Report on Efficacy Dependence on Environmental Changes of SSL Products in Outdoor, In-house and Street Lighting Applications

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Abstract : Efficacy of SSL products can change depending on environmental conditions of application. Large discrepancies can be noticed between the efficacy specifications from manufacturers and determined efficacy due luminous flux dependency on the environment.

This report presents measurement results on the change of efficacy of a SSL product in outdoor, indoor and street lighting applications at various induced temperatures. Different types of commercially available indoor and street lamps are used in the experiment. The changes of the of the devices efficacy under test as function of the induced temperature is found and reported.

Contact : http://www.m4ssl.npl.co.uk/contact

About the EMRP
The European Metrology Research Programme (EMRP) is a metrology-focused European programme of coordinated R&D that facilitates closer integration of national research programmes. The EMRP is jointly supported by the European Commission and the participating countries within the European Association of National Metrology Institutes (EURAMET e.V.). The EMRP will ensure collaboration between National Measurement Institutes, reducing duplication and increasing impact. The overall goal of the EMRP is to accelerate innovation and competitiveness in Europe whilst continuing to provide essential support to underpin the quality of our lives. See http://www.emrponline.eu for more information.

About the EMRP JRP "Metrology for Solid State Lighting"
In the EMRP Joint Research Project (JRP) "Metrology for Solid State Lighting", the following partners cooperate to create a European infrastructure for the traceable measurement of solid state lighting: VSL (Coordinator), Aalto, CMI, CSIC, EJPD, INRIM, IPQ, LNE, MKEH, NPL, PTB, SMU, SP, Trescal, CCR, TU Ilmenau and Université Paul Sabatier. See http://www.m4ssl.npl.co.uk/ for more information.

The research leading to these results has received funding from the European Union on the basis of Decision No 912/2009/EC.

SUMMARY

Efficacy of SSL products can change depending on environmental conditions of application. Large discrepancies can be seeing between the efficacy specifications from manufacturers and determined efficacy due luminous flux dependency on the environment.

In in-house applications,for example, the temperature can vary between the nominal temperature (for SSL measurements temperature is stabilized at 25°C) and 45°C. For outdoor and streetlight SSL, the time required to reach an environmental thermal equilibrium could be very long especially because the temperature that influence the light output is the LED junction temperature and not the temperature of the luminaire case. The influence of the internal power supply characteristics in stabilizing the LED current with the temperature could influence the behaviour of the tested luminaires but this aspect need more investigations

In this study the temperature dependence of the efficacy of two chosen SSL products has been identified and a hysteresis model has been fit. The main conclusion is made that the efficacy of SSL drops with the temperature on around 0.08-0.09% per degree Celsius with increase of temperature and rises on around 0.12-0.15% when temperature is decreased.

Hysteresis behavior is clearly pronounceable for both lamps. The difference between two runs though is quite large and within 0.09% for the lamp of type MB while only about 0.01 % for the lamp of type SB. The shape of hysteresis at the same time is very clearly seen.

This can be either related to the particular change in the properties of the MB type lamp or an error in the estimation of the mean temperature due to inhomogeneity of the warming process by flow.

Extra measurements after some time period would be recommended to see whether this effect will be seen again.

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LIST OF ABBREVIATIONS

EMRP	European Metrology Research Programme
NMI	National Measurement Institute
JRP	Joint Research Project
SSL	Solid State Lighting

1. Introduction

In practical applications the ambient temperature can vary from below freezing point to more than 30°C and hence the characteristics of the SSL lamp can change significantly. In in-house applications the temperature can vary between the nominal temperature (for SSL measurements temperature is stabilized at 25°C) and 45°C.

The aim of this research is to study the influence of temperature on efficacy of in-house SSL products based by externally warming SSL lamps and measuring their efficacy.

A standard measurement method developed by International Energy Agency (IEA, [1]) has been used for both photometrical and electrical measurements and is described in the text. A model is fit to the found dependency and some conclusions are made.

2. Standard measurement methods

The luminous efficacy η_v (lm/W) of the product under test can be determined by

$$— \qquad (1)$$

Where Φ_v is the luminous flux [lm] to be measured according to section 2.1. and $\boldsymbol{P}$ is the electrical input power [W] of the SSL product under test to be measured according to section 2.2.

For photometrical and electrical measurements of SSL products a method developed by IEA 4ESSL Annex and recommended to be adopted by CIE has been used in this study [1].

2.1 Luminous flux

Total luminous flux of an SSL product can be measured using an integrating sphere system (a sphere-spectroradiometer and/or a sphere-photometer) or a goniophotometer (configured for absolute photometry). Below the recommended test method conditions are given according to [1] for integrating sphere facility.

Integrating sphere facility

A sphere-spectroradiometer shall be calibrated with a total spectral radiant flux standard traceable to an NMI. It should be noted that the integrating sphere and the spectroradiometer together shall be calibrated as one system for total spectral radiant flux to take into account the relative spectral throughput of the integrating sphere.

The spectroradiometer used for the sphere-spectroradiometer system shall cover the wavelength range of at least 380 nm to 780 nm, and the bandwidth (full width half maximum) and scanning interval to be no greater than 5 nm. Wavelength scale uncertainty shall be within 0.3 nm.

