighting start voltage, and Lamp Voltage and Current)

2-1-1 Lamp Position

The lamp shall be set horizontally. Exert caution to prevent the heat of the lamp from affecting the temperature to be measured.

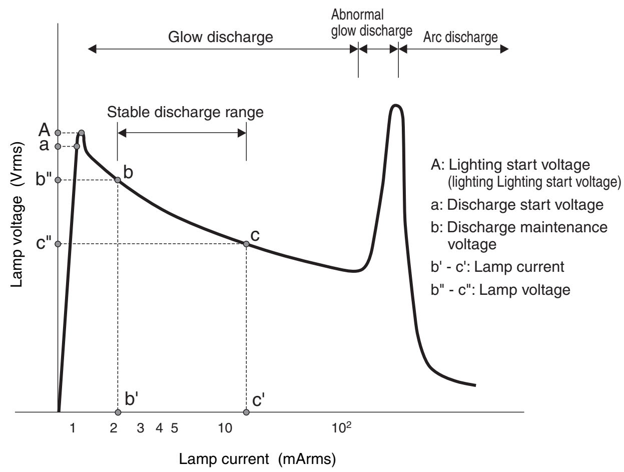
2-1-2 Measurement of lighting start voltage

The lamp starts discharging, as the voltage is gradually increased. Increase the voltage further until major discharge occurs. Then, measure the voltage. Since measured values may vary significantly for the reasons mentioned below, please confirm the measuring method before starting the measurement.

- Measured values are different subject to the measuring points, for example, transformer output side or lamp side (before or after the ballast capacitor). Sanken measures on the lamp side.
- Measured values are different subject to the capacitance of the ballast capacitor.
- For the ballast capacitor-less inverter, the transformer output voltage equals lamp voltage.

Sanken takes all measurements on the lamp side. The peak voltage across both ends of the lamp is measured by the NF AS114 system using its peak hold function. (See Fig. 17 V-I Characteristics Diagram.)

Fig. 17 Illustrated V-I Characteristics



2-1-3 Setting of Lamp Current

The lamp current is set to the specified value. (The high frequency ammeter is connected to the GND side.)

2-1-4 Measurement of Lamp Voltage

After the specified lamp current is set, the stabilized lamp voltages (at both ends of the lamp) are measured. Note that the precautions stated in Section 2-1-2, "Measurement of lighting start voltage," can also apply hereto.

2-1-5 Precautions for Measurement

(1) The high voltage probe for measuring the lamp voltage should

be of a small capacitance type as far as possible to minimize the effect of leakage current flowing to the probe on the measurement. Sanken uses the Tektronix high voltage probe Model P6015A for measuring high voltages. The measurement of absolute values with a probe is very difficult because of large changes in stray capacitance viewed from the lamp.
Capacitance of the NF AS114 instrument is about 2.5 pF, or the smallest of all currently available instruments. The stable measurement is assured with minimal effects of leakage current on the measurement.

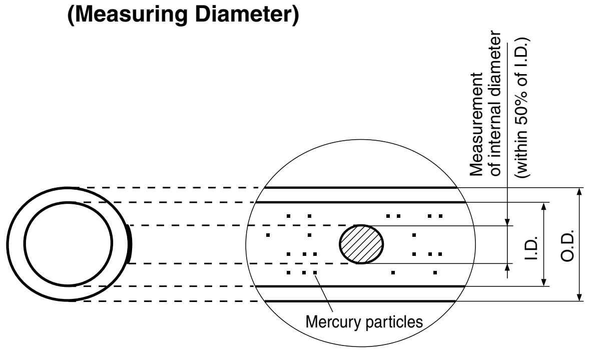
(2) Before lighting the lamp and measuring the Lighting start voltage, ensure that the lamp surface temperature and the ambient temperature are well balanced.

2-2 Measurement of Optical Characteristics (Luminance and Chromaticity)

2-2-1 Measuring Points

The measuring point is at the center of the lamp and within the visual angle of the measuring instrument (represented by the black circle in Fig. 18) (spectroradiometer or luminance colorimeter). The measuring point is sufficiently small in relation to the internal diameter of the lamp and luminance and chromaticity should not vary, even if the position of the measuring point is changed slightly. The measuring point is on the cylindrical surface, but the surface is considered flat by sufficiently reducing the size of the measuring point (Fig. 18). The visual angle of the instrument (spectroradiometer or luminance colorimeter) is set to 0.1 degrees for measurement of the luminance and chromaticity of a CCFL.

