

Correlated Color Temperature and Total Luminous Flux Influenced by Electrical Current Variation of Incandescent Lamps.

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Abstract

In the present research, both of correlated color temperature and total luminous flux are determined for eight incandescent lamps at different electrical current values. A set up based on NIS Spectroradiometer Ocean optics HR 2000 with uncertainty 4.7% and photometric bench have been used to measure the correlated color temperature for the lamps. Another set up based on 2.5 meter NIS integrating sphere and NIS photometer LMT U 1000 with uncertainty 4% and group of NIS total luminous flux standard lamps are calibrated at National Physical Laboratory (NPL) in England with uncertainty 0.8% are used to measure the total luminous flux for the incandescent lamps. The sphere photometer calibration factor (SCPF) is 0.15% with photometer quality factor f_1' is 6.25%. The correlated color temperature and total luminous flux curves and equations are very useful to determine the uncertainty due to changing in electrical operating current for each lamp.

Keywords: Correlated color temperatures, Total luminous Flux, Incandescent Lamps, Electrical Current, Uncertainty.

I. Introduction

Before the widespread use of fluorescent and other discharge lamps, most light sources were incandescent and therefore had a color similar to a blackbody radiator. Because of this, it became common to describe the color of a light source by its "correlated color temperature" [1]. This is the temperature of the blackbody radiator whose color is closest to that of the light considered.

As the temperature of a blackbody radiator is increased, its chromaticity co-ordinates move along a curved line in the chromaticity diagram as shown in Figure 1. This line is known as the blackbody locus or Planckian locus. Obviously, if the color of a light source is very far from this line, correlated color temperature is not a very good description of its color, as it describes only the yellow-blue variation of blackbody radiation and does not describe variation in other directions such as green-purple. The recommended method of calculating the correlated color temperature of a stimulus is to determine, on a chromaticity diagram, the temperature corresponding to the point on the blackbody locus that is intersected by an iso-temperature line which contains the point representing the stimulus. The iso-temperature lines currently recommended by the CIE [2] are those normal to the blackbody locus in a chromaticity diagram.

The correlated color temperature and distribution temperature of a source are normally determined either by a direct experimental method, such as red/blue ratio method, or graphically from the chromaticity coordinates. With the ever-increasing use of digital computers, methods for evaluation of these temperatures from the spectral power distribution are very useful [1].

The integrating sphere as shown in Figure 2 is a device for measuring total luminous flux for any light source and its function is to spatially integrate radiant flux. Light incident on a diffuse surface creates a virtual light source by reflection [3]. Items located inside the sphere, including baffles, lamps, and lamp sockets as shown in Figure 3 absorb some of the energy of the radiant source and decrease the throughput of the sphere. This decrease in throughput is best avoided by coating all possible surfaces with a highly reflective.

As any part of the sphere surface sees all other parts of the sphere surface equally; the detector at any point on the surface can measure the total power in the entire sphere [4]. In addition, the reflections from the coating added to the power of the lamp, lead to the fact that there is always more power inside a sphere than the lamp generates [5].

Since irradiance is the amount of light falling on a surface [6], we need to set up the diffusing surface at the point at which we wish to know the irradiance, and

measure the light reflected off the diffuser as shown in Figure 4. The more Lambertian the diffuser, the better the light reflected off the diffuser. A sample of the light from the diffuser is focused by the lens onto the input slit of the monochromator. Since the radiance of the diffuser is uniform, any slight motion of the lenses or the monochromator is not serious. Also, the radiance at any one point is due to incident light from all parts of the source. The flat diffuser, like the integrating sphere, is very sensitive to stray light since any light incident upon it will be reflected (diffused) into all directions, some of which are into the input to the monochromator.

II. Methods

2.1 Measurements Set-up of Correlated Color Temperature (CCT)

A set of eight incandescent lamps were aged for 60 hours [7]. Table (1) is representing the electrical control results of NIS total luminous flux standard lamps calibrated at NPL in England with uncertainty 0.8%. Table (2) is representing the electrical control results of eight incandescent lamps.

All the total luminous flux lamps are clear round bulb. The lamps were aged for 60 hours at correlated color temperature (CCT) as show in table (2). Spectroradiometer was used to measure the relative spectral output of the lamps, from which the CCT was determined. The Set up of measuring the spectral power distribution lamps [7] is in Figure. 5. It measured directly using the photometric bench and the Spectroradiometer ocean optics HR 2000 at NIS with uncertainty 4.7% [8-10].

2.2 Measurement Set-up of Total luminous flux of the lamps

The photometer used is LMT U1000 with 4% as shown in Figure 6 and the integrating sphere [7] used has a diameter of 2.5 meter and is coated internally with a uniform layer of barium sulfate ($BaSO_4$). The flux lamps are mounted in a base-up configuration at the center of this sphere into a lamp socket supported from the top of the sphere. Figure 7 shows the 2.5 meter integrating sphere photometer at NIS, Egypt.

The lamps are operated base-up, with the center terminal at positive potential. The electrical parameter used for setting the operating condition of the lamps is the lamp current. The lamps were allowed to stabilize at operating current for approximately 15 minutes with the sphere door partly open. The sphere door was then closed for approximately 1 minute before the photometer readings were taken.

III. Results and Analysis

3.1 Results of the Correlated Color Temperature (CCT)

It has been measured the correlated color temperatures (CCT) at several electrical operating conditions for each lamp to enable us to operate the lamps at the required CCT and to determine the behavior of the lamps at different operating conditions. The results of these measurements are presented in Figures 8 to 15. These Figures present the correlated color temperature at different current values. The equations of the fitted lines can help us to determine the correlated color temperature (CCT) for each lamp at different current.

3.2 Results of the total luminous flux

It has been measured the total luminous flux at several electrical operating conditions for each lamp to enable us to operate the lamps at the required CCT and to determine the behavior of the lamps at different operating conditions. The results of these measurements are presented in Figures 16 to 23. These Figures present the total luminous flux at different current values. The equations of the fitted lines can help us to determine the total luminous flux for each lamp at different current.

IV. Conclusions

This research demonstrates the correlated color temperature (CCT) as a function of the electrical current applied to the lamp. This enables to determine the uncertainty in the correlated color temperature of each lamp due to the changing in the electrical operating current of the lamp by using the curves and equations presented in Figures 8 to 15.

