Experimental Correction of Temperature Dependence for LED Filament Lamps

Zhao Weiqiang[1], Liu Hui, Yan Jinyun, Su Ying

National Institute of Metrology,, Beijing, China

[1]Corresponding e-mail address: zhaowq@nim.ac.cn

Experimental correction model of temperature dependence for LED filament lamps is reported. The quantities approximate relations of the ambient temperature, the voltage and the flux are analysed. The flux deviation is nearly linearly to voltage deviation while the ambient temperature changes in a small range. While flux correction method applied according to voltage deviation, the experimental results show that the flux fluctuation of the LED filament lamp is less than 0.03% without any thermal control.

1. MOTIVATION

Since the incandescent lamps are phasing out and alternative LEDs become popular in the lighting market, the research of LED standard lamp now are an active topic in field of photometry and radiometry [1]. The National Institute of Metrology (NIM) is developing LED filament standard lamps. They are two types of standard lamps, one is for total luminous flux, other is for luminous intensity. In our design, the lamps are made of LED filaments, mimicking the classical tungsten filament type. As the temperature control module is cumbersome in our case, we measure the ambient temperature-dependence and propose a flux correction method according to the voltage. The temperature effect of LED filament is compressed.

2. CORRECTION MODEL

As well-known, the temperature-dependence of flux can be describe as following:

$$\Phi(T) = \Phi(T_0)e^{k(T-T_0)} \quad (1)$$

Here $\Phi(T)$ is the flux at temperature T, $\Phi(T_0)$ is flux at temperature T_0, k is temperature coefficient. Since the $\Phi(T)/\Phi(T_0) \approx 1$, it deduces:

$$\frac{\Phi(T)-\Phi(T_0)}{\Phi(T_0)} = k(T - T_0) \quad (2)$$

Also, the voltage deviation is linearly to PN junction temperature deviation. Due to thermal equilibrium, the ambient temperature deviation is the same as the junction temperature deviation. So,

$$\frac{\Phi(T)-\Phi(T_0)}{\Phi(T_0)} = k(T - T_0) = k_2\big(\mathrm{V}(T) - \mathrm{V}(T_0)\big) \quad (3)$$

Here $\mathrm{V}(T)$ is the voltage at temperature T, $\mathrm{V}(T_0)$ is the voltage at temperature T_0, k_2 is voltage coefficient. Approximately, at a certain current, we get a fitting equation used as the correction model:

$$\Phi(V) = k_3 \cdot \mathrm{V} + b_3 \quad (4)$$

and other two fitting equations:

$$\Phi(T) = k_4 \cdot T + b_4 \quad (5)$$

$$V(T) = k_5 \cdot T + b_5 \quad (5)$$

Here k_3, b_3, k_4, b_4, k_5, and b_5 are the fitting parameters.

3. FITTING PARAMETERS MEASUREMENT

A spherical photometer is used to measure the fitting parameters. 4-wire connection is applied for voltage remote sensing. Ambient temperature sensor is installed inside the sphere and close to the baffle, placed in the shadow side. Auxiliary halogen lamp is used to be reference lamp to reduce the temperature influence of photometer. We test one LED filament lamp, GQ#67, which are made of 12 filaments, and proposed to be luminous intensity standard lamp. The experimental results are shown in Figure 1, 2 and 3.

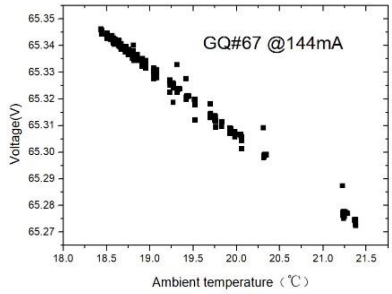

Figure1. Voltage vs temperature

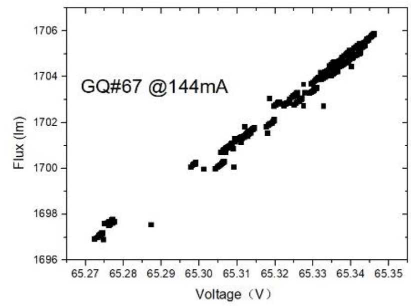

Figure 2 Flux vs voltage

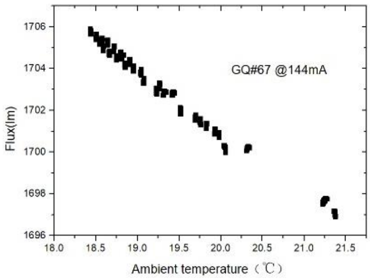

Figure 3. Flux vs temperature

Using least square fit, the fitting equations are described as:

