

Life

1 List of Product Life

* Life of standard phosphor

● CCFLs for Notebook PCs

		$\phi 1.8 (1.4)$, electrode length: 6 mm (Ni)/4 mm (Nb)					
		Standard Ar ratio: 5% 10.0kPa (75 Torr)		Standard Ar ratio: 5% 10.6kPa (80 Torr)		Standard Ar ratio: 5% 11.3kPa (85 Torr)	
Electrode		Ni	Nb	Ni	Nb	Ni	Nb
Lamp current		min / typ	min / typ	min / typ	min / typ	min / typ	min / typ
3mA		30,000 / 40,000	27,000 / 32,000	30,000 / 40,000	30,000 / 40,000	30,000 / 40,000	30,000 / 40,000
4mA		28,000 / 36,000	22,000 / 27,000	30,000 / 35,000	25,000 / 32,000	30,000 / 37,000	28,000 / 36,000
5mA		22,000 / 28,000	17,000 / 22,000	25,000 / 30,000	20,000 / 25,000	27,000 / 32,000	22,000 / 28,000
6mA		17,000 / 20,000	12,000 / 16,000	20,000 / 25,000	15,000 / 18,000	22,000 / 27,000	17,000 / 20,000
7mA		12,000 / 15,000	7,000 / 11,000	15,000 / 20,000	10,000 / 13,000	17,000 / 22,000	12,000 / 15,000

● CCFLs for Notebook PCs

		$\phi 2.0 (1.5)$, electrode length: 6 mm (Ni)/4 mm (Nb)					
		Standard Ar ratio: 5% 9.3kPa (70 Torr)		Standard Ar ratio: 5% 10.0kPa (75 Torr)		Standard Ar ratio: 5% 10.6kPa (80 Torr)	
Electrode		Ni	Nb	Ni	Nb	Ni	Nb
Lamp current		min / typ	min / typ	min / typ	min / typ	min / typ	min / typ
3mA		30,000 / 40,000	30,000 / 40,000	30,000 / 40,000	30,000 / 40,000	30,000 / 40,000	30,000 / 40,000
4mA		30,000 / 35,000	25,000 / 30,000	30,000 / 37,000	27,000 / 32,000	30,000 / 40,000	30,000 / 40,000
5mA		25,000 / 30,000	20,000 / 25,000	27,000 / 32,000	22,000 / 27,000	30,000 / 35,000	25,000 / 30,000
6mA		20,000 / 25,000	15,000 / 20,000	22,000 / 27,000	17,000 / 22,000	25,000 / 30,000	20,000 / 25,000
7mA		15,000 / 20,000	10,000 / 15,000	17,000 / 22,000	12,000 / 17,000	20,000 / 25,000	15,000 / 20,000

● CCFLs for monitors

		$\phi 2.2 (1.8)$, electrode length: 6 mm					
		Standard Ar ratio: 5% 8.0kPa (60 Torr)		Standard Ar ratio: 5% 9.3kPa (70 Torr)		Standard Ar ratio: 5% 10.6kPa (80 Torr)	
Electrode		Ni	Nb	Ni	Nb	Ni	Nb
Lamp current		min / typ	min / typ	min / typ	min / typ	min / typ	min / typ
3mA		50,000 / 65,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000
4mA		50,000 / 60,000	50,000 / 65,000	50,000 / 65,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000
5mA		45,000 / 55,000	50,000 / 60,000	50,000 / 60,000	50,000 / 65,000	50,000 / 65,000	50,000 / 70,000
6mA		40,000 / 50,000	45,000 / 55,000	45,000 / 55,000	50,000 / 60,000	50,000 / 60,000	50,000 / 70,000
7mA		35,000 / 45,000	40,000 / 50,000	40,000 / 50,000	50,000 / 55,000	45,000 / 55,000	50,000 / 65,000
8mA		25,000 / 35,000	30,000 / 40,000	35,000 / 45,000	40,000 / 50,000	40,000 / 50,000	50,000 / 60,000