2.2 Electrical power

AC Voltage and current measurements

According to [1] the voltage is to be measured at the socket (for screw-base or bayonet-base lamps), or at the power input line as close to the product as possible. The measurement position (length from the socket or the power input line) shall be reported. *Note*: This is critical especially for low-voltage lamps. For screw base lamps, 4-pole socket is commercially available, which allows measurement of voltage directly across the cap with no effect of contact resistance. The calibration uncertainties of the instruments for AC voltage and AC current shall be ≤ 0.2 %.

AC power measurements

For AC-input SSL products, an AC power meter shall be connected between the AC power supply and the SSL product under test, and AC power as well as input voltage and current shall be measured.

The AC power meter shall have the capability of measuring power factor. The AC power meter shall have a sampling rate that is capable of resolving the current wave for the SSL product. Many LED drivers based on capacitors and diode bridges have very sharp current waves requiring a high sampling rate. Analogue AC power meters will not measure properly.

Note: IEC 61000-3-2 [2] states that the electrical characteristics of lighting products should be analyzed in a frequency range covering the fundamental (50 Hz or 60 Hz) and up the 40th order (2 kHz or 2.4 kHz).

IEC 61000-4-7 [3] indicates that power measurement equipment should be able to analyze components up to 9 kHz

The calibration uncertainty of the AC power meter shall be ≤ 0.5%.

3. Efficacy of SSL products

3.1. Indoor SSL

For indoor lamps, the room temperature can be much higher than the LED operating temperature. Thus the light output performance of such SSL devices can be significantly affected.

Two types of indoor lamps were used in this investigation: 1) omnidirectional white SSL lamp based on blue LED and phosphor and 2) spot SSL lamp. The specification of SSL lamps under test chosen for this study is given in table 1.

Table 1. Specification of chosen SSL lamps

ID	Lamp Type	Manufacturer	Model	Nominal CCT	Rated Voltage	Rated Power	
MB	MasterLED bulb	Philips	934489 00 E27	2700 K	230 V AC	12 W	

SB	Spot Bulb	OSRAM	PAR16 20 CW	5000 K	230 V AC	5 W	

Facility set-up

A 3 m Integrating Sphere facility (refer to Figure 1.) has been used at VSL for both photometric and spectroradiometric measurements. The 3 m integrating sphere facility is validated and is traceable to 3D goniometer (RAD3D). A schematic of instrumentation of sphere facility is given in figure 2.

Figure 1. 3 m Integrating Sphere facility at VSL

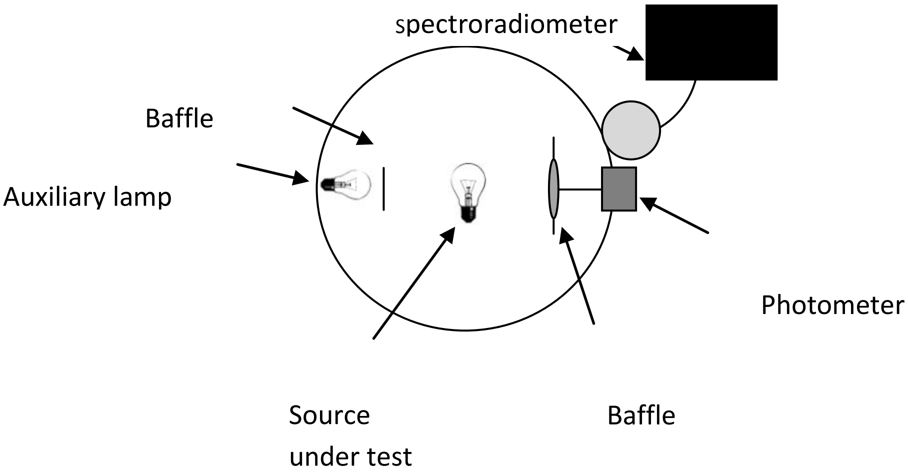

Figure 2. Schematic of instrumentation of sphere facility at VSL

Instrumentation

Photometric measurements

A standard LMT photometer has been used for the measurements of luminous flux at VSL. It is traceable to the primary radiometry standard Absolute Cryogenic Radiometer (ACR) through a transfer reference standard.

Luminous flux is computed as follows:

Where i_{ν}, i_{ref} – is the photometer current reading of SSL lamps and a reference lamp respectively, $I_{aux\ \nu}$ and $i_{aux\ ref}$ – is the photometer current reading of the auxiliary lamp for SSL lamp and reference lamp respectively absorption, Φ_{ref} - is the luminous flux of the standard lamp, F - is spectral correction detector

Electrical measurements

The electrical measurements of the current and voltage at VSL have been done by a Keithley multimeter traceable to VSL Electricity (further EL) reference standards.

The effective power has been measured by means of Yokogawa WT210 power meter (refer to figure 3) also traceable to EL reference standards.

The following settings have been used for Yokogawa digital power meter:
- Voltage range: auto
- Current range: auto
- Sync to: voltage
- Average: 64
- FF: on
- LF: off

Figure 3. Yokogawa power meter traceable to EL reference standards.