$$\Phi(V) = 119.397 \cdot V(T) - 6096.52 \quad (6)$$

$$\Phi(T) = -2.94165 \cdot T + 1759.82 \quad (7)$$

$$V(T) = -0.0245994 \cdot T + 65.7995 \quad (8)$$

The calculated temperature coefficient is -0.17%/℃

4. EXPERIMENTAL RESLUTS

The test of stability of GQ#67 is ongoing following the produce. After 500 hours aging, the lamp operates for 1 hour every day and then the flux, the voltage and the ambient temperature are monitored and recorded in 3 minutes.

We compared these two correction ways, one is based on equation (6) according to voltage, the other is based on equation (7) according to the ambient temperature as a contrast. *T*=25℃ is the temperature reference point. *V*(25℃)= 65.1845 V according to the equation (8) is the voltage reference point .

With correction applied, 19 days results are shown in figure 4.

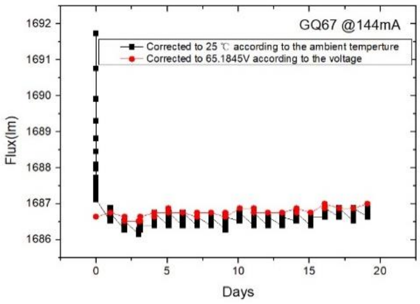

Figure 4. Flux stability in 19 days

In day 1, when using temperature correction, the flux drops from 1692 lm to 1687 lm due to the thermal non-balance in 3 minutes. However, using voltage correction, the flux multiple readings in 3 minutes are consistent. The voltage of lamp indicated the PN-junction temperature, related to the output flux. Voltage is a direct way to response to the flux. Use voltage correction is a better choice than temperature correction.

We show the corrected fluxes vs ambient temperature results in figure 5 and 6.

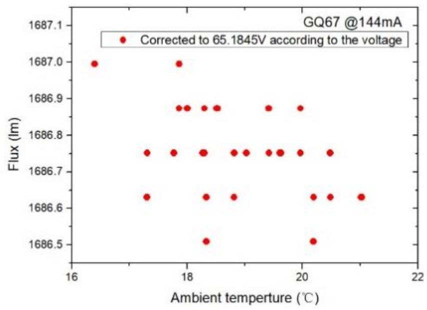

Figure 5. Voltage corrected flux vs temperature

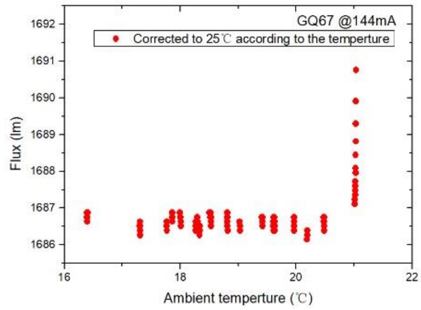

Figure 6. temperature corrected flux vs temperature

The figure 5 shows the voltage corrected flux is in the range of (1686.5 ~ 1687.0) lm in these 19 days, that means less than 0.03% fluctuation when the ambient temperature varies. The related ambient temperature is in the range of (16 ~ 21) ℃. No obvious decay is observed according to the figure 4.

Figure 6 shows a larger fluctuation of temperature corrected flux in same temperature variation range

5. CONCLUSION

NIM is developing LED filament standard lamps. An experimental correction method of temperature dependence for LED filament lamps is discussed in this report. The correction method is based on voltage deviation. After correction, flux fluctuation is less than 0.03% when the ambient temperature varies in range of (16 ~ 21) ℃.

ACKNOWLEDGMENT

The authors are thankful to NIM colleague Mr. Lin Yandong for helpful discussion.

REFERENCES

1. CCPR Strategy Document for Rolling Development Programme, 2017.
2. Yan J.Y. etc, LED filament standard lamps for total luminous flux and luminous intensity, Proceedings of 29th CIE Session 2019