Also, the research demonstrates the total luminous flux as a function of the electrical current applied to the lamp. This enables to determine the uncertainty in the total luminous flux of each lamp due to the changing in the electrical operating current of the lamp by using the curves and equations presented in Figures 16 to 23.

The equations of the fitted lines can help us to determine the correlated color temperature (CCT) and total luminous flux for each lamp at different current.

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Table 1. The Electrical Control Results of NIS standard Lamps

<i>NIS Standard Lamps</i>	<i>SET Current</i>	<i>Voltage</i>	<i>Colour temperature</i>	<i>Total luminous flux</i>
	<i>(amperes)</i>	<i>(Volts)</i>	<i>(Kelvin)</i>	<i>(lumen)</i>
<i>NIS-E21</i>	1.7869	102.1	2750	2587
<i>NIS-E22</i>	1.7991	101.6	2750	2597
<i>NIS-E31</i>	0.20482	91.9	2400	131.5
<i>NIS-E32</i>	0.20315	92.0	2400	130.8
<i>NIS-E33</i>	0.20382	92.4	2400	132.4

Table 2. The Electrical Control Results of incandescent lamps.

<i>NIS Standard Lamps</i>	<i>SET Current</i>	<i>Voltage</i>	<i>Colour temperature</i>	<i>Total luminous flux</i>
	<i>(amperes)</i>	<i>(Volts)</i>	<i>(Kelvin)</i>	<i>(lumen)</i>
<i>NIS-M1-200</i>	0.6050	116.7	2095	232
<i>NIS-M2-200</i>	0.6052	113.7	2070	225
<i>NIS-M3-200</i>	0.6051	117.0	2073	244
<i>NIS-M1-150</i>	0.4551	114.9	2074	150
<i>NIS-M2-150</i>	0.4551	116.7	2054	164
<i>NIS-M3-150</i>	0.4551	114.5	2084	152
<i>NIS-M1-100</i>	0.3050	116.9	2049	89
<i>NIS-M2-100</i>	0.3050	116.8	2043	89

Figure 1. CIE 1931 Chromaticity Diagram Showing the Spectrum Locus, the Purple Boundary, the Locus of Blackbody Radiators, and Standard Illuminants A, B, C and D65 [1]

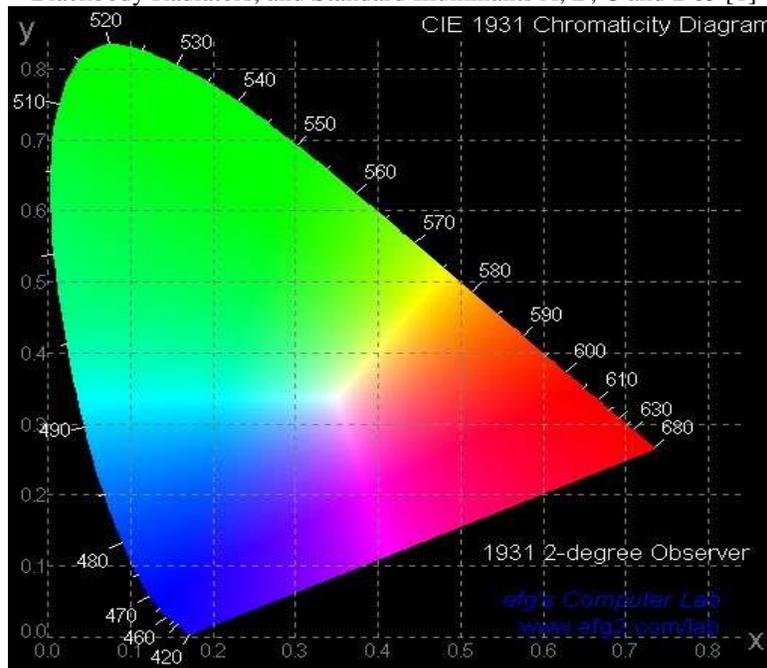


Figure 2. The NIS Integrating Sphere Photometer system (2.5meter diameter).



Figure 3. The Lamp baffle, the photometer port, and the lamp holder of the 2.5 integrating sphere system.

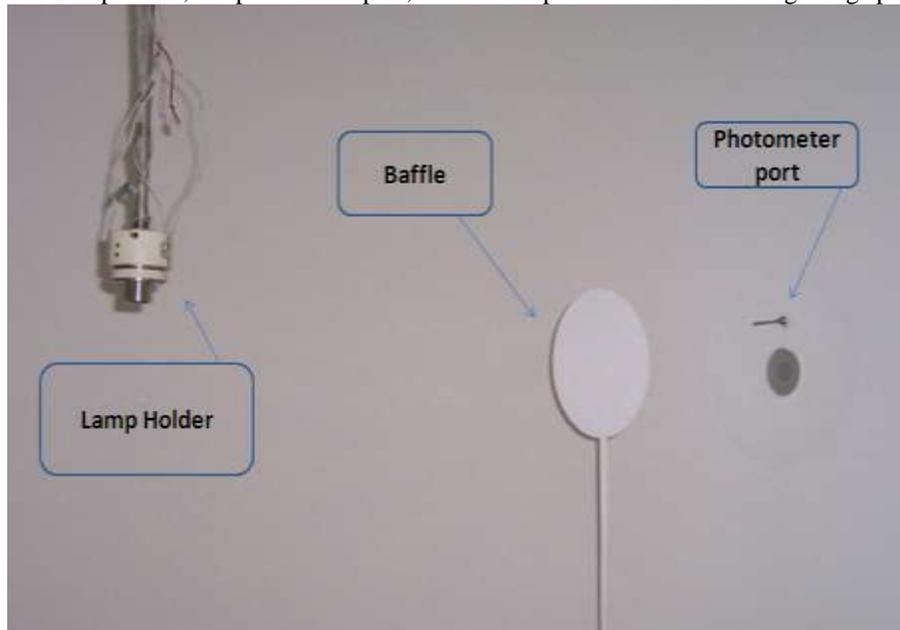


Figure 4. Set up for measuring correlated color temperature of lamps [6].