Measurements of ambient laboratory and lamp temperature

The ambient temperature during the measurement of the product in the laboratory has been maintained at (25 ± 1) °C by local Climate System at VSL and used as a reference. Further the sphere facility was warmed up with the use of industrial dryer in the range between 25°C and 40°C.

For the measurements of actual temperature inside the integrating sphere facility a set of calibrated temperature sensors has been used. The set consists of 7 sensor numbered as 1,2,3,5,6,8 and 9 was equally distributed in the sphere. Sensor number 9 was placed within vicinity to the SSL lamp.

On the figure 4 a scheme of the temperature sensors is given. The temperature profiles of all the channels have been traced all the measurements time long.

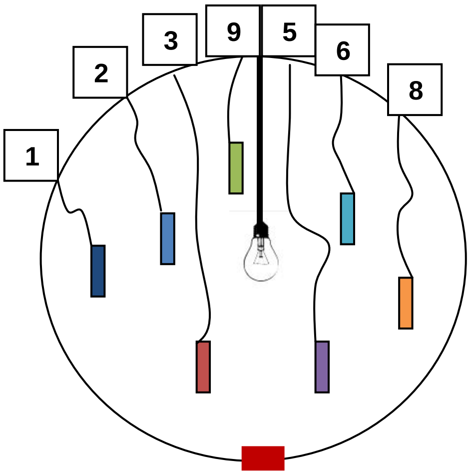

Figure 4. Scheme; Vertical profile: Set of temperature sensors (colorful blocks) used in the study. Channel numbers are given in squares. Red block at the bottom is the place where the heat was brought to warm up the sphere.

Measurements

The measurements of the luminous flux have been done according to the scheme given in table 2.

Table 2. Scheme for the measurements

Lamp	**Temperature**	**Stabilization**
MB	25 degree	LM-79 [5]
MB	25 to 43 degree	At 25 degree
SB	At 25 degree	LM-79 [5]
SB	25 to 43 degree	At 25 degree
Reference lamp	At 25 degree	10 min
Auxiliary Reference	At 25 degree	8 min
Auxiliary SB & MB	At 25 degree	8 min

The measurement results for both lamps for luminous flux, electrical power and temperature are given below.

The measurements with both lamps have been repeated which is shown in terms of two runs: Run 1 and Run2. The temperature was increased from the nominal of around 25°C to around 42-43°C and then decreased back to the nominal. This has been fulfilled two times for each lamp.

The results for the temperature measurements of both lamps are given in absolute values (°C = degree) in figures 5 to 8. An averaging over all the sensors has been determined. The standard deviation among the sensors has been estimated of around 1.5% for MB lamp and 0.9% for the SB lamp.

On the figures 5 and 7 the relative flux (normalized to luminous flux at 25°C) is also shown. Clear temperature dependency can be observed and the pattern is repeated with each run and for both test lamps.

On the figures the part of the measurements where the temperature has been rising is marked with letter "**A**" and has been dropping with letter "**B**".