Fig. 18 Measuring Point for Optical Characteristics (Measuring Diameter)

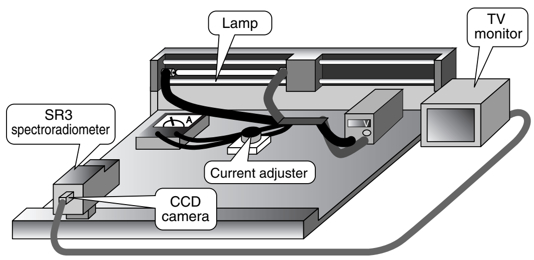


At Sanken, signals from the CCD camera installed on the SR3 finder are imaged on a monitor for checking and making necessary adjustments as required (Fig. 19). This reduces the shift of the measuring position for those engaged in the measurement.

2-2-2 Measuring Distance

Measuring distance is defined as the distance between the lamp surface and the receiving lens of the instrument. The focal point is set on the lamp surface. Sanken standard measuring distance is 450±45 mm.

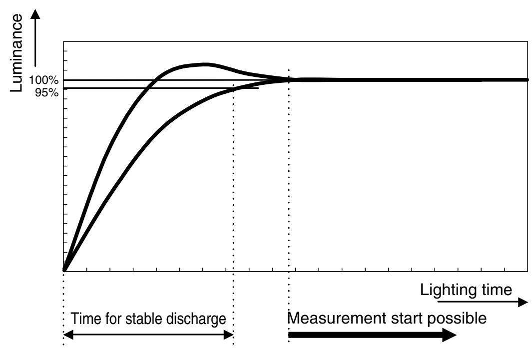
Fig. 19 Measuring Environment



2-2-3 Time for Measurement

Measurement starts after luminance stabilizes. Since the time required for luminance to stabilize depends upon the time required for the lamp temperature to stabilize, it varies subject to lamp diameter, gas pressure, etc. (Fig. 20).

Fig. 20 Time for Measurement and Time for Stable Discharge



2-2-4 Measurement of Luminance and Chromaticity

Set the spectroradiometer or the luminance colorimeter vertically to the measuring surface and measure under the above conditions.

2-2-5 Precautions for Measurement

(1) Avoid the influence of the shadow of mercury particles adhered to the lamp surface.

(2) Since high frequency and high voltage are applied for lighting the CCFL, care must be taken of electric shock to human body, short circuit to metallic objects and firing or generation of smoke due to sparks.

(3) Since very small amount of mercury is contained in the lamp, handle the lamp carefully to prevent inhalation of mercury particles, when it is broken.

2-2-6 Instrumental Error of Optical measuring Equipment

In general, each optical measuring instrument is likely to present different measurement values and even among the instruments of the same model, such differences of measured values (instrumental error) are found to the extent that the measured values need to be compensated. Instrumental error is briefly explained below for your reference.

One type of instrumental error of optical measuring instruments originates from manufacturer's calibration (accuracy limit) and another type is attributable to long-term use of the instrument (aging).

(1) Instrumental Error Originating from Manufacturer's Calibration (accuracy)

The accuracy of measurement of the luminance and chromaticity of the SR3 spectroradiometer which is the current standard equipment in the industry and the BM7 luminance colorimeter which was used as the standard equipment in the past, is summarized in the table below (quoted from the manufacturer's specifications).

Instrument	Accuracy of luminance *1	Accuracy of chromaticity *1	Accuracy of chromaticity *2
Spectroradiometer SR3	±2%	Within ±0.002	Within ±0.005
Luminance colorimeter BM7	±4%	Within ±0.002	Within ±0.03

*1: When measuring Std A Light Source
*2: For radiations equivalent to CCFL (reference only)

Accuracy of chromaticity measurement published by the manufacturer is ±0.002 for both SR3 and BM7 as shown in the table above (Accuracy of Chromaticity *1). The user tends to believe that the instrumental error (accuracy) of the newly purchased or manufacturer-calibrated instrument is a maximum ±0.002 for chromaticity measurement.

Actually, however, the published accuracy is subject to the condition of using the Standard A Light Source (see Note *1). The declared accuracy is not achievable with CCFLs that have different color temperatures.

Then, what level of the accuracy (instrumental error after calibration) can we expect for the CCFL?

