Capability of testing the ageing behaviour of incandescent lamps

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Abstract. The ageing behaviour, with respect to Correlated Colour Temperature (CCT), illuminance and voltage changes across a tungsten halogen lamp were measured and analysed. The lamp was current controlled at 6.35 $\pm$ 0.07A. The initial voltage was 20.25 V, and the initial CCT was 2869 K. Data was collected for up to 25 hours of operation in one case and up to 330 hours of operation in a second case. The lamp was simply run continuously; hence the seasoning period for the lamp is included in the data. During the 25 hours of operation; the lamp voltage increased, the current decreased, the illuminance decreased and the CCT increased. For the operating time of 330 hours; the voltage increased, the current and then fluctuated between a range of 6.352 A and 6.372 A and the illuminance increased. The CCT was measured up to 130 hours, and had decreased by 42 K from the start of the test. From these results, it was concluded that in terms of CCT this particular lamp is the most stable between approximately 68 hours and 116 hours of burning (ΔCCT = 4 K). During the burn time, before this period, the CCT increases steadily initially, peaks and then follows a decreasing trend. The illuminance measurements however, show that the lamp starts to stabilise at longer operating times. The data collected from 250 hours to 330 hours shows that the lamp illuminance increased at a rate of approximately 0.10 lux/hour. For the period of 0 to 25 hours, the rate of decrease was 0.33 lux/hour.

1. Introduction

In the laboratories at Optronics Sensor Systems (OSS), there are various facilities being used, which have tungsten halogen (incandescent) lamps fitted. The purpose for using these lamps is to be able to have a stable luminous intensity for a total burning time that does not require the lamp to be replaced too often.

Incandescent lamps age with use and the long-term and short-term stability of these lamps needs to be considered. It would be valuable to know the anticipated lifetime of the incandescent lamp as well as the changes in the lamp characteristics (in terms of luminous intensity and colour temperature) over time. Thus, a capability for testing the ageing behaviour of incandescent lamps would have to be established, in order to obtain these characteristics.

Furthermore, an experimental setup was designed and implemented, where a 150W tungsten halogen lamp was burnt for 330 hours. The intensity of the incident light (illuminance) from the lamp was monitored using a Hamamatsu Silicon (Si) photodiode. The response of this photodiode is similar to the spectral luminous efficiency of the human eye, as defined by the Commission Internationale de I'Eclairage (CIE). The CCT of the lamp was monitored with a Photo Research spectroradiometer.

An analysis of the data from the photodiode and spectroradiometer was performed and then compared to results from a paper "Characterization of modified FEL quartz-halogen lamps for photometric standards" [1].

2. Theory

2.1. Incandescent Lamps

These types of lamps have halogen added to the filling gas of the lamp. As the lamp burns the tungsten (from the filament) evaporates and chemically combines with the halogen gas near the bulb wall, the tungsten is then re-deposited on the filament. This cycle repeats for the lifespan of the lamp. This chemical reaction reduces the darkening of the bulb and increases the life span of the lamp. This also ensures that the illuminance remains almost constant throughout the life span. For this reason, this type of lamp is most suitable for our purposes of illumination.

However, the stability of individual lamps does vary from one to another. The only way to test for stability is to burn several lamps for several hundreds of hours and then analyse the measured data, such as CCT, lamp voltage, illuminance etc.

This data is then used to obtain a trend line for the specific types of lamps tested. The more lamps of the same type and make tested, would give greater confidence in the trends observed.

2.2. Illuminance

Illuminance is a photometric quantity, which is a measure of the intensity of incident light on a surface that correlates with the human brightness perception [2]. This is measured in lux (1 lux = 1 lumen per square meter).

The luminosity function, describes the average visual sensitivity of the human eye to light of different wavelengths. It is used to convert radiant energy into luminous or visible energy.

To calculate illuminance, the intensity of the incident light is wavelength-weighted by the luminosity function, the data for this function can be downloaded from [3].

2.3. Correlated colour temperature

Planck's radiation law describes the radiation of a black body radiator. A theoretical black body emits no radiation at zero Kelvin, and is therefore black, since it absorbs all radiation incident on its surface. As temperature increases, so does the radiation emitted by a black body, which gives rise to a change in colour.

