Final manuscript, Metrologia 1995/96, 32, 693-696

Characterization of Modified FEL Quartz-Halogen Lamps for Photometric Standards

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Abstract

The stability of luminous intensity and color temperature of modified FEL type, 1000 W quartz halogen lamps has been tested at various color temperatures to investigate the suitability of these lamps for use as photometric transfer standards. Over 60 h of operation at 2856 K, after seasoning for 100 h, the changes of luminous intensity of these lamps were 0.2% to 0.6%, and the changes of color temperature were less than 2 K. The changes in relative spectral power distributions (normalized at 550 nm) over the 60 h of operation were within 0.5% in the visible region. The FEL type lamps operated at 2856 K showed satisfactory stability within the limited duration of these tests. Characteristics of the lamps are also investigated for operation at 2000 K to 3100 K, for reversed polarity, and for long-term storage.

1. Introduction

Absolute detectors are extensively used by many national laboratories to realize photometric scales, whereas lamps are still generally used to maintain and disseminate the scales. Many of the gas-filled type incandescent lamps which were extensively used in the past as luminous intensity and color temperature transfer standards are no longer commercially available. The FEL type quartz halogen lamps, which were used as spectral irradiance transfer standards at NIST [1], also have not been available as standard quality lamps for the past several years. The characteristics of these lamps at ~3200 K have previously been reported [1,2].

Stability of incandescent lamps depends not only on the type of lamp but also varies from one lamp to the next for lamps of the same type. While some types of lamps show excellent stability [3], other types show poor stability [4]. Although there are several design factors to be noted, there is no way to assure the lamp stability other than by actually testing the lamps.

Recently, a new type of FEL, 1000 W quartz halogen lamp [5] has become commercially available in the U.S. These lamps have filament mounts specifically constructed for standard lamps and have a T-6 clear bulb, 18 mm in diameter. These lamps are produced with bi-pin bases, but are also available in a potted medium bi-post base. We have investigated the suitability of these lamps for use as transfer standards of luminous intensity and color temperature. We have tested the stability of luminous intensity and color temperature of these lamps during operation over 60 hours at various color temperatures. Tests of old gas-filled type incandescent lamps are also reported for comparison.

2. Measurement equipment

One of the NIST standard photometers [6] was used for luminous intensity measurements during these tests. This photometer is of the temperature-monitored type, consisting of a silicon photodiode, a V(λ) filter, a precision aperture, and an electronic assembly all in one unit. The temperature coefficient of the responsivity of the photometers is -0.088 %/°C. When the luminous intensity is measured, the output signal of the photometer is always corrected for the photometer temperature. The room temperature is controlled to be 24°C± 1°C.

All the measurements were performed on the NIST photometry bench [6]. The bench is equipped with a medium bipost-base socket which has four separate contacts, two for current supply, and two for voltage measurements. A DC constant-current power supply is used to operate the standard lamps and test lamps. The lamp current is measured as the voltage across a reference current shunt (0.1 Ω), using a 7 digit DVM. The lamp current is automatically controlled by a computer feedback system to keep the current drift within ±0.002%.

For color temperature measurements, a spectroradiometer (photodiode array type) is used in combination with a Lambertian diffuser made of polytetrafluoroethylene (PTFE) plaque placed on the photometry bench. The plaque is placed on a kinematic base and can be removed when luminous intensity is measured. The plaque is placed approximately 0.5 m from the lamp, irradiated at normal incidence, and viewed at 45° by the spectroradiometer. Prior to measurements of a group of test lamps, the spectroradiometer is calibrated against two spectral irradiance working standard lamps. Correlated color temperature was calculated from the spectral distribution data.

An automatic stability testing program was used in the luminous intensity measurements. This program performs measurements of luminous intensity and electric parameters, while keeping the lamp current in a control range, at specified time intervals for any duration of time. When the measurement is complete, the lamp is automatically turned off. The lamp current is ramped up and down in approximately 40 s.