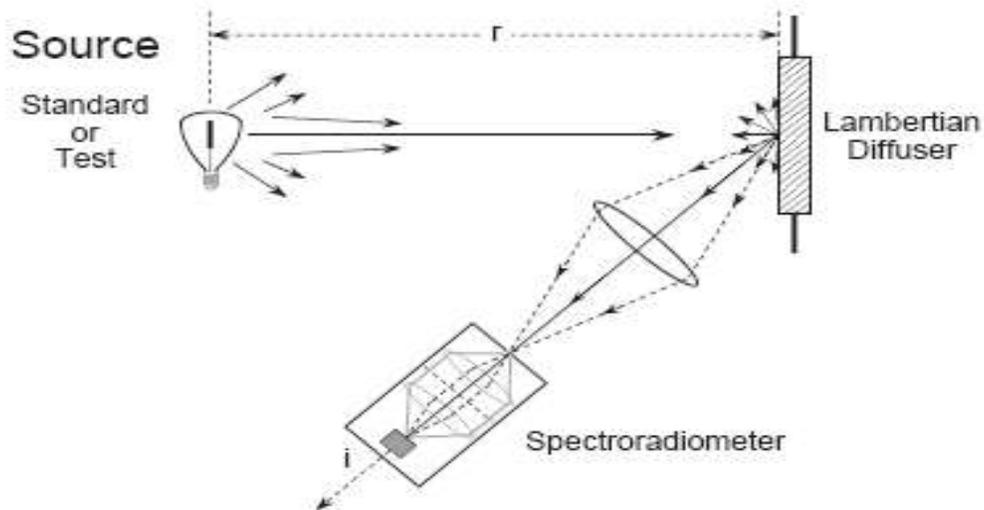


Figure 5. Set up of measuring the spectral power distribution of NIS total luminous flux lamps.

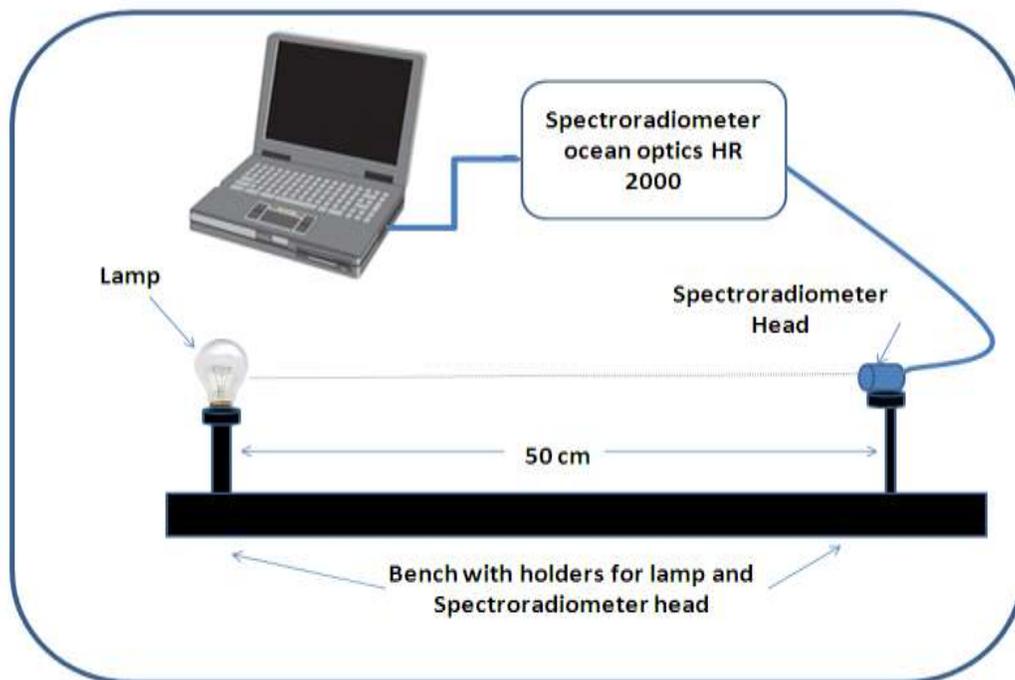


Figure 6. The LMT U1000 NIS photometer.



Figure 7. The 2.5 m NIS integrating sphere photometer system set up for the luminous flux measurement.

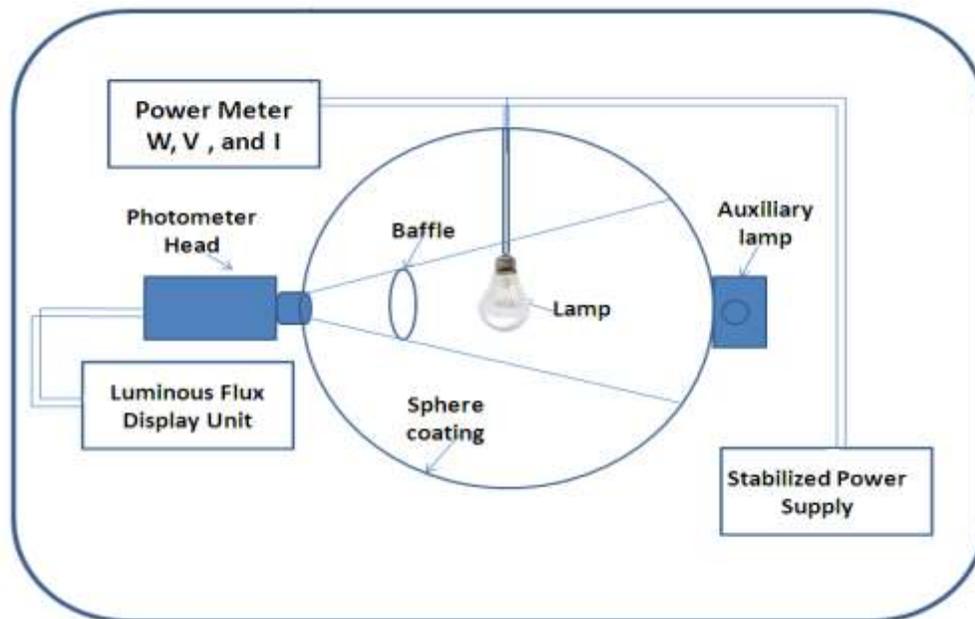


Figure 8. Correlated Color Temperature (CCT) (Kelvin) of NIS-M1-200 at different electrical current.