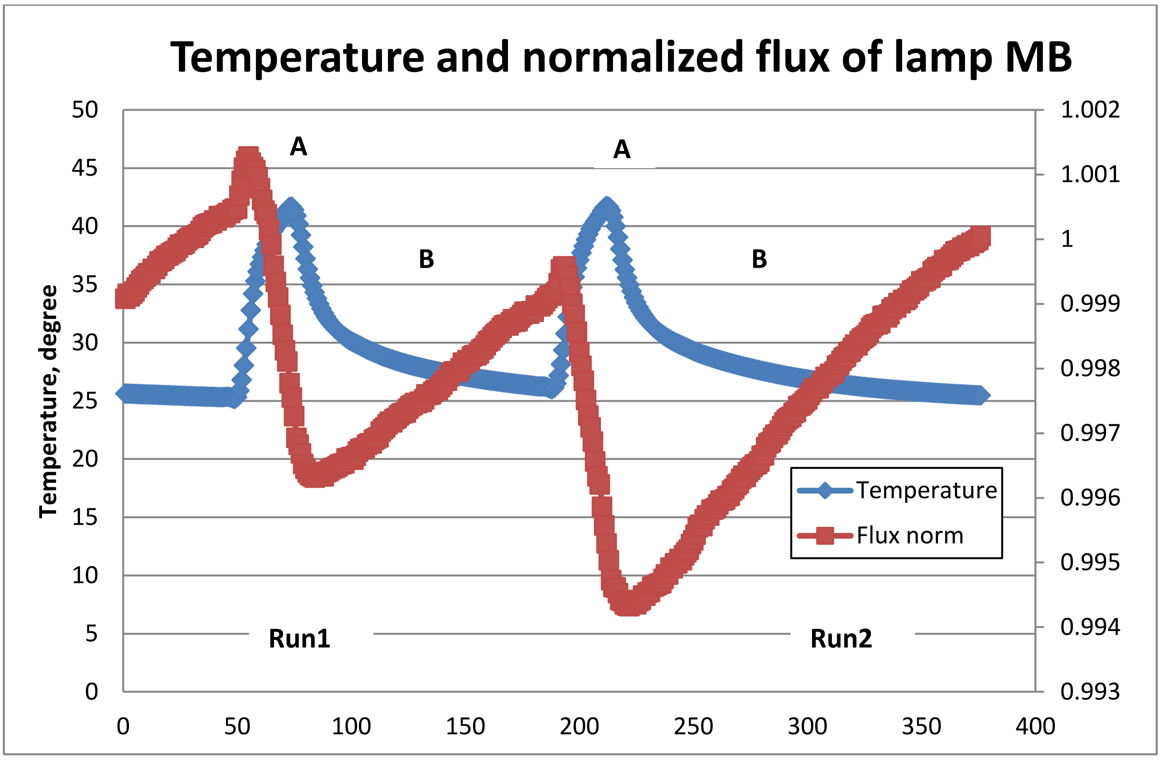

Figure 5. Temperature measurements and the normalized luminous flux of the lamp MB

Additionally true electrical power measurements are shown in figures 6 and 8 with respect to temperature. The noise in the power measurements is estimated to be at the level of **0.05%** for the lamp MB and **0.02%** for the SB lamp.