3. Preparation of the lamps.

Six each of the new FEL type lamps and the gas-filled type incandescent lamps were prepared. All of the lamps were initially seasoned with DC power at the specified electrical polarity for 72 h at currents which provide color temperatures of approximately 2856 K. The actual operating current of each lamp was then determined by the color temperature measurements. After this calibration, all the lamps were further seasoned at 2856 K for an additional 30 h using the automatic stability testing program. One FEL type lamp was rejected at this stage because of instability.

The lamps were mostly operated in a seasoning rack at the same current and polarity as used for measurements, and brought to the photometry bench for measurement at each 30 h of operation. Some lamps were seasoned on the photometry bench by using the stability testing program to plot the change of lamp parameters during 24 h of operation.

4. Measurement procedures

Each lamp is mounted on a photometry bench in the base-down position. Lamp orientation is accomplished by autocollimation of a laser beam on an alignment jig (a mirror mounted on a bi-post base). The distance and the height of the lamp is aligned using a side telescope. During the entire test period, the photometer was fixed at a position at approximately 3.5 m from the lamp. The lamps are operated at the specified current and polarity. After the lamp has stabilized for 10 min, the color temperature is first measured (which takes less than one minute) and then the luminous intensity is measured.

The reproducibility of the luminous intensity and color temperature measurements during this test was checked by measuring two reference lamps (200 W frosted quartz halogen) each time the test lamps were measured. The total operation time on these reference lamps during this test was less than one hour. The reproducibility of the luminous intensity of these lamps was 0.1% (2σ). The reproducibility of the color temperature of these lamps was 1 K (2σ). These values are considered to be the uncertainties of the results of this test. The uncertainty of the 24 h stability test (as shown in Figure 4 and Figure 5) is estimated to be less than 0.05 % (2σ) according to our data on the short-term stability of the photometer.

5. Results.

Figure 1 shows the results of the changes in luminous intensity and color temperature of the FEL type lamps after 30 h and 60 h of operation at 2856 K. The luminous intensity of the lamps decreased by 0.2 % to 0.6 % in 60 h. The maximum drift rate is - 0.1% / 10 h. Color temperature of the lamps changed by + 1 K to - 2 K. For comparison, Figure 2 shows the results for the gas-filled type incandescent lamps. Lamp 2 is a 500 W inside frosted lamp and Lamp 3 is a 500 W clear bulb lamp. All other