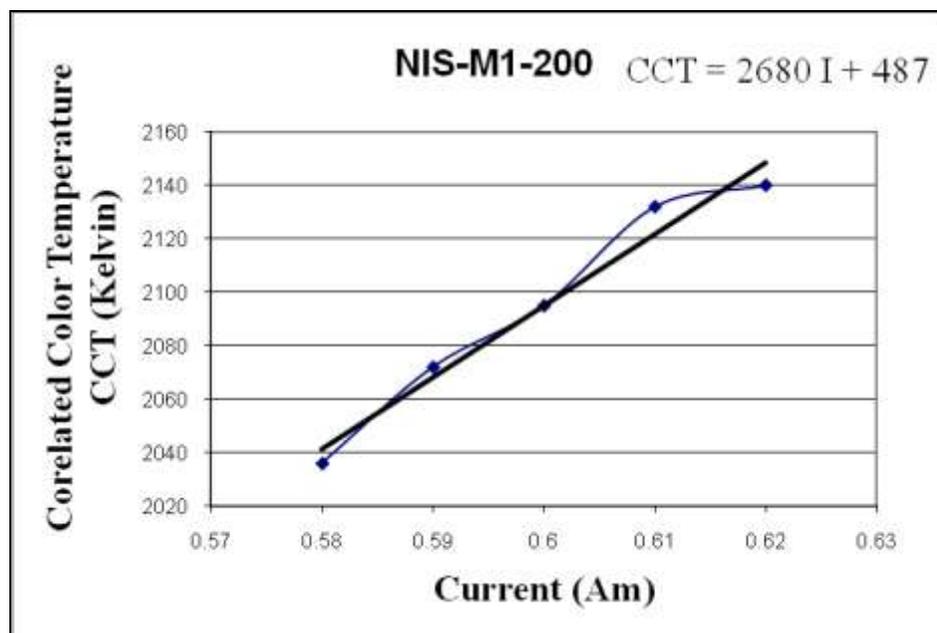


Figure 9. Correlated Color Temperature (CCT) (Kelvin) of NIS-M2-200 at different electrical current.

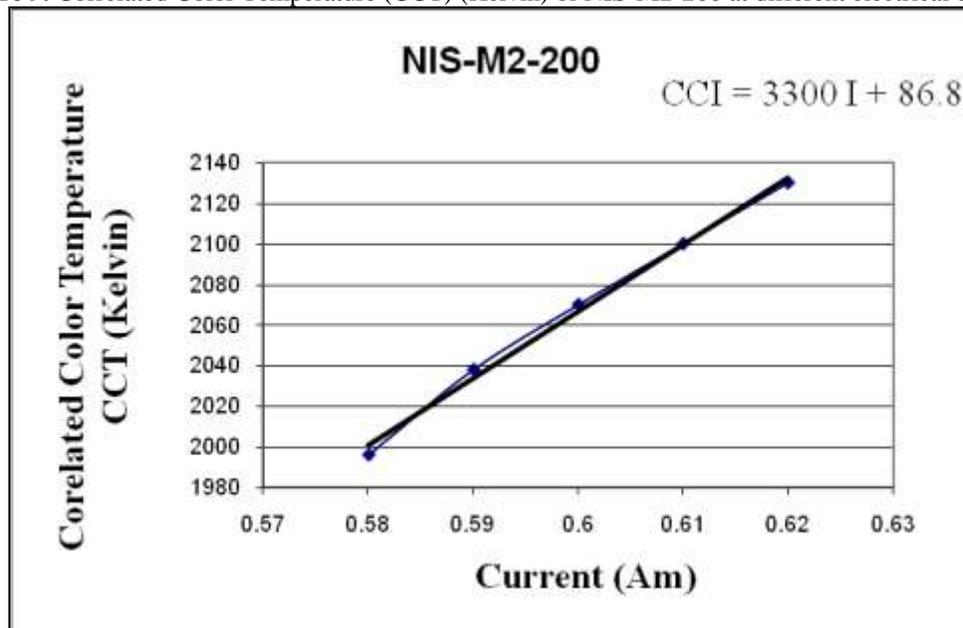


Figure 10. Correlated Color Temperature (CCT) (Kelvin) of NIS-M3-200 at different electrical current.

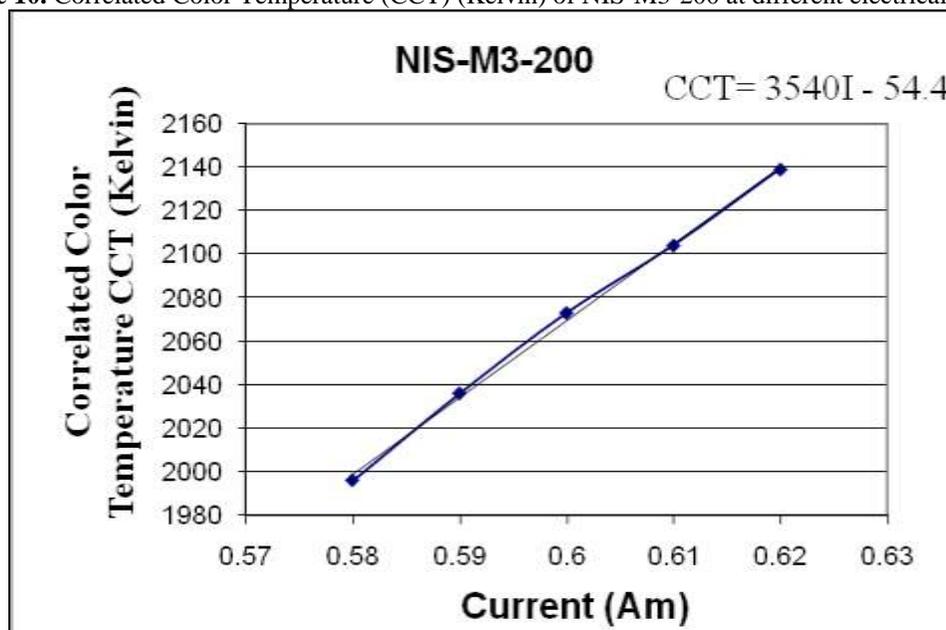


Figure 11. Correlated Color Temperature (CCT) (Kelvin) of NIS-M1-150 at different electrical current.