● CCFLs for TV and monitors

		$\phi 2.4 (2.0)$, $\phi 2.6 (2.0)$, $\phi 3.0 (2.0)$, electrode length: 8 mm					
		Standard Ar ratio: 5% 6.7kPa (50 Torr)		Standard Ar ratio: 3% 8.0kPa (60 Torr)		Standard Ar ratio: 3% 9.3kPa (70 Torr)	
Electrode		Ni	Nb	Ni	Nb	Ni	Nb
Lamp current		min / typ	min / typ	min / typ	min / typ	min / typ	min / typ
3mA		50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000
4mA		50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000
5mA		50,000 / 60,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000
6mA		40,000 / 60,000	50,000 / 70,000	50,000 / 60,000	50,000 / 70,000	50,000 / 70,000	50,000 / 70,000
7mA		30,000 / 50,000	50,000 / 70,000	40,000 / 60,000	50,000 / 70,000	50,000 / 60,000	50,000 / 70,000
8mA		25,000 / 40,000	40,000 / 55,000	30,000 / 50,000	50,000 / 70,000	40,000 / 60,000	50,000 / 70,000

● CCFLs for TV

		$\phi 3.4 (2.4)$, electrode length: 8 mm				$\phi 4.0 (3.0)$, electrode length: 8 mm	
		Standard Ar ratio: 5% 6.7kPa (50 Torr)		Standard Ar ratio: 5% 8.0kPa (60 Torr)		Standard Ar ratio: 5% 8.0kPa (60 Torr)	
Electrode		Ni	Nb	Ni	Nb	Ni	Nb
Lamp current		min / typ	min / typ	min / typ	min / typ	min / typ	min / typ
4mA		60,000 / 70,000	70,000 / 80,000	60,000 / 70,000	70,000 / 80,000	60,000 / 80,000	70,000 / 90,000
5mA		55,000 / 65,000	65,000 / 75,000	60,000 / 70,000	70,000 / 80,000	60,000 / 80,000	70,000 / 90,000
6mA		50,000 / 60,000	60,000 / 70,000	55,000 / 65,000	65,000 / 75,000	60,000 / 75,000	70,000 / 85,000
7mA		45,000 / 55,000	55,000 / 65,000	50,000 / 60,000	60,000 / 70,000	55,000 / 70,000	65,000 / 80,000

2 Definition of Life

The life of a CCFL is defined by one of the following events:

[Definition of End of Life of CCFL]

- (1) Luminance falls to 50% or less of the initial value.
- (2) Normal lighting is no more available. (*)
- (3) Lamp voltage or Lighting start voltage exceeds the specified value.

(*) Flickering, pink lighting, no lighting, etc.

Note: Flickering of a CCFL is due to the presence of impure gases residual in the lamp or having entered the lamp from the environment. Flickering may disappear when turning the lamp off and then on but recurs when the lamp is continuously lit for an extended period of time. The amount of impure gases decreases because they are captured in the spatter as the lamp is repeatedly lit and extinguished.

Flickering due to residual impure gases:

Occurring in the initial lighting period (initial period following production), flickering of this type is likely to occur in a high ambient temperature atmosphere.

Flickering due to impure gases entering the lamp from outside:

Flickering of this type is called as slow leak, due to impure gases entering the lamp when the lamp is stored for a long period of time. Flickering decreases temporarily, when the lamp is repeatedly lit and extinguished but recurs some time after. Ingress of a large quantity of impure gases results in non-lighting of the lamp.

The life of a CCFL ends mainly due to electrode spattering and phosphor deterioration.

The lamp diameter is closely related to these causes of life expiration.

- $\phi 1.8$ (1.4) thru $\phi 2.6$ (2.0) for Notebook PCs and monitors;
 $\phi 3.0$ (2.0) for TV

Electrode spattering is the major determinant of life because of the large current density relative to the discharge area of the electrode.

- $\phi 3.0$ (2.4), $\phi 3.4$ (2.4), $\phi 4.0$ (3.0) for TV

Decreased luminance maintenance ratio due to phosphor deterioration is the major determinant of life because of the small current density relative to the discharge area of the electrode and low electrode spattering.