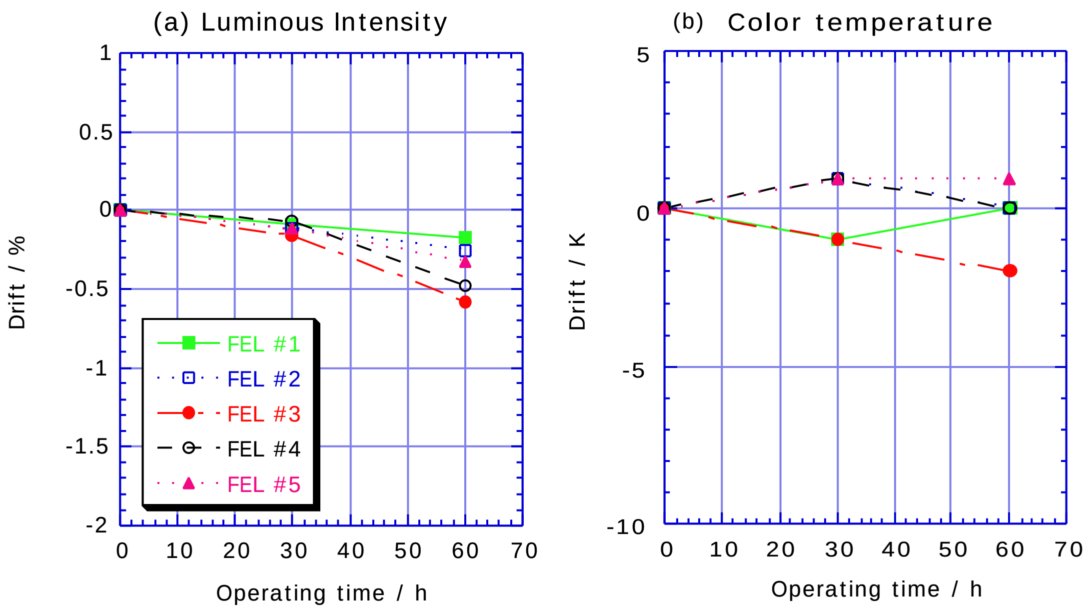

Figure 1. Drift of FEL type lamps vs. operating time

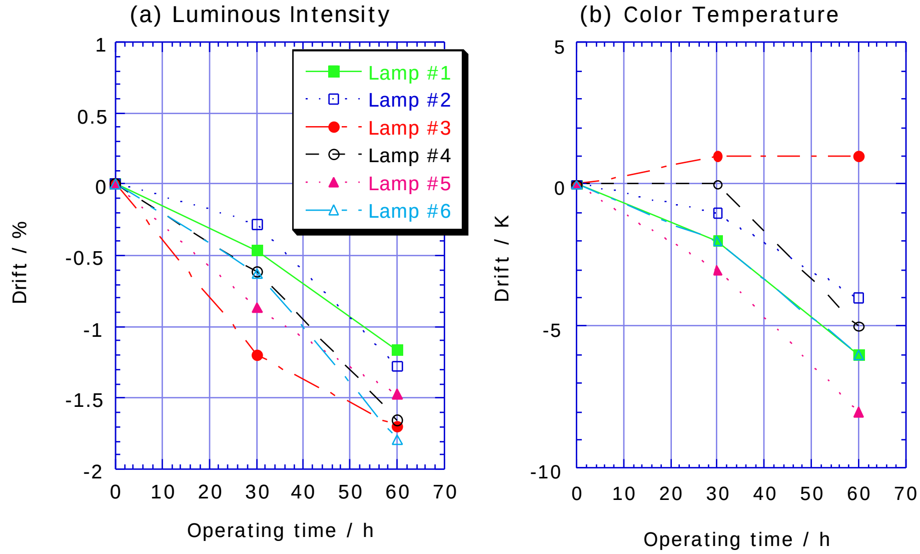

Figure 2. Drift of gas-filled type incandescent lamps vs. operating time

lamps are 300 W inside frosted lamps. These aging characteristics are similar to those of the gas-filled type incandescent lamps reported in reference [2]. These results indicate that the new FEL type lamps are superior in aging stability to the old gas-filled type incandescent lamps.

Figure 3 shows the change in the spectral power distributions of the FEL type lamps after 60 h of operation (2856 K). Each plot represents data taken relative to the value at the beginning of measurements, and each curve is normalized at 555 nm. The large scatter below 420 nm is due to the noise of the spectroradiometer. The results