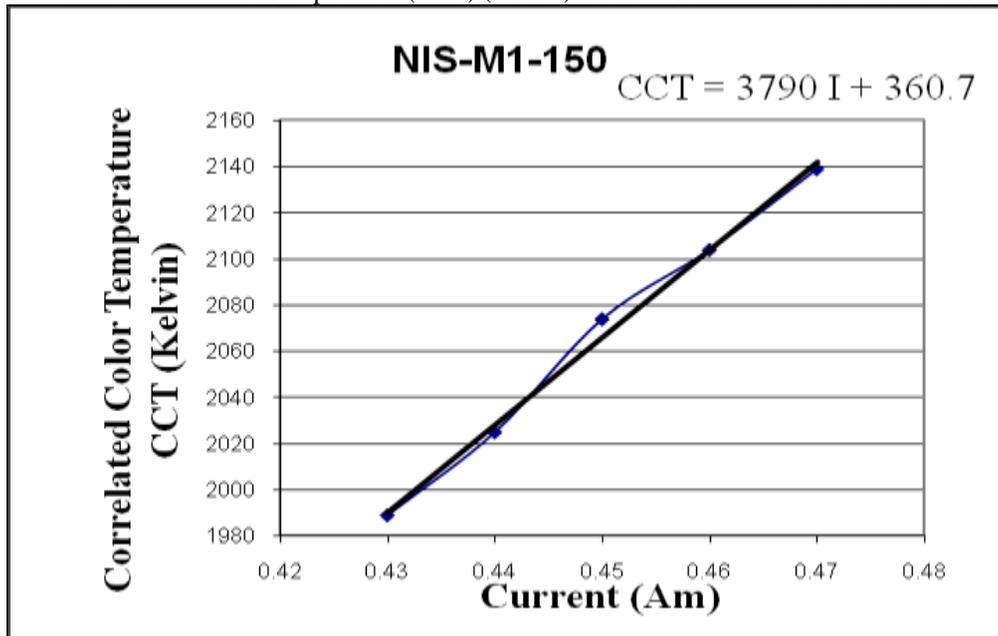


Figure 12. Correlated Color Temperature (CCT) (Kelvin) of NIS-M2-150 at different electrical current.

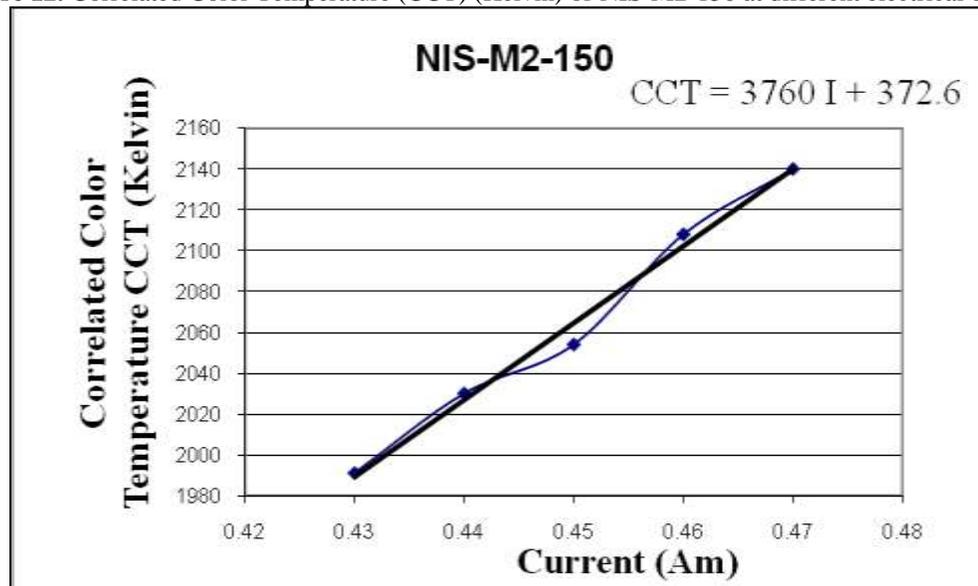


Figure 13. Correlated Color Temperature (CCT) (Kelvin) of NIS-M3-150 at different electrical current.

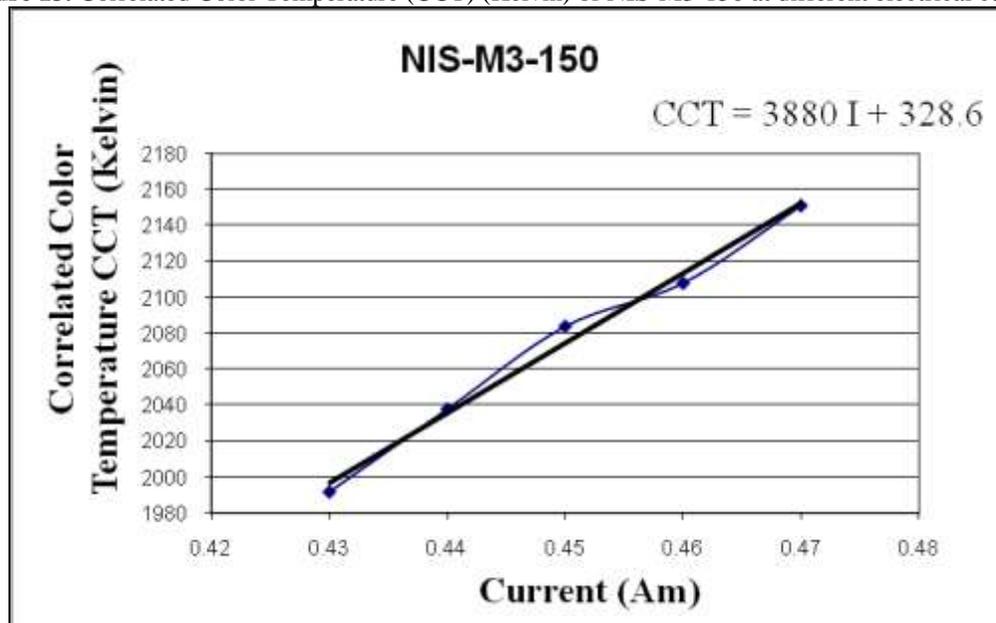


Figure 14. Correlated Color Temperature (CCT) (Kelvin) of NIS-M1-100 at different electrical current.