According to the equipment manufacturer, the accuracy of the SR3 spectroradiometer is ±0.005 for the CCFL. The accuracy of the BM7 luminance colorimeter is ±0.03 of the maximum value. This is because each tristimulus value is calculated by measuring the intensity of radiations passing through three RGB glass filters, and dispersion of the spectral transmittance of color glass filters installed in the instrument thus becomes the most important factor.

For supplementary information:

- Refer to Section 4, "Terminology," for the reference light.
- Refer to Section 5, page 22, for instrumental error of the Topcon luminance colorimeter (BM-series).

(2) Instrumental Error due to Aging (long-term use)

Measurement becomes unstable, when the instrument is used over a long period of time. Generally, the measured chromaticity tends to shift to the higher side, while the measured luminance tends to shift to the lower side. Major reasons of these shifts include variation in the transmittance of the optical system due to stains, variation in the sensitivity of receiving elements and change in the resistance of the board due to humidity. To deal with the inevitable instrumental error and shift from the absolute value caused by aging, the user must control the variation within a certain allowable range by compensating the measured values and calibrating the equipment periodically.

(3) Instrumental Error with Measuring Instrument beyond Control

With respect to these two types of instrumental error, each manufacturer warrants and controls the measured values by setting compensation values for each piece of equipment and implementing periodical calibration using their standard measuring instruments and standard light source.

However, the instrumental error of uncontrollable measuring instruments is, in reality, totally unknown. The same measurement results are never warranted, even when using measuring instruments of the same type for the reasons stated above. To compare with the measurements by uncontrollable instruments, we need to measure the same light source under the same conditions to evaluate the instrumental error.

(4) Standardization of Measured Values

As discussed in paragraphs (1) through (3) above, the measurement in absolute values is difficult for the measuring instrument for luminance and chromaticity. Lamp manufacturers and backlight manufacturers must evaluate correlation of measured values between them by setting correction factors for the relevant data. For example, the measured values for the same lamp by the lamp manufacturer and the backlight manufacturer are compared in the table below respectively after data conversion using the correction values shown in the parentheses.

	Luminance (cd/m^2)	Chromaticity x	Chromaticity y
Measured by backlight manufacturer	36000	0.260	0.272
Measured by lamp manufacturer	40000	0.250	0.260
Correction factor for evaluation	0.90 (ratio)	-0.01 (difference)	-0.012 (difference)

At Sanken, luminance data are converted by ratio and chromaticity by relativity. To compare the measured values by the backlight manufacturer with data of the lamp manufacturer using the correction factors, we use the equations shown in the table of Results of Conversion to Measured Values of Lamp Manufacturer.

	Luminance (cd/m^2)	Chromaticity x	Chromaticity y
Measured by backlight manufacturer	L1	x1	y1
Converted to measured values of lamp manufacturer	L1/0.9	x1 −0.01	y1 −0.012

Periodical checking of instrumental error and evaluation of both parties' measured values after correction are essential in the optical measurement of CCFL.

2-3 Measuring Effective Emission Length

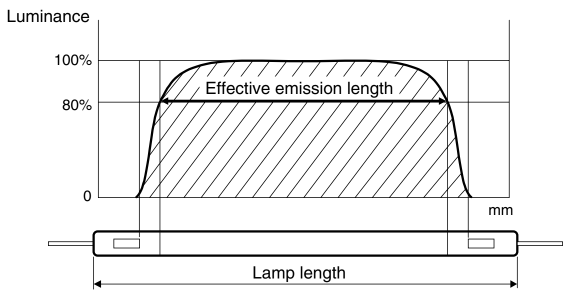
Effective emission length is the section of emission length where luminance is at least 80% of the luminance measured at the center of the lamp with luminance roughly uniformly distributed along the axis of the lamp (Fig. 21). Measurement must be taken when luminance is sufficiently stable. The effective length is varied by lamp diameter, electrode type, etc.

2-4 Measurement of Time required for Stabile Discharge

Time to stable discharge is the time for a CCFL to reach 95% of the luminance that is measured five minutes after applying the lighting voltage, assuming this to be 100% (Fig. 20).

It is important for the measurement that the lamp temperature and the ambient temperature are constant.

Fig. 21 Effective Emission Length



3 How to determine the Lamp Specifications (Verification of Matching of Lamp Specifications with Backlight)

The requirements for chromaticity for CCFLs are defined by the chromaticity required by the backlight. Backlight specifications and lamp specifications are correlated as shown below. At first, the correlation is confirmed and then lamp specifications are calculated.