2-1 Life Ending Mode of Electrode Spattering

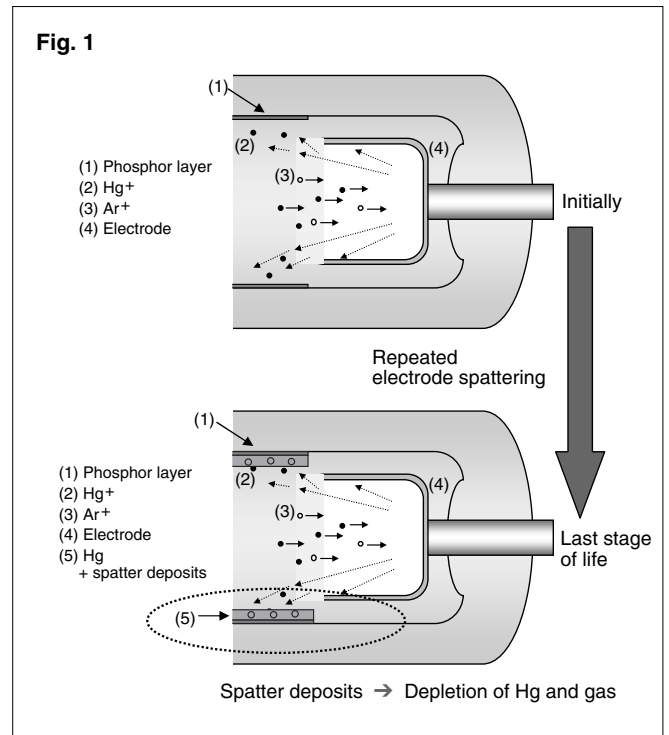
Electrode spattering occurs due to the depletion of effective mercury and sealing gas (Fig. 1).

[Depletion of Effective Mercury]

- Radiation from mercury lessens and the lamp turns dark when mercury in the lamp (effective mercury) is captured in the spatter and depleted (low luminance \rightarrow no lighting).

[Depletion of Sealing Gas]

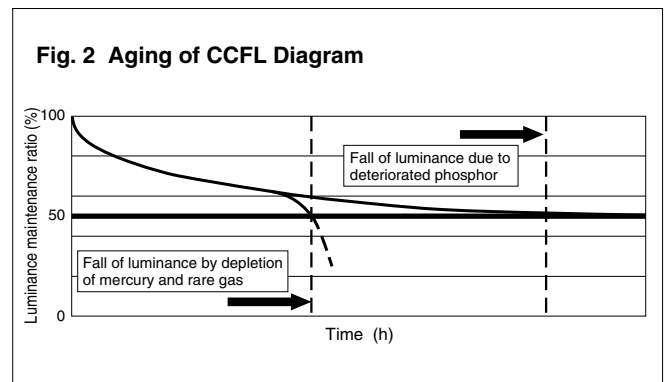
- The electrical characteristics deviate to cause pink lighting, when the sealing gas in the lamp is captured in the spatter and depleted.



2-2 Life Ending Mode due to Deteriorated

Phosphor deteriorates due to:

- Mercury adsorption:
Emission efficiency falls due to the adsorption of mercury on phosphor.
- Ion bombardment:
Emission efficiency falls due to structural deterioration of the phosphor surface layer.



3 Precautions at End of Lamp Life

When running a CCFL continuously after its life expiry date, the spatter deposits grow in size and may connect to the electrode. The spatter deposits, once connected to the electrode, become red-hot and increase the glass surface temperature to above 300°C (for certain areas, typically, within about 5 mm from the tip of a cup electrode). Gas consumption is accelerated to increase both the lighting start voltage and lamp voltage.

Note that the following failures can occur:

- Electrode temperature and lamp current increase due to gas consumption

Increased gas consumption increases ion bombardment to the

electrode and thus raises the electrode temperature. Increased gas consumption also distorts the lighting waveform. Usually, lamp current is fed back by an inverter to stabilize the waveform. The average of the lamp current is generally detected and if the distortion of the lighting waveform becomes large, the difference between effective and average current increases with the result that the current value is increased to be more than the detected current, thereby increasing the electrode temperature.

The effect of increased electrode temperature on the adjacent components should be considered in the system design.

4 Examples of Lamp Failure

Lamp failures include pink lighting, uneven mercury migration due to improper gradient of the lamp surface temperature, and irregular lighting waveform and optical waveform.