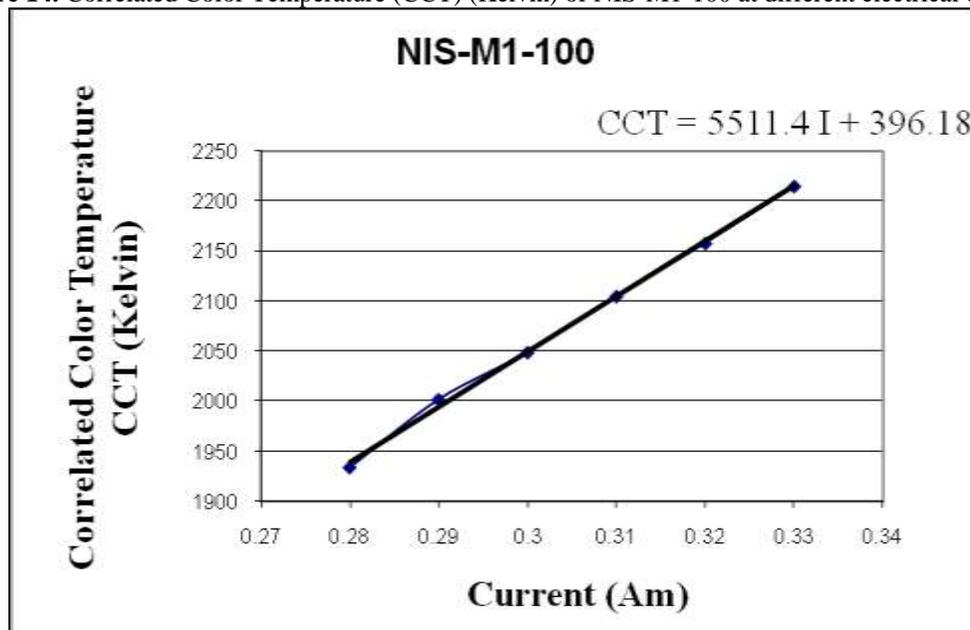


Figure 15. Correlated Color Temperature (CCT) (Kelvin) of NIS-M2-100 at different electrical current.

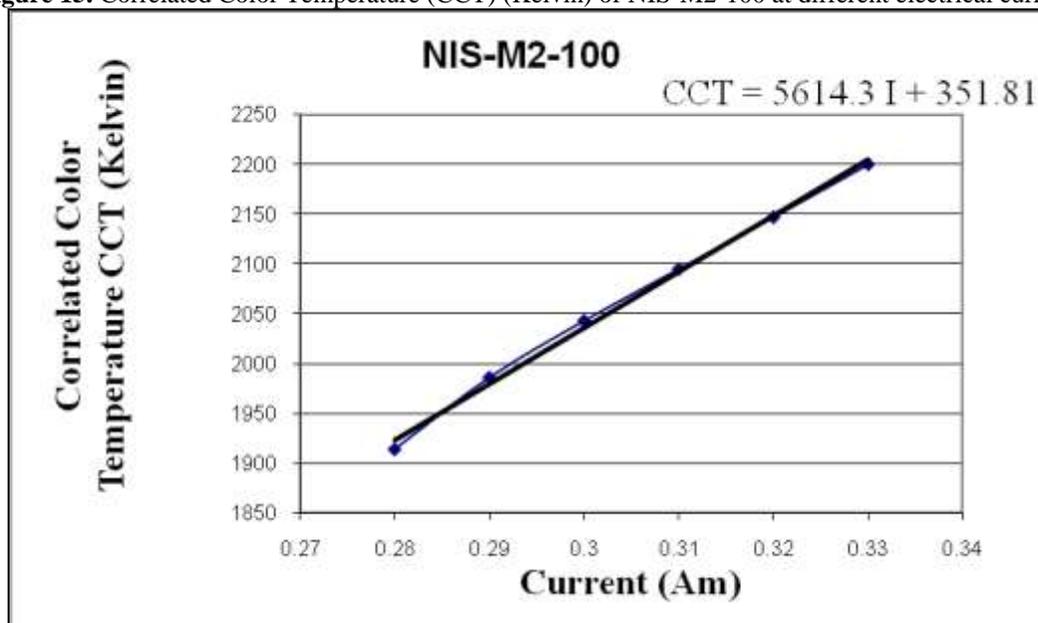


Figure 16. Total luminous flux (lumen) of NIS-M1-200 at different electrical current.

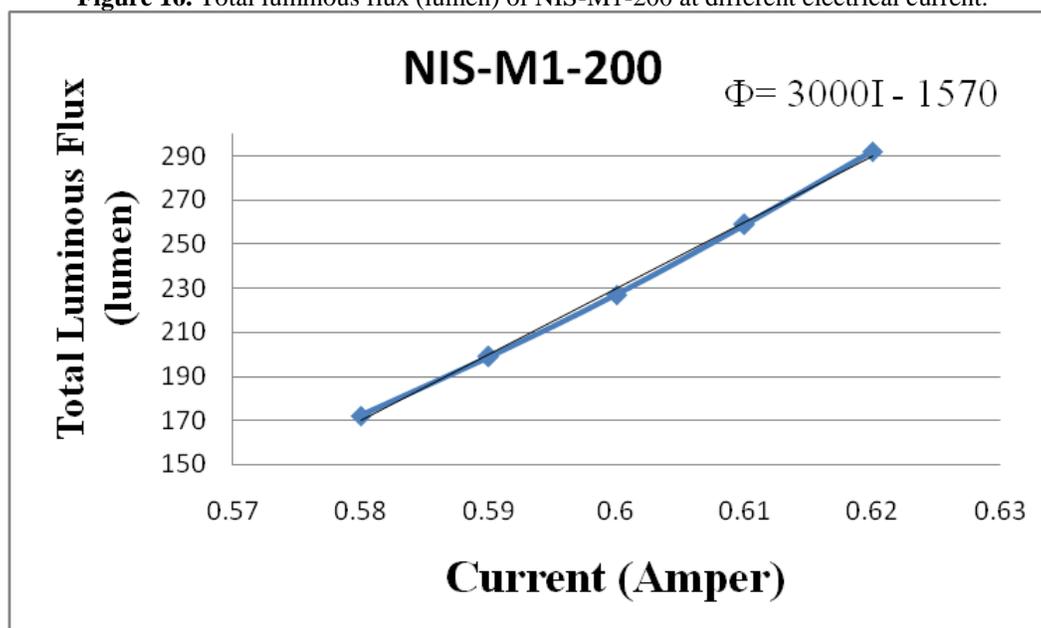


Figure 17. Total luminous flux (lumen) of NIS-M2-200 at different electrical current.