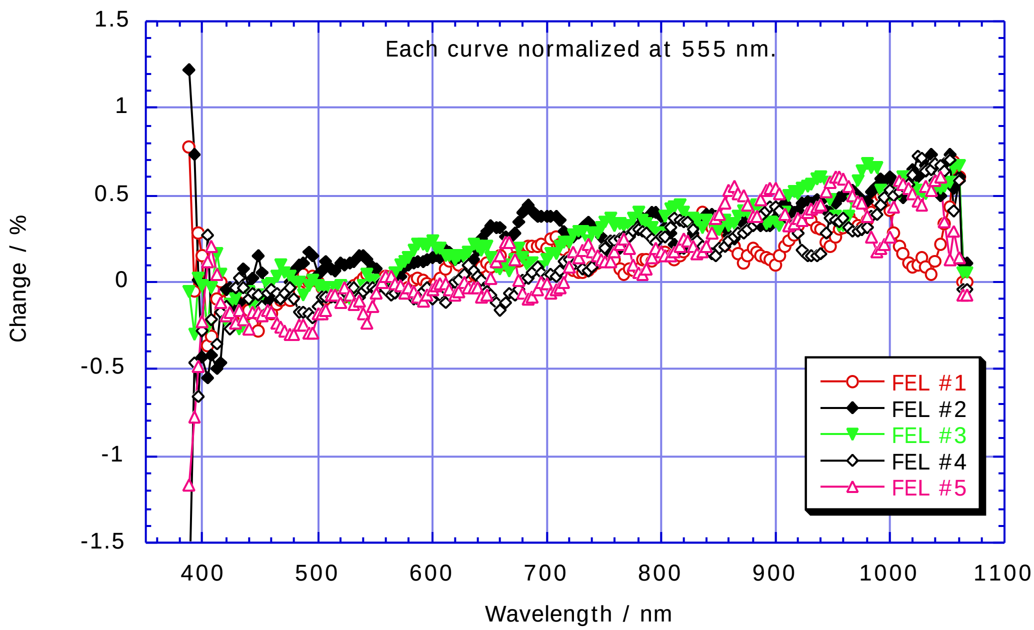

Figure 3 Change of spectral power distribution
– FEL type lamps, 2856K, after 60 h of operation –

indicate a slight increase of power at the longer wavelengths relative to 555 nm, which should result in a slight decrease in color temperature.

Figs. 4 and 5 show the stability of another FEL type lamp (#6) during 24 h of operation at different color temperatures, 3100 K (8.2 A) and 2856 K (7.2 A), respectively. Data were also taken at 2600 K (6.2 A) with the similar results as at 2856 K. It is noted that, at 3100 K, the lamp voltage and the luminous intensity increase with operating time (this agrees with the results shown in reference [2]), and at 2856 K and 2600 K, they decrease. These results indicate that the halogen cycle is still effective at

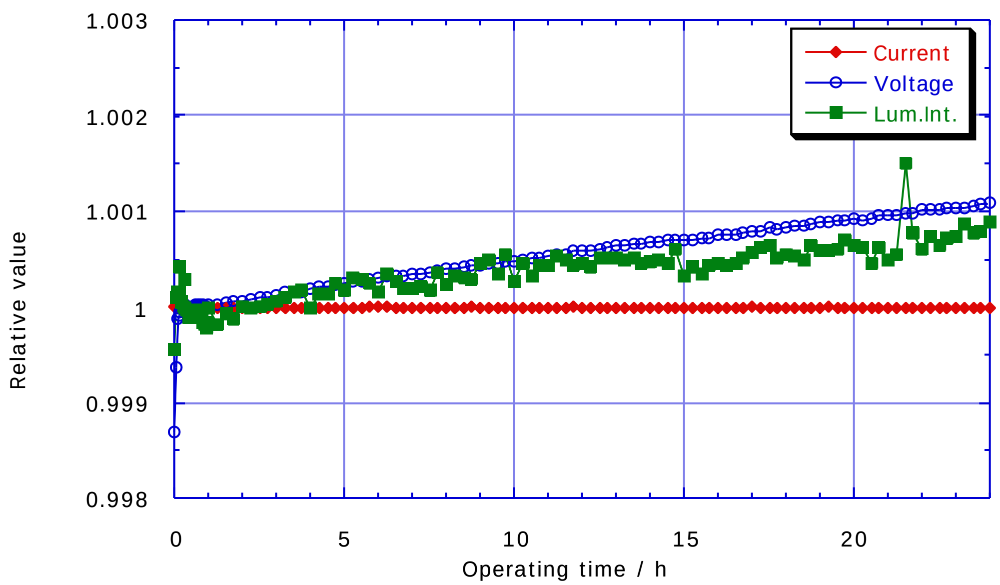

Figure 4. Drift of an FEL type lamp operated at 3100 K - FEL #6, 8.2 A, for 24 h -