4-1 Pink Lighting

Pink lighting is classified into three types as follows:

Mode	Phenomena	Features	Causes
a	Entire pink lighting	The symptom continues.	Mercury depletion
b	Initial partial pink lighting	Disappears in a few minutes.	Uneven Mercury migration
c	Initial full pink lighting	Disappears shortly.	Ar gas depletion

a. Entire pink lighting

[Cause] Mercury depletion (at the end of life)

The lamp lights in pink over its entire length for many hours when mercury is depleted as a result of excessive spatter deposits as mentioned above.

b. Initial partial pink lighting

[Cause] Uneven mercury migration

When the uneven mercury migration occurs, mercury vapor is low in some specific areas and emissions (in pink) from Ne-Ar discharge only are visible. In a few minutes, as the lamp temperature rises, the mercury vapor increases to provide white luminescence from mercury and dispel pink lighting.

c. Initial entire pink lighting

[Cause] Ar gas depletion

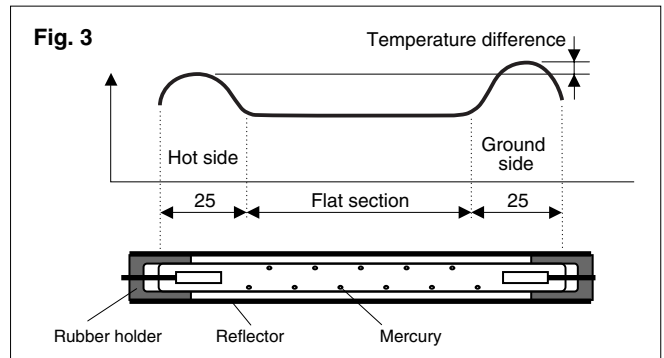
Normally, Ar gas stimulates mercury to discharge UV rays and phosphor is excited to emit radiations. Discharge of UV rays from mercury is delayed, when Ar gas is low. As a result, the entire lamp emits radiations (pink) by only Ne discharge for about several tens of seconds before luminance stabilizes.

4-2 Failures Mode due to Uneven Mercury Migration caused by Presence of Gradient in Lamp Surface Temperature

The surface temperature of a CCFL is nearly uniform over the emitting section (flat section) while it is relatively high near the electrodes on both sides (Fig. 3). (The temperature is slightly

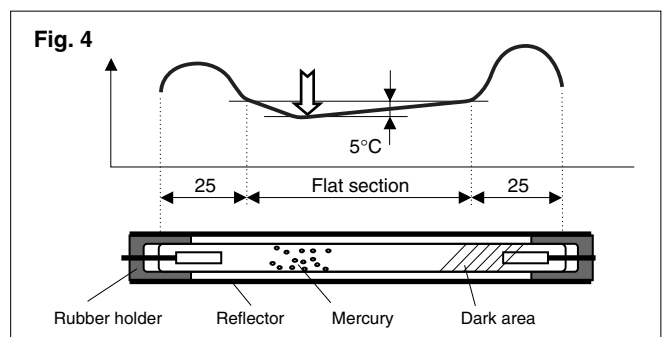
different between both electrodes; the ground side is generally higher than the other.)

On lighting the lamp, mercury present near the electrodes migrates uniformly over the entire flat section. Mercury near the ground-side electrode will never migrate to the hot-side electrode area.

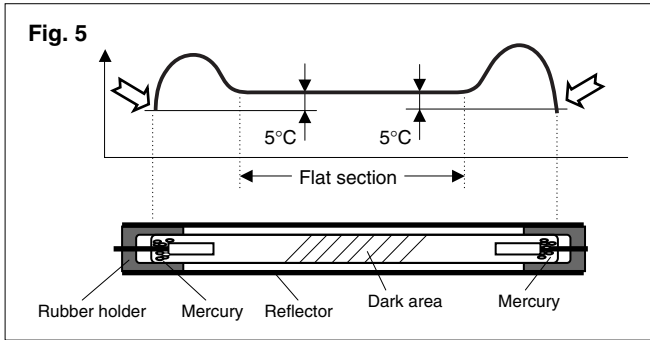


(1) In the case that temperature gradient exists on the flat section between electrodes (Fig. 4)

Mercury gathers on the coldest area (migration) and is depleted on the opposite side if the lamp surface temperature is not uniform over the entire flat section between electrodes. Mercury vapor is low and a dark area appears when mercury is significantly depleted. Even if a dark area does not appear, lack of mercury vapor increases spattering at the electrode and shortens the life of the lamp.