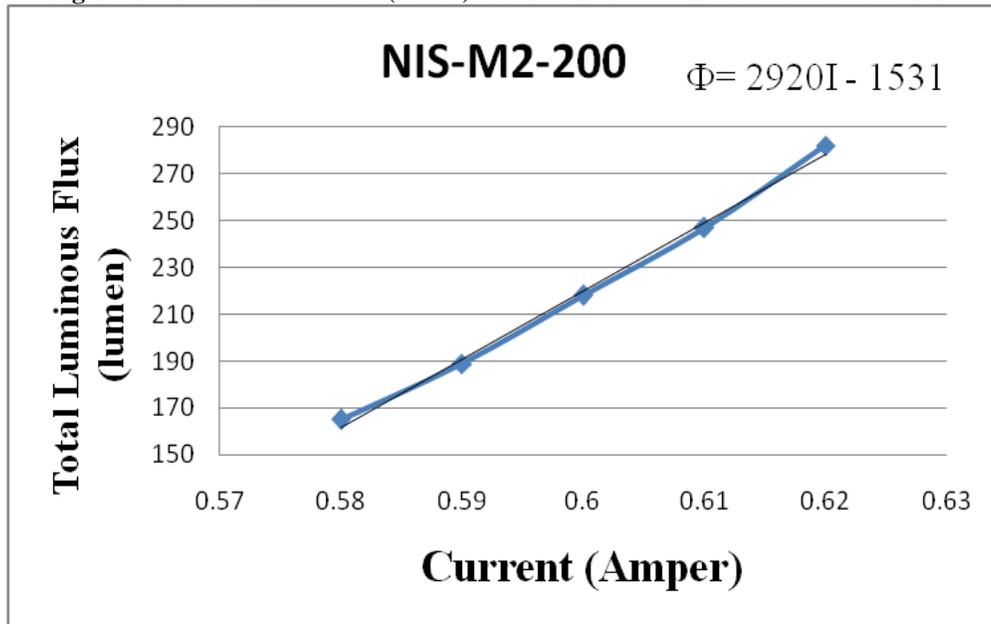


Figure 18. Total luminous flux (lumen) of NIS-M3-200 at different electrical current.

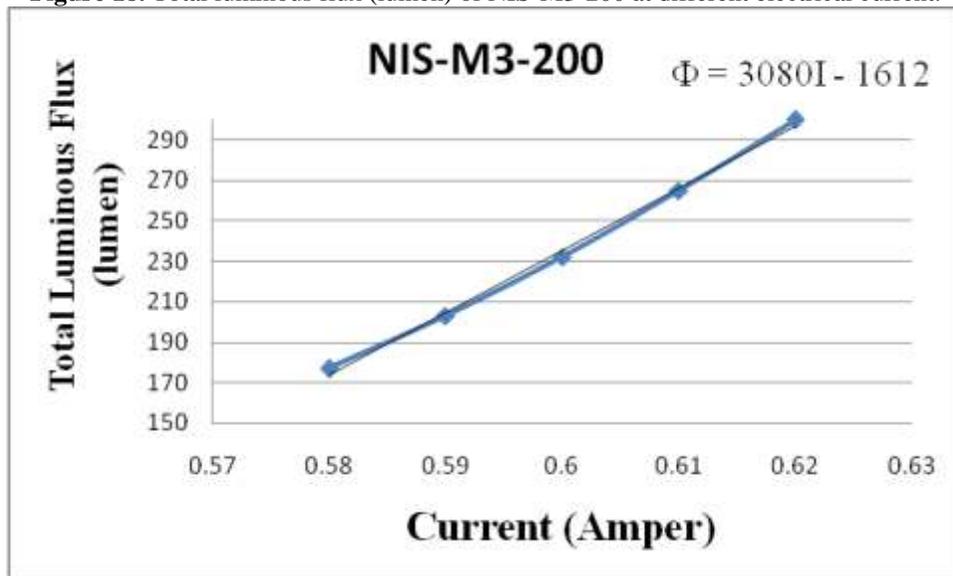


Figure 19. Total luminous flux (lumen) of NIS-M1-150 at different electrical current.

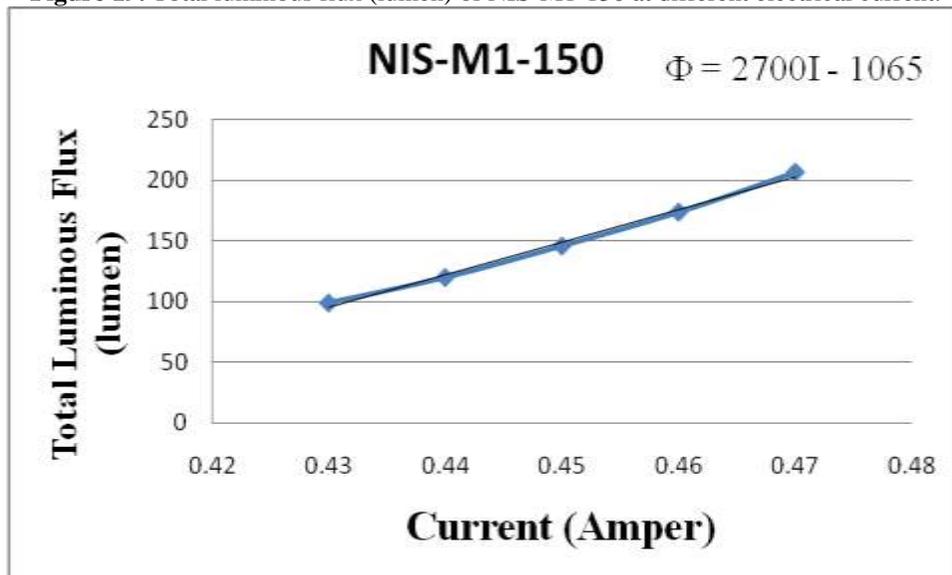


Figure 20. Total luminous flux (lumen) of NIS-M2-150 at different electrical current.