Colour is specified by colour coordinates or chromaticity, which is colour that is projected into a two-dimensional space that ignores brightness.

Correlated Colour Temperature (CCT) is used to compare a lamp's colour to that of a black body radiator at a certain temperature, as seen by a human observer. . It needs to be mentioned that this is usually not a spectral match.

To perform this comparison the process described by [4] was carried out.

3. Experimental setup

The schematic of the experimental setup is shown in Figure 1 and a circuit diagram of the experimental setup is shown in Figure 2. The equipment used for this experiment is described in the sections that follow.

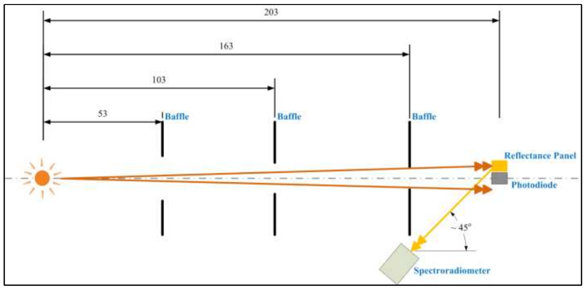

Figure 1. Schematic of Lamp Ageing Experimental Setup

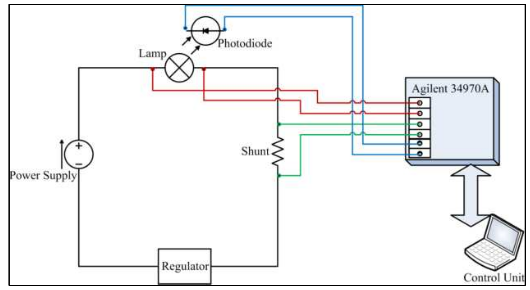

Figure 2. Circuit Diagram of Lamp Ageing Experimental Setup

3.1. Tungsten halogen lamp

The tungsten halogen lamp chosen for the test was an Osram Xenophot lamp, model HLX 64640. These lamps are currently been used in the target illuminator for the day resolution tests in the laboratory. The rated characteristics are, 24 V, 6.35 A and 150 W.

3.2. Power supply and active load

The lamp was current controlled at 6.35 A, with a Trygon bench power supply and a Hewlett Packard active load. The active load was used to keep the current from the power supply stable.

3.3. Photodiode

A Hamamatsu Silicon (Si) photodiode, together with a Hamamatsu amplifier, were used to measure the illuminance from the incandescent lamp. The sensor has a built-in V(lambda) filter, which weighted the measurement with the human eye's spectral luminous efficiency function for photopic vision. The active area is 2.8 mm × 2.4 mm and a spectral response range of 480 nm to 660 nm
Spectral response analogous to CIE spectral luminous efficiency function

3.4. Baffles

Three Aluminium baffles were spray painted matt black to ensure that there would be no reflected or scattered light. The diameters for the baffle openings were 30 mm, 40 mm and 50 mm. The largest diameter was placed closest to the lamp and the smallest placed closest to the photodiode. These were used to align the lamps' output to the centre of the photodiode.

3.5. Current shunt

The current shunt was used to determine the current flowing through the circuit. This was done by measuring the voltage across the shunt, and using its rated resistance to calculate the current.

3.6. Spectroradiometer and reflectance standard

A spectroradiometer, was used, together with a white reflectance standard, to measure the CCT. The reflectance standard was placed next to the photodiode, both facing the incident light at approximately normal incidence. This placement was to ensure that the reflectance standard is approximately the same distance from the lamp as the photodiode

4. Results

The following data was recorded:

- Shunt and lamp voltages as well as current: 0-330 hours
- Photodiode voltages: 0 – 25 hours and 240 - 330 hours (no data was recorded between 25 – 240 hours).
- CCT measured 0-130 hours.

4.1. Voltage
0 – 25 hours: the drift in lamp voltage is seen in Figure 3, where it starts at 20.24 V and increases to 20.31 V. This is a 0.35% increase.

0 – 330 hours: follows an increasing trend as shown in Figure 3. This increased to 20.59 V, which is a 1.73% increase. This agrees with the results from [1], for a lamp at 3100 K. Although, for the same publication, a similar lamp at 2856 K, the trend is for the voltage to decrease.