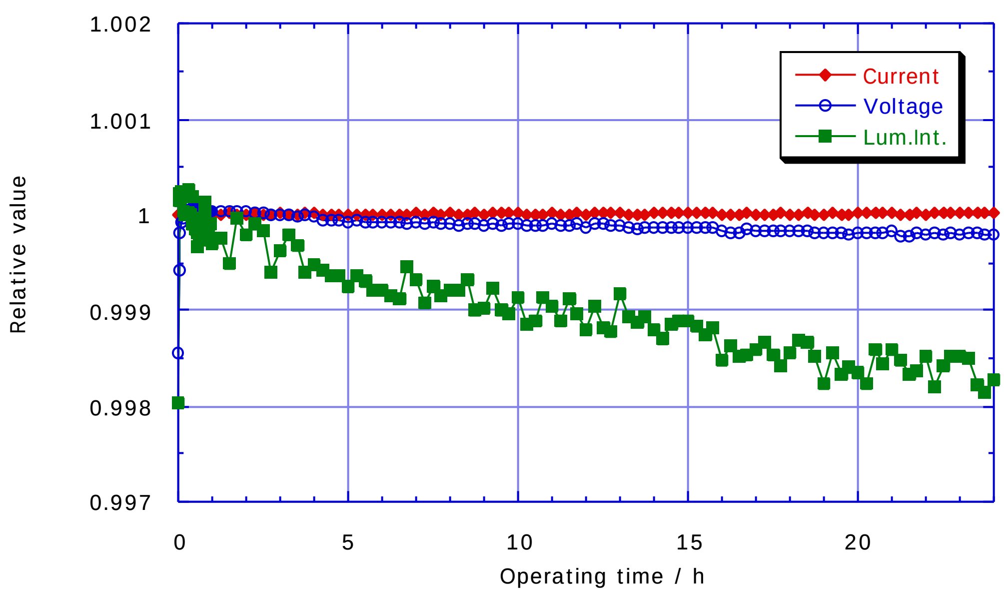

Figure 5. Drift of an FEL type lamp operated at 2856 K - FEL #6, 7.2 A, for 24 h -

2856 K and even at 2600 K, but not as effective as at 3100 K. One lamp was tested at 2000 K, and surprisingly, showed excellent stability (less than 0.1% change for 24 h). It is inferred that, at 2000 K, the luminous intensity is so low (two orders of magnitude lower than at 2856 K) that the tungsten evaporation is negligibly small. It seems that this type of lamp can be used as a color temperature standard over a wide range.

A stability test was made on a lamp which was not used for a five month period. There was an initial drop of lamp voltage and luminous intensity by ≈ 0.2% during the first hour. When the lamp was turned off, and then relighted within several hours, the lamp stabilized in five minutes and maintained its luminous intensity to within ± 0.03% for one hour.

Figure 6 shows the results when the electrical polarity was reversed for 96 h. Values are plotted relative to the value at normal polarity just before this test was made. The luminous intensity did not change immediately, but changed gradually by as much as 1% in 96 h of operation. This implies that if a reverse polarity is applied to a lamp by accident, the change of the lamp may not be serious if the time of the reversed operation is short. After this test, the polarity was changed back to normal again, and the lamp was operated for 60 h. During the 60 h, the lamp maintained its luminous intensity within 0.2 % from the value at the end of the reverse polarity operation, and no noticeable instability was observed.

The angular uniformity of luminous intensity was also measured for each FEL type lamp. The lamp with its filament fixed parallel to the lamp posts had a uniformity of ± 1.5 % in a 3° x 3° field. The lamp with its filament slightly tilted from the line parallel to the lamp posts had a uniformity of ± 4.5% in a 3° x 3° field, a large difference from the best one. These data indicate that lamps can be screened by a visual check of filament orientation for acceptable angular uniformity.