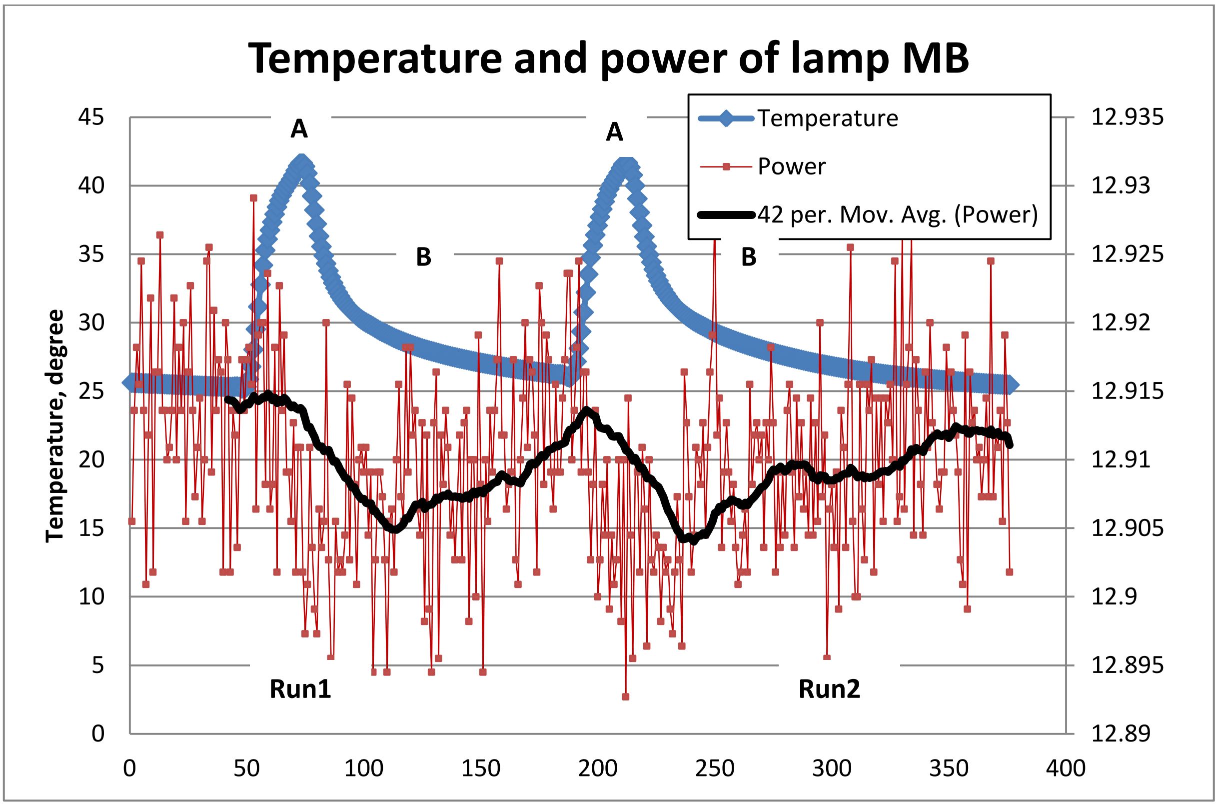

Figure 6. Temperature and true power measurements of the lamp MB

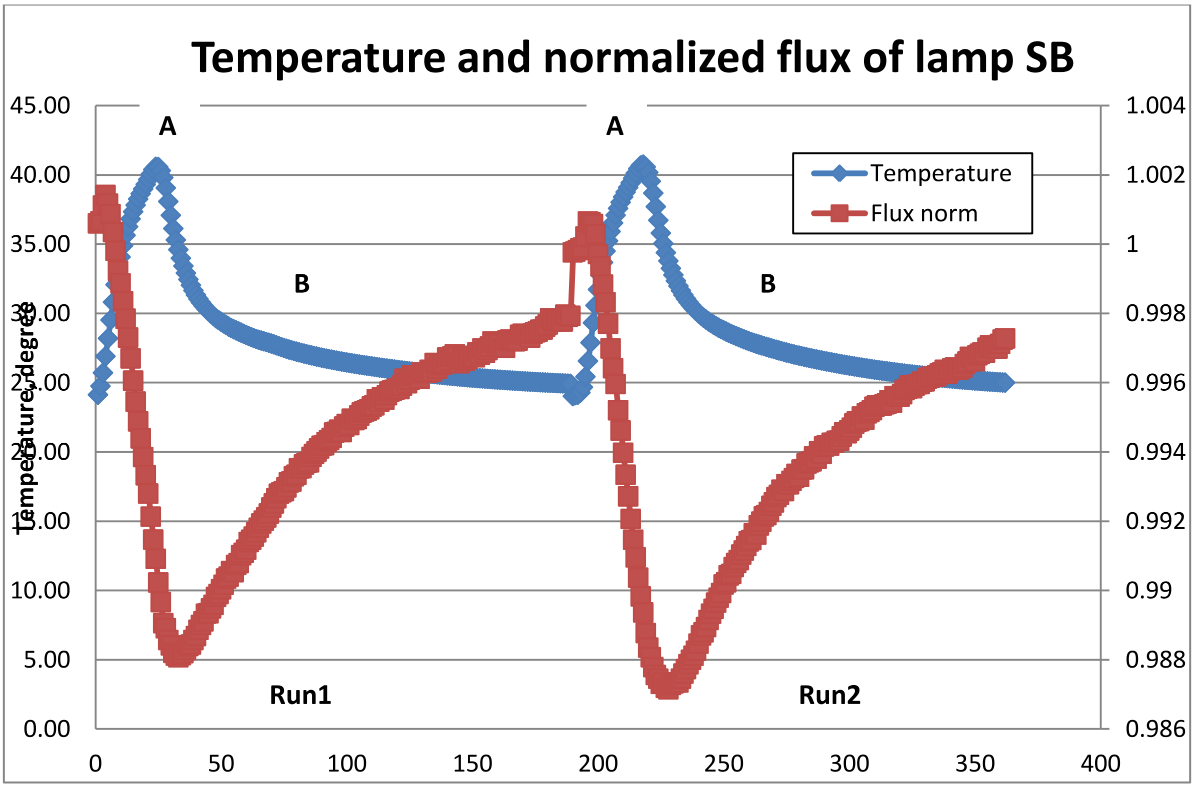

Figure 7. Temperature measurements and relative luminous flux of the lamp SB

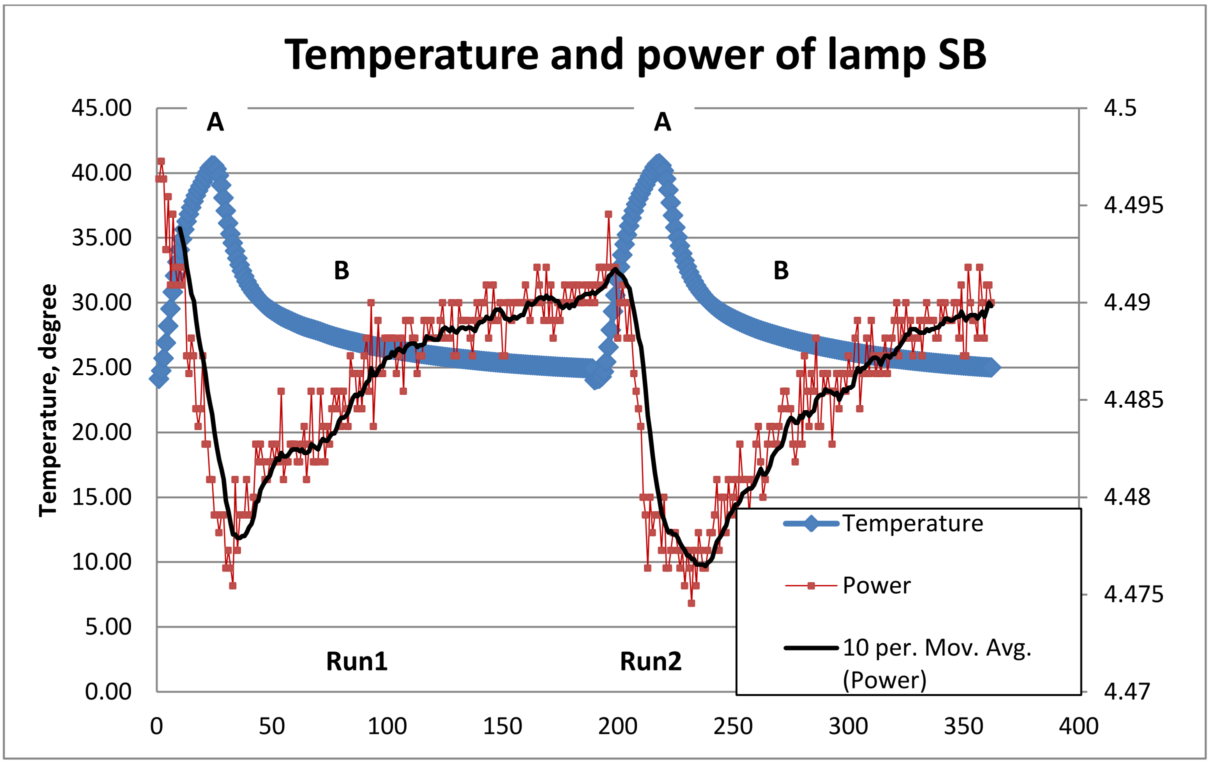

Figure 8. Temperature and the true power measurements of the lamp SB

3.2 Outdoor and Street SSL

Facility set-up

The INRIM goniophotometer is a type 4 instrument [**Error! Reference source not found.**] adopting the C-plane coordinate system. The photometric head is moved on a virtual sphere with a radius of (2 793 ± 0,1) mm. At the centre of the sphere the light source photometric centre can be located with an uncertainty of ± 1 mm using two aligned laser beams. The same beams permit the definition of the second and third axes with an uncertainty of 0,1°. The first axis is defined considering the encoder of the vertical photometric angle at the 0 ° and 90 ° positions. The resolution of this encoder is of 0,01 ° and therefore also the first axis is defined with an uncertainty of 0,1°.

The detector can be moved in spherical zones (parallel to the equator) or in spherical segments (from pole to pole). This is the movement generally adopted for luminaires. For mechanical reasons the maximum vertical photometric angle measurable is 175°. During the measurement the detector moves continuously at different angular speeds. The acquisition of the photocurrent can be done at fixed angles (generally with C planes steps of 5° and vertical photometric angle γ steps of 1°) or at variable angles linked to the maximum speed permitted by the acquisition system of the photocurrent.

The goniophotometer mounts two detectors:

- a silicon cell, thermally stabilized, with a picoammeter, working as an illuminance meter, for the luminous flux measurement and the luminous intensity distribution of luminaires of small dimensions;
- an ILMD for the measurement of luminaires of greater dimensions using the near field techniques.

For luminous flux measurement, the first detector is used.

The laboratory is divided into two rooms: in the first one, high about 7 m, the goniophotometric system is mounted; in the second one all the measurement instruments, the power supplies, the drivers for rotating the gonio frame and the computer to control the measurement and to acquire data are allocated.