4.2. Current
0 – 25 hours: the lamp current shown in Figure 4, shows a decreasing trend from 6.424 A to 6.404 A, which is a 0.31% decrease.

0 – 330 hours: At approximately 240 hours, the current drops by 6.032 A and is stabilised to a current in the region of 6.372 A to 6.352 A. The reason for this is probably due to the fact that the photodiode was switched on again at this point, and caused a disturbance to the circuit.

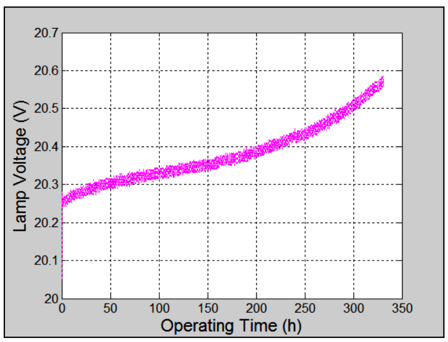

Figure 3. Lamp voltage drift for 330 hours of operation

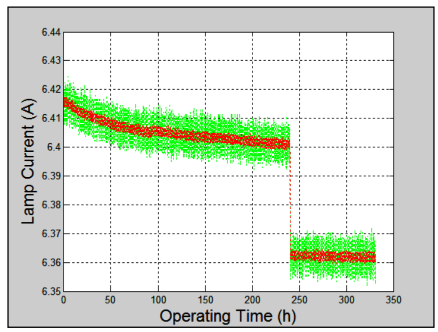

Figure 4. Lamp current drift with associated moving average plot [5] in red for 330 hours of operation

4.3. Illuminance
0 – 25 hours: the lamp illuminance shown in Figure 5 has decreased from 123.92 lux to 115.59 lux, which is a 6.72% decrease. This is quite substantial, however, this type of behaviour is expected, as there is a period for which the lamp must stabilise.

0 – 330 hours: the lamp illuminance has increased to 137.26 lux. The blank portion, as seen in Figure 5, between 25 hours and 240 hours is the period for where there is no data. The values after 240 hours fall within a band which is approximately 4 lux wide. The data spread for illuminance is very large, compared to the data captured during 0-25 hours). This could possibly be a characteristic of the photodiode, after being exposed to such a bright light source for a long period.

4.4. Power
0 – 25 hours: the drift in lamp power and lamp illuminance is shown in Figure 6. The lamp power is obtained by multiplying the lamp voltage with the lamp current. The drift shown here is from 129.73 W to 130. 25 W, which is an increase of 0.40%.

0 – 330 hours: as seen with the current, at approximately 240 hours there is a sharp decrease in power, of which the cause is probably due to the fact that the photodiode was switched on again at this point, and caused a disturbance to the circuit. The power however, increases to 131.05 W, due to the fact that the current also increases.

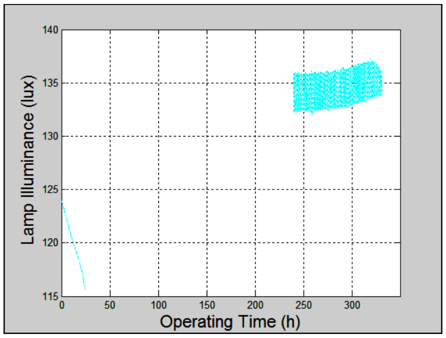

Figure 5. Lamp illuminance drift for 330 hours of operation

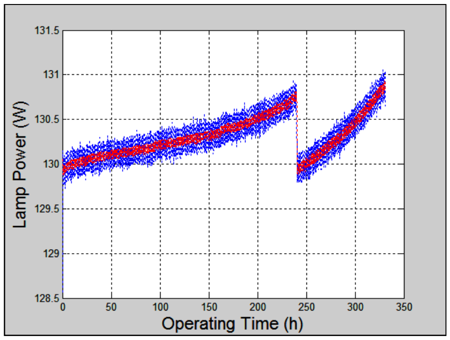

Figure 6. Lamp power with associated moving average plot [5] in red for 330 hours of operation

4.5. Correlated colour temperature

The CCT measurements were done for an operating time of up to 130.5 hours (see Figure 7). The CCT behaviour was as follows:

- Increased for about 20 hours of operation and peaked to 2883 K (change in CCT of 14 K).
- After the peak in CCT, there is a decreasing trend up until 88 hours.
- From this point to 116 hours the change in CCT was 5K, which is the most stable point from the data gathered.
- Thereafter, there is a sharp decrease up to 130.5 hours.
- Decreased by 42 K since the start of the test to 130 hours.