(2) In the case that the lamp end is the coldest area (Fig. 5) Mercury gathers on the lamp ends, when the temperature of the lamp ends is lower than that of the flat section. Mercury vapor decreases and the dark portion appears at the center of the lamp.



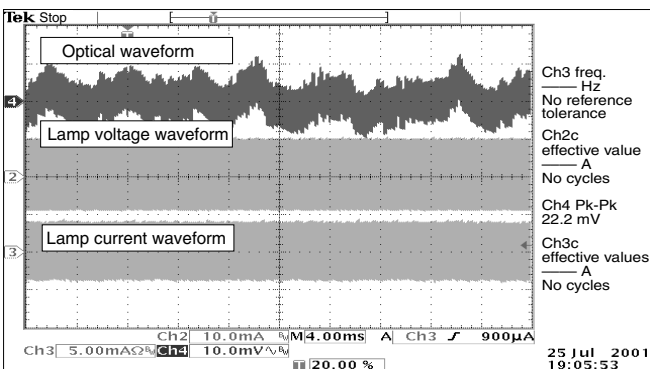
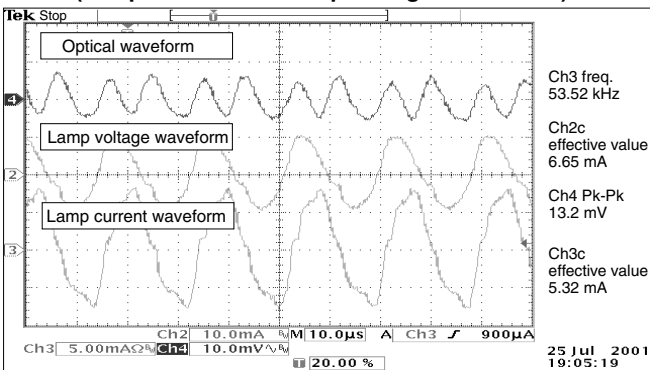
4-3 Failure Mode due to Irregular Lighting Waveform

Excessively distorted lighting waveforms lead to uneven mercury migration or gas consumption. Sanken defines the lighting waveform by the level of imbalance and crest factor. See Chapter 5, “Notes on Lamp Lighting Waveform.” Lamp life is prolonged by improving the imbalance and crest factor.

4-4 Failure Mode due to Irregular Optical Waveform

Mercury vapor pressure falls and the lamp lights unstably affecting the luminescence when the lamp surface temperature falls. Figure 6 shows a typical failure. The optical waveform fluctuates to generate flickers even though the lighting waveform and the lamp voltage are stable.

Fig. 6 Optical and Lighting Waveforms (Lamp Current and Lamp Voltage Waveforms)



The dimming range changes because the lamp surface temperature varies with heat dissipation of the system and the lighting waveform of the inverter. Before setting the dimming range, check the optical waveform that appears under the operating conditions of the lowest lamp surface temperature (low temperature, minimum dimming) using the actual system.

Lamp surface temperature decreases due to the reasons mentioned below. The customer is requested to consider this point in the system design.

< Factors of Lamp Surface Temperature Fall >

Item	Factor of Lamp Surface Temperature Fall	Remarks
Ambient temp	Low	Fall of ambient temp → Rise of lamp voltage
Lamp dia.	Large	The smaller the lamp dia., the more sensitive the lamp is to ambient temp.
Gas pressure	Low	Caution: Luminance may fall if gas pressure is increased.
Reflector cap	Small	Lamp surface temperature will fall when the system’s heat dissipation is appropriate.
Dimming	Large burst dimming	Compared to current dimming at the same lamp current (effective value).
Soft start time	*1 Long	Compared at the fixed peak current, duty and burst frequency.
Burst frequency	*2 High	Compared at the fixed peak current, duty and soft start time.
Lighting frequency	Low	High lighting frequency → Large leakage → Beware of possible deterioration of lighting waveform.