The lab is provided with two independent temperature control systems:

- to maintain stable the temperature around the light source at (25 ± 0.1) °C;
- to maintain stable the temperature of the room with instruments at (23 ± 0.3) °C.

Independently from the control system transducers, six detectors are used to monitor continuously the temperature at the following key points:

- the oil bath of the resistors used to measure the power current of the source;
- the ambient temperature near the rack with instruments for reading the power supply conditions of the source;
- the ambient temperature of the first room, at its half height;
- the ambient temperature near the picoammeter, installed on the rotating arm;
- the ambient temperature close to the light source according to European standards [**Error! Reference source not found.**];
- the temperature on a suitable point in the luminaire case.

The range of the ambient temperature control is about ± 10 °C, depending of the outdoor climatic conditions and temperatures.

Instrumentation

During the acquisition, the instrumentations for the measurement of the luminous flux of luminaires is used. The main instruments are:

- **Power supply**: Edgar 230 V 2 KVA AC line conditioner, modified to be controlled by an HP digital to analogue converter.
- **Measurement of luminaire voltage for its stabilization**: HP 3458 A multimeter (100 ms sample rate).
- **Measurement of luminaire voltage**: HP 3458 A multimeter (5 s integration time).
- **Luminaire current**: HP 3458 A multimeter with a Tinsley standard resistor as shunt.
- **Other AC electrical parameters**: Yokogawa WT3000 wattmeter.

The voltage at the luminaire terminals is controlled/stabilized at the given values (230 V) for all the measurement time using an ad hoc algorithm and a feedback circuit realised with the HP multimeter and the HP A/D converter. To increase accuracy the same voltage is also measured with another voltmeter working at a long integration time.

An example of the stabilization conditions obtained during a typical measurement section is show in Figure 1.

According to previous measurements carried out on the same luminaires, this instability in irrelevant to the stability of the luminous flux emitted and the active power adsorbed by the luminaires.