Due to various improvements of the backlight LCD and the color filter, the established correlation between system and backlight or lamp can be no more effective. If we aim at the center value of the CCFL requirement, the center value of the backlight requirement is missed. To ensure stable chromaticity for backlights at all times, chromaticity correlation between CCFL and backlight surface must be established and both requirements must be matched by aligning the center values of the CCFL and the backlight requirements (refer to Reference Materials for Selection of Lamp Specifications).

[Reference Materials for Selection of Lamp Specifications]

A Typical Procedure to Match Backlight and Lamp

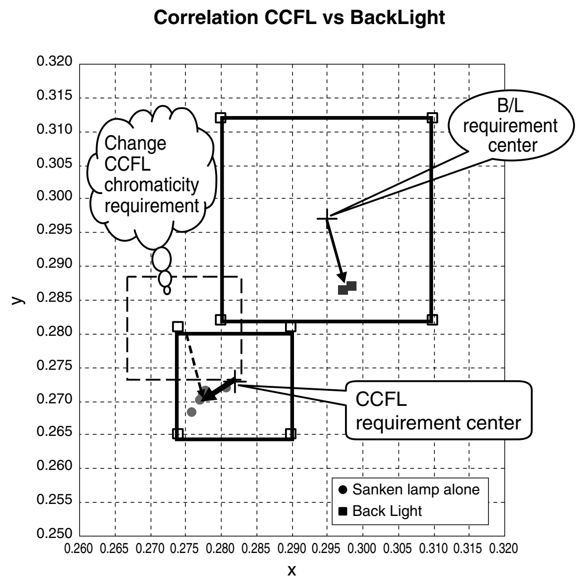
Results of measurement of B/L and Lamp	Instrument	Luminance	x	y
B/L Spec Center		L1	x1	y1
B/L measured value	SR-3	L2	x2	y2
Lamp Spec Center		L3	x3	y3
Lamp measured value (B/L measured unit)	SR-3	L4	x4	y4

		Luminance	x	y
Center of CCFL only	max	—	typ +0.01	typ +0.01
	typ	L4−(L2−L1)	x4−(x2−x1)	y4−(y2−y1)
	min	—	typ−0.01	typ−0.01

(max. and min. values apply to general cases)

Conclusion

Value for lamp only to match B/L typical chromaticity	Chromaticity	Typical value for center of lamp alone	Correction factor (for the current CCFL standard value)
	x	x4−(x2−x1)	{x4−(x2−x1)}−x3
	y	y4−(y2−y1)	{y4−(y2−y1)}−y3



* In the above figure, we can aim at the center value of B/L chromaticity requirement by shifting the center value of the CCFL requirement in a manner that the deviation of CCFL chromaticity from the center of the standard equals the deviation of B/C chromaticity from the center value of the requirement.

4 Terminology

The terms relating to the CCFL are defined below.

◆ Luminance

The volume of luminous flux per unit area. Generally it represents the level of luminance of the light emitting (reflection/ transmission) from surface.

Unit: cd/m^2. nt or nit is also used.

◆ Luminous intensity

The level of luminous flux per unit solid angle, which is emitting from a light source to all directions. Generally it represents the intensity of point source light. Unit: candela (cd). Solid angle: The surface area of a unit sphere (r = 1m) is equivalent to a solid angle of 4π.

◆ Illuminance

The ratio of light flux per unit surface, which falls from all directions to a minute surface. Unit: lux (lx) = lm/m^2

Illuminance is the volume of incident luminous flux per unit area. Luminous radiance is the volume of emitting luminous flux per unit area. Luminance is the luminous intensity emitting from per unit area with directional movement.

◆ Chromaticity

Numerically defined types of color excluding luminance. It is neither luminance nor luminous intensity but the color quality of the light, which is defined by chromaticity coordinate whose hue to chroma of the light is correlated. Chromaticity is generally plotted by x- and y-coordinate values. Representation on plane coordinates is called as a chromaticity diagram.

◆ Color temperature

Assuming that object and celestial body radiations in the visible range are blackbody radiations, the black body temperature having the chromaticity same as that of the radiations. Unit: Kelvin (K). The higher the color temperature, the light contains more short-wave radiations with bluish color. The lower the color temperature, the light contains more long-wave radiations with reddish color.