*1 & 2: Take into consideration the following points when setting the soft start time and burst frequency:

Soft start time:

Should be as short as possible without overshoots of lamp current. For reference: 100 to 200 μs max.

Burst frequency:

The lamp turns off before the rated current flows, if the frequency is too high. Use a frequency not to turn off till the rated current flows.

Reference values: 150 to 500 Hz.

4-5 Life Factor Analysis of Defective Lamps

Defective lamps are analyzed at Sanken for both CCFL factors and system factors considering the following points:

[Items for Analysis]

(1) Electrical and Optical Characteristics: Lighting start voltage, lamp voltage, luminance and chromaticity
When the lamp is ready to be lit, the lighting start voltage and lamp voltage are measured in the NF circuit. The gas depletion

is generally accelerated at the end of life to raise the lighting start voltage and the lamp voltage.

Ar depletion is accelerated if the lighting waveform is irregular (see Chapter 5, "Notes on Lamp Lighting Waveform"). The Ar ratio is correctly measured by a gas analysis (destructive test) but Ar depletion can roughly be estimated by checking the lighting condition.

Sanken has no Ar gas blend process, since it procures blended units. The Ar gas ratio does not decrease in our manufacturing process.

(2) Mercury Volume: Measurement of Effective and Ineffective Mercury Volume

Low mercury volume at manufacturing is a cause of short life of the lamp. It can be determined whether the problem is attributable to manufacturing process or not by measuring the mercury volume (both effective and ineffective) of the defective lamp.

(3) Mercury Distribution: Mercury distribution is measured using X-rays, etc.

The actual unit is required to determine if uneven mercury migration is due to a general manufacturing issue or a specific issue of the application. Sanken requests the customer to return the defective lamp as mounted on the actual product.

(4) Spattering: Wearing of the electrode and spattering conditions are measured using X-rays, etc.

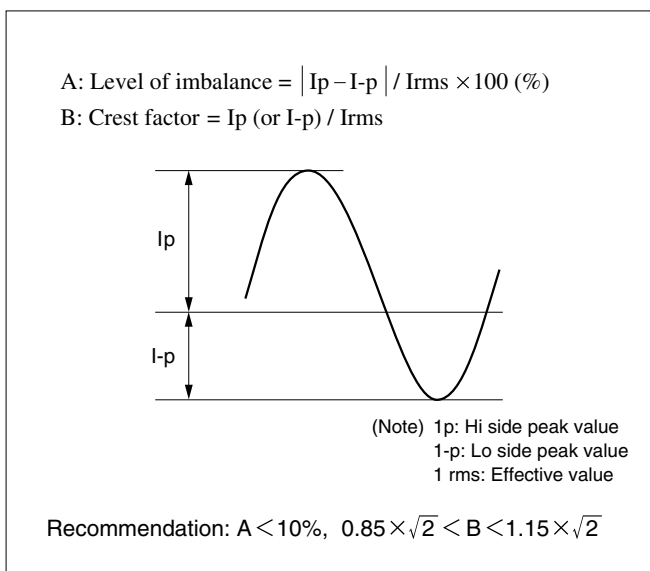
Life factors are estimated by observing the spattering conditions. If gas pressure is low at manufacturing, spattering is accelerated to shorten the life of the lamp. It is difficult to determine whether the problem is attributable to manufacturing process or application by simply checking the defective lamp alone. Sanken requests an analysis at the actual product (PC).

Sanken estimates the cause of the defects by the above analyses. To estimate more accurately, we need the CCFL as it mounted in the system. The modern systems (actual units) are increasingly thin and use magnesium housing, thereby presenting severe environments for CCFLs. Analysis of lamps in these new environments is becoming increasingly important.

5 Notes on Lamp Lighting Waveform

5-1 Lighting Waveform

Heavily distorted lighting waveforms lead to uneven mercury migration and gas consumption. Sanken defines the distortion of lighting waveforms by the level of imbalance and crest factor. Sanken recommends the application within $\pm 10\%$ allowance for the level of imbalance and $\sqrt{2} \pm 15\%$ for the crest factor.