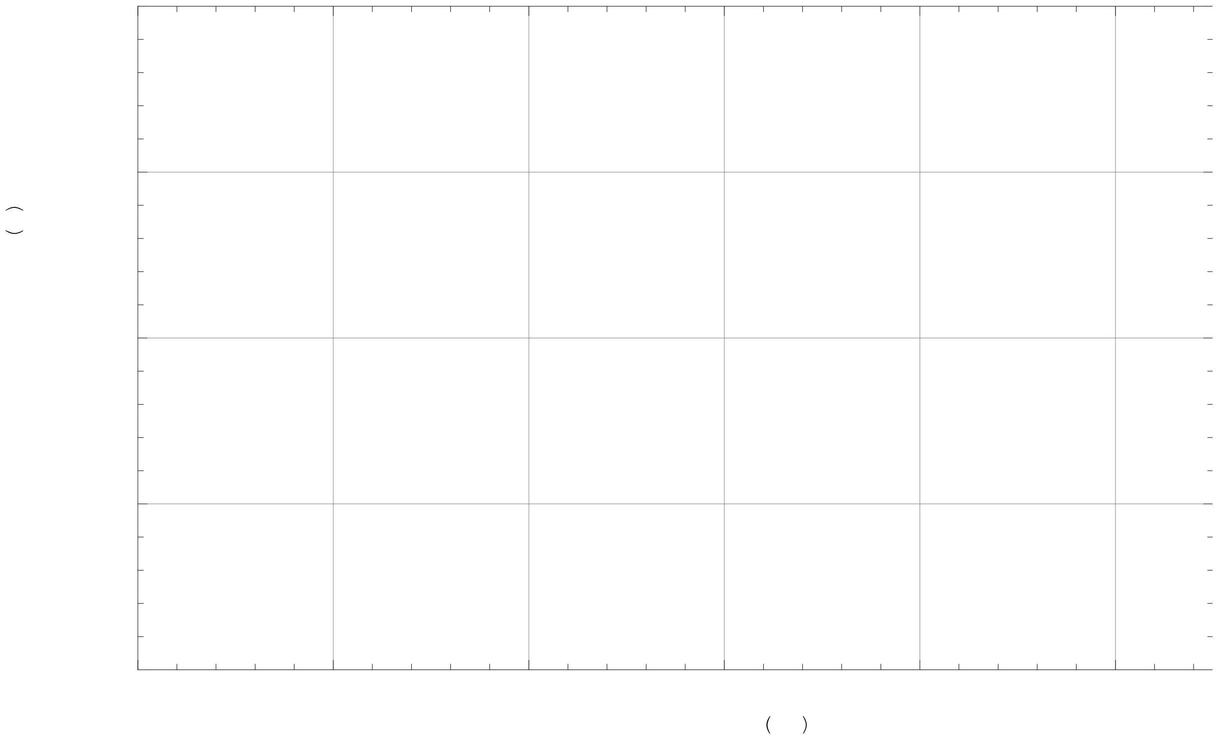

Figure 1 Typical stability of the power supply system during an acquisition periods.

Measurements

The measurement has been carried out following the INRIM procedure for the measurement of the luminous flux of LED luminaires with the following differences:

- The luminaire is stabilized at the ambient temperature of 25 ° for 24 hours.
- The luminaire luminous flux is measured.
- The ambient temperature control system is stopped until the ambient temperature is reduced of 2 °, following the thermal time constant of the lab. During this period the illuminance in the $C0$ $\gamma 0$ direction is measured continuously.
- When the ambient temperature reaches the new value, the temperature control system is reactivated at this new value of temperature and, after 1 hour, a flux measurement is carried out.
- The cycle is repeated until the minimum temperature of test is reached.

The illuminance readings at $C0$ $\gamma 0$ are used an a approximation of the luminous flux values between two consecutive luminous flux measurement.

The decrease of temperature is obtained without using the temperature control system in order to avoid an increasing of air movement near the luminaire during the transition phase. This solution increases the measurement time but guarantees a better thermal equilibrium of the luminaire under test.

The natural decrease of the ambient temperature of the lab is about 1,8°C h^{-1} (see Figure 2).