Figure 7 also shows a second order polynomial fit to the measured data, which has an R^2 value of 0.9016. According to this polynomial, the longer the lamp burns, the lower the CCT will get, which is what would be expected intuitively.

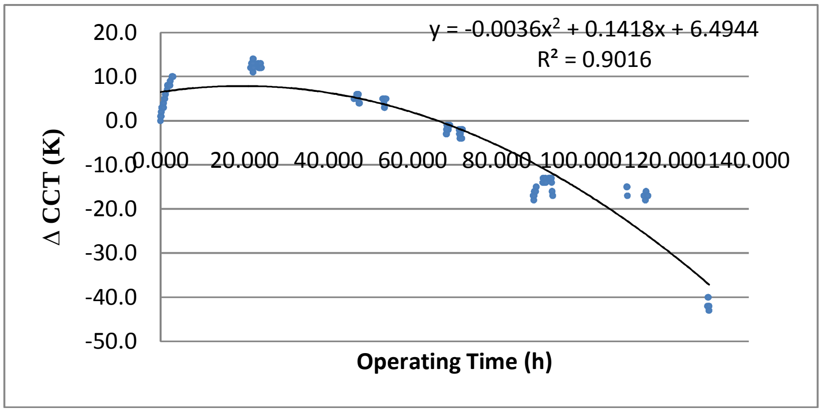

Figure 7. Change in CCT for an Operating Time up to 130 hours

5. Conclusions and recommendations

A tungsten halogen lamp was operated for a total time of 330 hours.

The increase in voltage agrees with the results from [1] for a lamp operated at 3100 K. However, according to the results from [1], the current should follow the behaviour of the voltage, and should also increase. In the results from this experiment, the behaviour does not follow this trend. The reasons for this could be due to the long term behaviour of the active load or behaviour of this specific lamp.

The illuminance should also follow the trend of the voltage, as seen in [1], which is the case here.

The CCT does follow the same trend as shown in [1], where there is an initial increase followed by a decrease in CCT.

This test was performed on a single lamp for a limited time, and the following is recommended:

In order to gain confidence in the characteristics measured, more lamps should be tested.

The data obtained for the illuminance is confined to between 0-25 hours and 240-330 hours of operation, and information has been lost in-between. Repeating the experiment to obtain this information would be extremely valuable.

It would be highly desirable to obtain CCT measurements continuously, since this changes quite a bit from the start of lamp operation, and does not seem to stabilise very much at any given point. In order to perform this measurement, a program would have to be written to control the spectroradiometer for long continuous periods.

More measurements would have to be performed on the photodiode detector itself, in order to understand its behaviour with operating time as well as to the intensity of light it will be measuring. This is due to the fact that the band width for the illuminance measured by the photodiode had increased drastically during the latter part of the experiment.

References

[1] Y Ohno and J K Jackson, “Characterization of modified FEL quartz-halogen lamps for photometric standards”, Metrologia, 1995/96, 32, pp 693-696

[2] A. E. F. Taylor, 2000, “Illumination Fundamentals”, Lighting Research Center, California, viewed 14 May 2012, http://www.opticalres.com/lt/illuminationfund.pdf

[3] CIE, 2012, “Selected Colorimetric Tables”, CIE Central Bureau, Vienna, viewed 14 May 2012, http://www.cie.co.at/index.php/LEFTMENUE/index.php?i_ca_id=298

[4] Y. Ohno and M. Jergens, 1999, “Results of the Intercomparison of Correlated Color Temperature Calculation”, NIST, http://cie2.nist.gov/CR3/Documents/Results_CCTcomparison.pdf

[5] MathWorks, 2012, “Filtering and Smoothing Data”, MathWorks, United States, Massachusetts, Viewed 24 April 2012, http://www.mathworks.com/help/toolbox/curvefit/bsz6ber-1.html