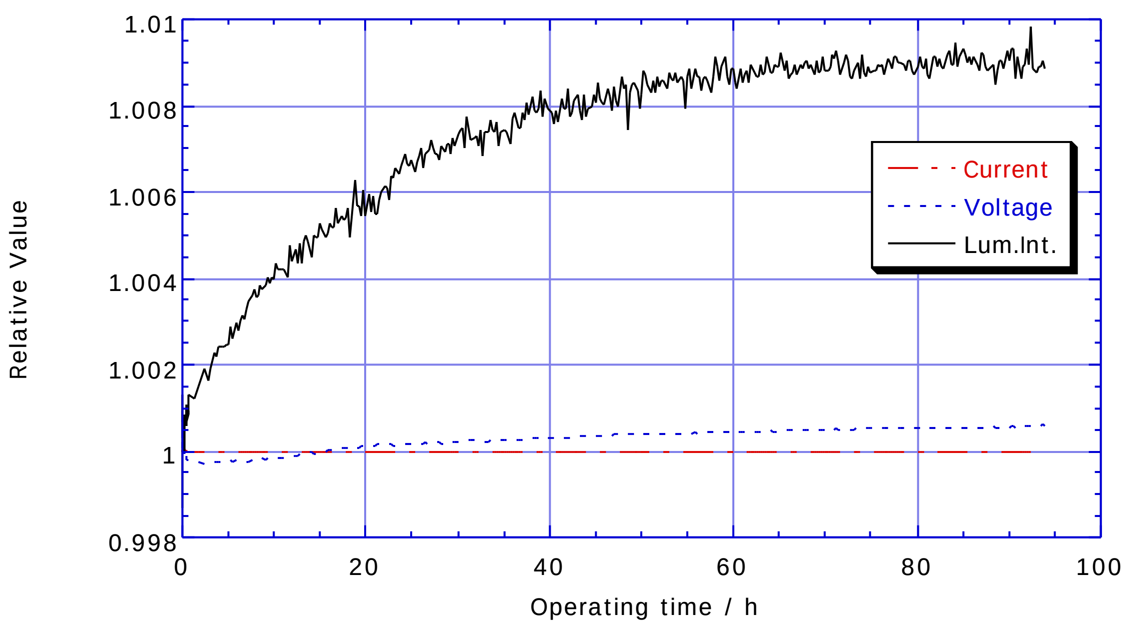

Figure 6. Drift of an FEL type lamp with reversed polarity.
- FEL #4, 7.2A, 2856 K, for 96 h -

6. Conclusion

Over 60 h of operation at 2856 K, the change of luminous intensity of five FEL type lamps, initially seasoned for 100 h, was 0.2 % to 0.6 %, at a rate of 0.03 % to 0.1 % in 10 h. The changes of color temperature were less than 2 K. The changes in relative spectral power distributions (normalized at 550 nm) in the visible region were within a few tenths of a percent. The FEL type lamps operated at 2856 K showed satisfactory stability within the limited duration of the tests and were found suitable as photometric transfer standards.

The tests were performed on only a small number of lamps from one batch of production. The characteristics of other batches of lamps may not be similar. More tests are necessary to gain confidence in the characteristics of the lamps. Also, the lamps should be tested for longer time periods to assure the characteristics during their lifetime, although the stability of lamps usually improves with operation time. Seasoning conditions should also be studied because a later batch of the FEL type lamps seasoned at 2856 K for 72 h failed in stability. The stability tests on the same type of lamp used for spectral irradiance calibrations are being carried out at NIST and at PTB, which will be published elsewhere.

Acknowledgements.

The authors express thanks to R. Low of Osram Sylvania Inc. and A. Gaertner of NRC, Canada who provided us with useful information and discussion on the lamps tested.

Notes

Specific firms and trade names are identified in this paper to specify the experimental procedure adequately. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

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