When the lighting waveform is asymmetrical, the Hg^+ ions in the discharge space are strongly attracted to either of the two electrodes, resulting in uneven mercury migration.

For a high crest factor, Ne and Ar ions (Ar ions in particular) impinge on the electrode and are depleted (clean-up). This event occurs particularly in a low temperature environment.

Lighting waveforms are more distorted, when the CCFL is used in an LCD module than used separately. Please confirm this phenomenon on your actual machine. The Sanken inverters are designed in consideration of this phenomenon.

< Method for Improving Imbalance and Crest Factor >

The following methods are available for improving imbalance and crest factor:

- [Methods for improving imbalance and crest factor]**
- (1) Inverter:
 - Perform the following inverter-side changes:
 - Lamp power, driving frequency, capacitance of ballast capacitor and of resonance capacitor
 - (2) Unit:
 - Increase the distance between lamp surface and reflector to the maximum extent.
 - (3) Lamp:
 - (1) Increase the Ar gas ratio
 - (2) Increase gas pressure
 - (3) Use a lamp of a larger diameter

Note that luminance may fall, when you select the lamp-related measures.

CCFL

5-2 Lighting Frequency

Refer to the following table for the recommended lighting frequencies. When the lamp diameter is smaller, the higher lighting frequency should be set. When the lighting frequency is too high, it is likely to increase leakage and to distort the waveform. When the lighting frequency is too low, lighting waveforms are easily distorted to make lighting unstable.

< Recommended lighting frequency >

Lamp I.D.	φ1.4	φ1.5	φ1.8	φ2.0	φ2.4	φ3.0
min	45kHz	45kHz	40kHz	35kHz	30kHz	30kHz
typ	60kHz	55kHz	50kHz	50kHz	45kHz	45kHz

Refer to the lighting frequency-related data.

Fig. 7 Luminance - lamp current characteristics

Lamp: φ2.0 (1.5) × 292mm Ar3% - 9.31kPa (70Torr) **CCFL only**
INV: NF circuit (AS-114A), C_B=22pF, T_a=25°C

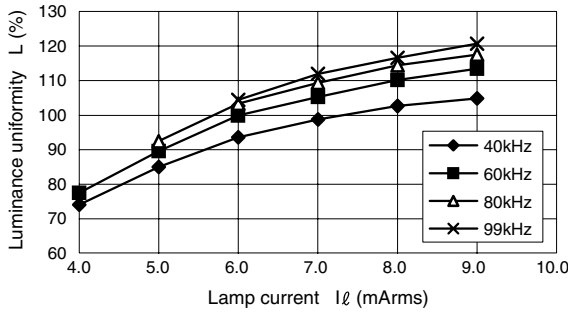


Fig. 8 Luminance/emission efficiency - lighting frequency

CCFL only

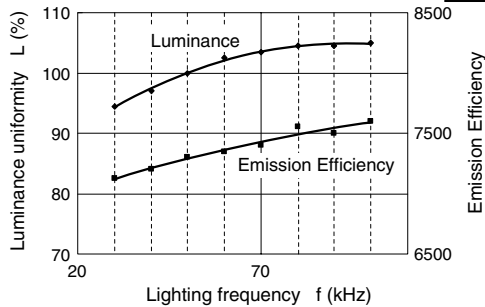


Fig. 9 Luminance/leakage current - lighting frequency

LCD backlight system

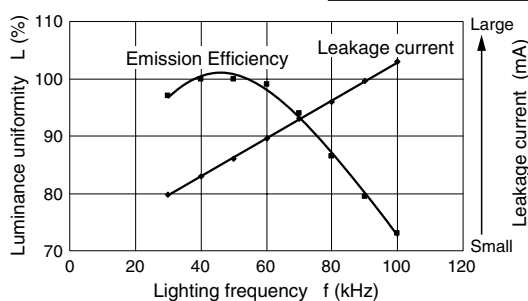


Fig. 10 Lamp voltage - lighting frequency characteristics

CCFL only

Lamp: φ1.8 (1.4) × 254mm, Ar5% - 85Torr, Nb4
INV: NF circuit (AS-114A), C_B=22pF, T_a=25°C