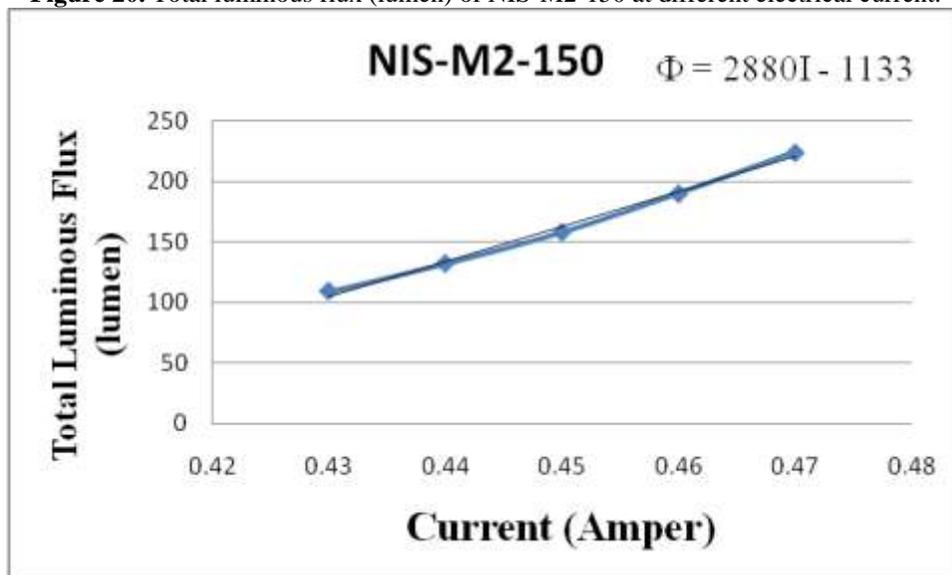


Figure 21. Total luminous flux (lumen) of NIS-M3-150 at different electrical current.

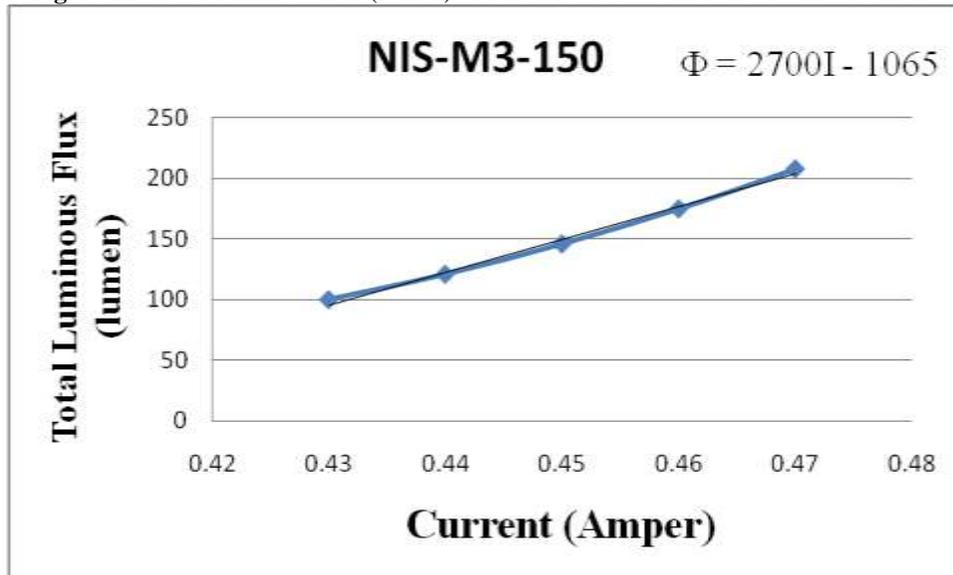


Figure 22. Total luminous flux (lumen) of NIS-M1-100 at different electrical current.

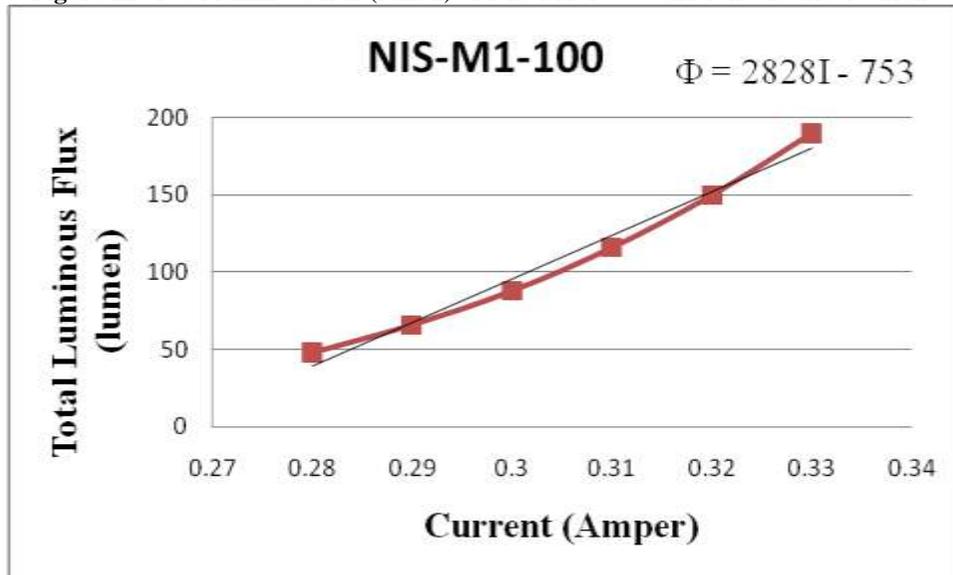


Figure 23. Total luminous flux (lumen) of NIS-M2-100 at different electrical current.