◆ Blackbody radiation

Thermal emission from the object (blackbody) which is assumed to absorb all wavelengths radiations.

Blackbody radiation is influenced only by temperature and its magnitude is given by Planck’s law.

◆ Luminous flux

The value of radiant flux evaluated by CIE standard spectral luminous efficiency and the maximum visibility. Generally it represents the volume of light. Unit: lumen (lm)

◆ Quantity of light

He volume of luminous flux that is integrated by time.

Unit: lumen-sec (lm-s).

◆ Spectral distribution

Distribution of radiation wavelengths which is included in a small wavelength range with λ at its center.

◆ CIE standard spectral luminous efficiency

The inverse of the relative value for the radiance of monochromatic radiation of wavelength λ, where monochromatic radiation of the wavelength λ is determined equal to the luminance of radiations that are the standard for comparison under certain conditions of observation. The spectral luminous efficiency is normally standardized to have the maximum value of unity (1). The standard spectral luminous efficiency refers to the values agreed at CIE (International Commission on Illumination).

$V(\lambda)$: standard spectral luminous efficiency with photopic vision (max. visibility: 555 nm 683 lm/W)

$V'(\lambda)$: standard spectral luminous efficiency with scotopic vision (max. visibility: 507 nm 1700 lm/W)

◆ Visible radiation

The radiation which enters human eyes and excite a visual sense. (Within the range of radiations recognized by human being) Generally, the radiation in the wavelength range of 380 nm to 780 nm is called visible radiations (visible light).

◆ Light of standard

Color temperature is measured by a color temperature meter. The light source used as the standard for the color temperature meter is called as the standard light source. CIE classifies the light of standard as A, B, C or D.

Light of standard A is the light of the perfect radiator of 2856K. To generate this light, a gas-filled tungsten lamp (transparent lamp) close to 2856K is used. This standard was set in 1968, and is very different from the chromaticity of CCFLs. Accuracy for measuring the CCFL equivalent radiations cannot be within the manufacturer warranted accuracy of ±0.002.

Light of standard B is the light of 4874K. Light of standard C is equivalent to the light of 6774K. These lights simulate sun light. Radiations of 4875K are yellowish daylight while those of 6774K resemble to bluish daylight. To generate these lights, a filter (Davis-Gibson filter B or C) with a solution of a specified composition is mounted on lamp A.

Light of standard D65 represents daylight of a color temperature of approximately 6504K. Spectral distribution is statistically studied under natural sunlight and the values are specified by wavelength. CIE has developed and published the method to calculate the spectral distribution of daylight of any color temperature in the 4000K to 25000K range to describe light D. D65 is one of the radiations defined by the above method. The light of standard shows that it is equal to sunlight itself or radiations from the perfect blackbody.

5 Error of Topcon Luminance Colorimeter (BM-series)

The Topcon BM-series luminance colorimeter combines spectroscopic transmittance of the optical system with color glass filters and receptor elements to approximate the spectroscopic responsivity of color-matching function.

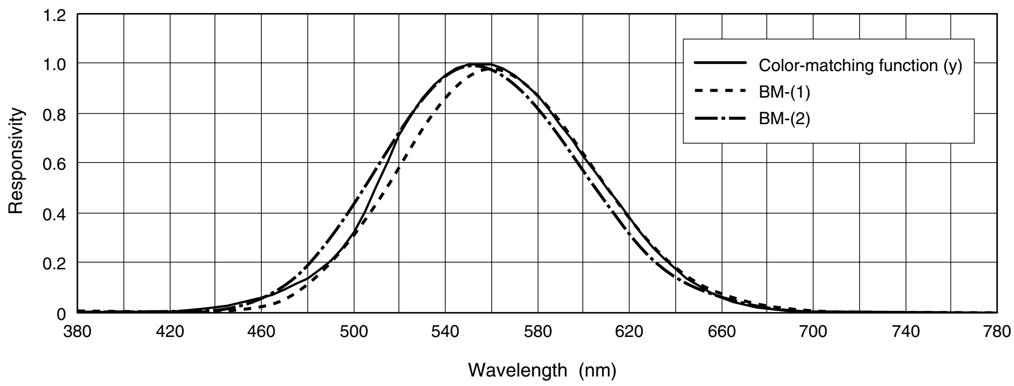
Spectroscopic transmittance of color glass filters is the most important factor for approximating the spectroscopic responsivity. If characteristics of color glass filters are uniformly fabricated, instrumental error will be reduced. However it is difficult to realize that, and even among products of the same series (BM-5A, BM-7, etc.), there is certain variation in spectroscopic characteristics.