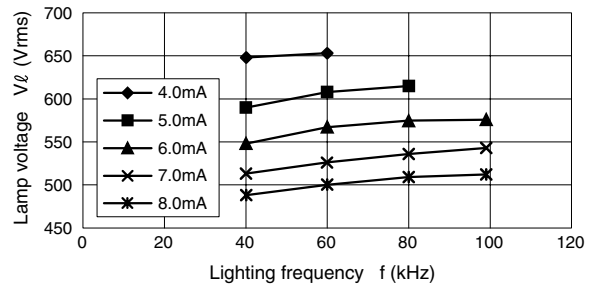


Fig. 11 Lamp voltage - lighting frequency characteristics

LCD backlight system

Lamp: φ1.8 (1.4) × 254mm, Ar5% - 85Torr, Nb4
INV: NF circuit (AS-114A), C_B=22pF, T_a=25°C

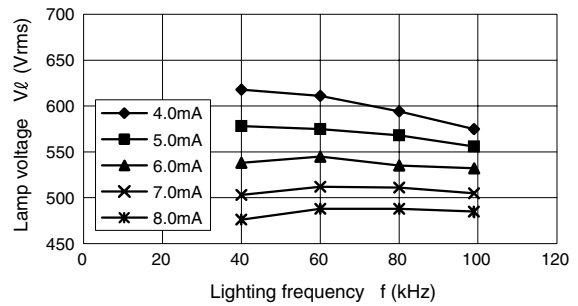
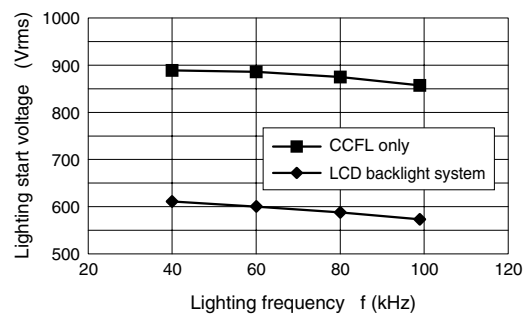


Fig. 12 Lighting start voltage - lighting frequency characteristics

CCFL only

LCD backlight system

Lamp: φ1.8 (1.4) × 254mm, Ar5% - 85Torr, Nb4
INV: NF circuit (AS-114A), C_B=22pF, T_a=25°C



[Cautions] Lamp voltage and Lighting start voltage of a CCFL used as an independent lamp are different from those of a CCFL used in a system.

Luminance of a CCFL, when used as an independent lamp, increases with increasing frequency. For a CCFL used in a system, the leakage current increases and efficiency deteriorates, when the frequency is increased.

5-3 Lighting start voltage

Lighting start voltage of a CCFL increases, as temperature becomes lower. Lighting start voltage of a CCFL used in an LCD backlight system can be higher or lower than the lighting start voltage of a CCFL used separately.

[Lighting start voltage when using a ballast capacitor]

Edge light: CCFL only > LCD backlight system

Directly below: CCFL only < LCD backlight system

[Lighting start voltage for a ballast capacitorless system]

Edge light: CCFL only > LCD backlight system

Directly below: CCFL only > LCD backlight system

When designing an inverter, confirm the lighting start voltage assuming use of the lamp in the LCD backlight system at low temperature.

5-4 Protection Function

For the design of an inverter, Sanken recommends providing a protection function in consideration of the lamp life and other factors described above. For details, contact our Engineering Dept.

6 Decreased Luminance of CCFL and System

Luminance of a system is lost faster than that of the lamp itself. This is because the backlight components (reflector, light guide, etc.) gradually deteriorate by exposure to the UV rays and heat from the lamp (Fig. 13).

The Sanken's CCFL is warranted for life as an independent lamp. The warranty does not apply to the life of the CCFL used in a system.

The Sanken's CCFL uses special glass for reducing UV emissions. CCFLs made of UV cut glass are also available. Contact our Engineering Dept for details.

Fig. 13 Results of Normal Temperature Backlight Test of 14.1-in Notebook PC (One CCFL: ϕ 2.0, lamp current 6 mA)