Spectroscopic responsivity of equipment is defined in accordance with JIS Z 8724 Methods of Measurement for Light Source Color.

However, even if the JIS requirements are satisfied, some products have different spectroscopic characteristics as shown below.

* BM-(1) and BM-(2) in the figure below are not actual products. Because products are calibrated by using the standard light source A, no instrumental error occurs in terms of light A.

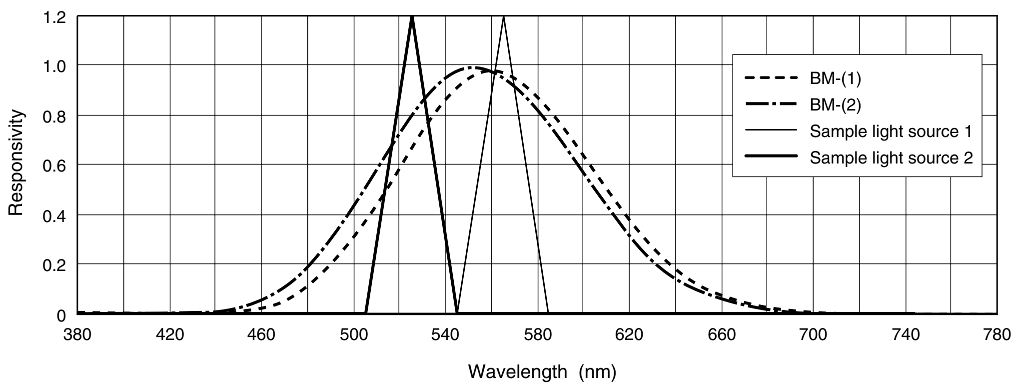
Fig. 22 Spectroscopic Characteristics (y)



Let us assume measuring other light sources with respect to spectroscopic characterization.

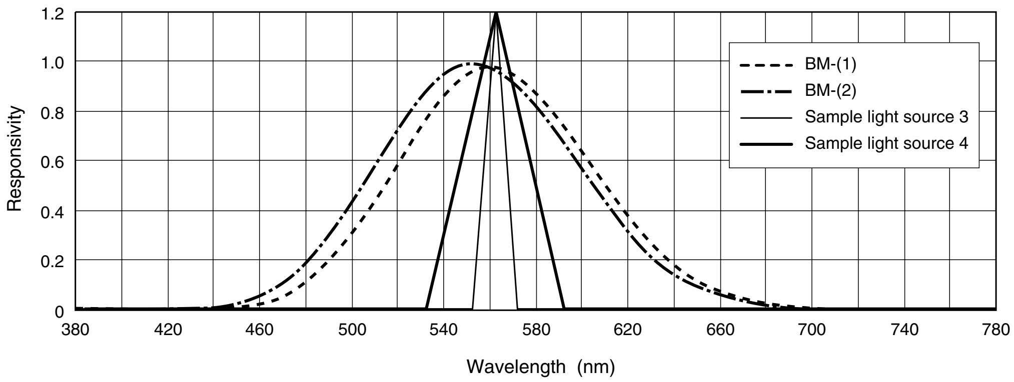
Assume two imaginary sample light sources 1 and 2 with their peak wavelengths have 40 mm difference like the figure shown below. If two BMs with spectroscopic characteristics BM-(1) and (2), are used to measure sample light source 1, Instrumental error between the two BMs will be small. However when sample light source 2 is measured, the instrumental error between the same two BMs will increase. (Two BMs have a similar sensitivity for sample light source 1 while they clearly show instrumental error for sample light source 2.)

Fig. 23



Instrumental error between two BMs can increase, even when measuring a light source with the same peak wavelength. For example, in the figure below, instrumental error is greater when sample light source 4 was measured rather than when sample light source 3 was measured. (For sample light source 3, the output exists only in the area where the BM sensitivity is nearly identical while for sample light source 4, the output also exists in areas where the difference in sensitivity between two BMs increases.)

Fig. 24



As described above, the instrumental error is closely related to the spectral characteristics of the instrument and the light source to be measured. This also applies to the tristimulus values XYZ. Therefore it is impossible to define BMs' instrumental error uniformly.