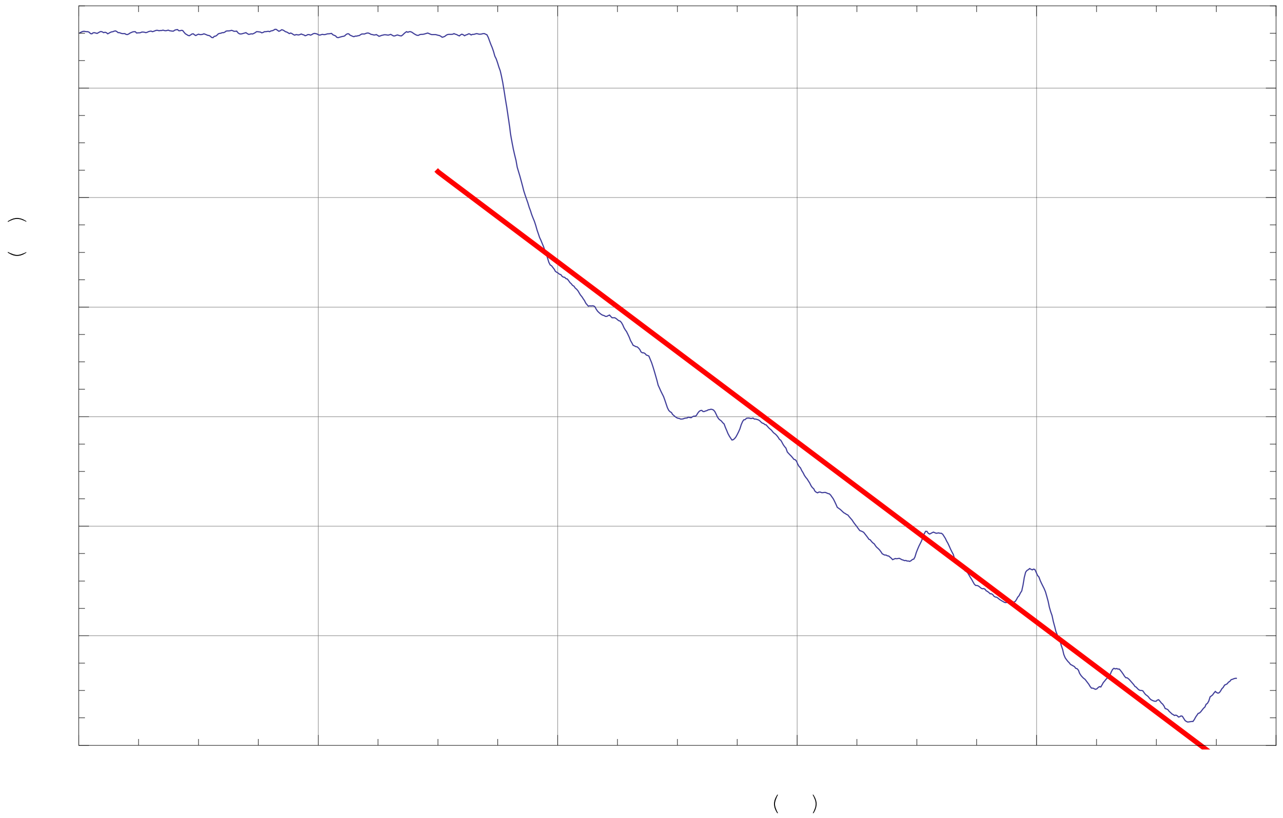

Figure 2 Typical natural decrease of the ambient temperature of the lab, measured.

4. Results and Discussion

4.1 INDOOR SSL

To identify the temperature dependence of the efficacy of two test SSL products described in the section 3.1 the temperature measurements have been interpolated to the time points of the photometrical measurements. A cubic spline interpolation has been used.
Further efficacy has been estimated according to the equation (1) for both lamps per each run out of two.

The results of the analysis are given in the figures 9 and 10 for the lamps MB and SB respectively. Each run is given with its own color (Run1 in blue and Run2 in red). As it can be seen that efficacy has a clear temperature dependency and the full cycle is repeated following a hysteresis model given in table 3 and figure 11.

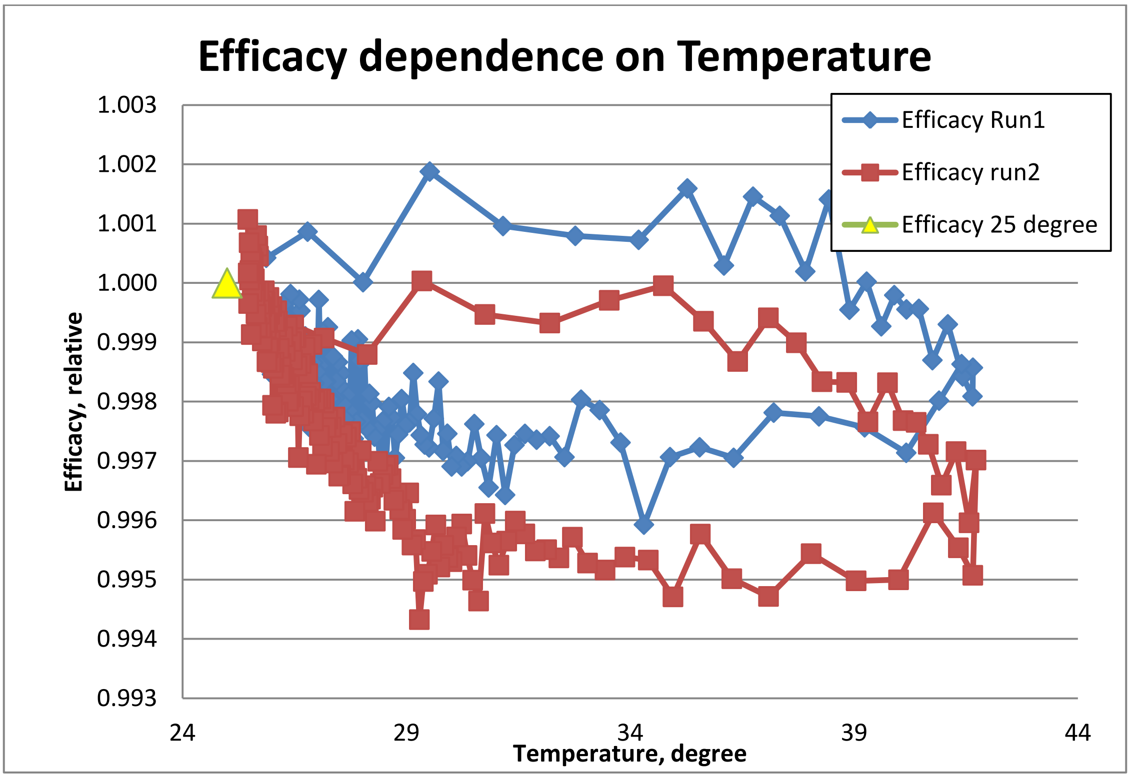

Figure 9. Temperature dependence of efficacy of the MB lamp

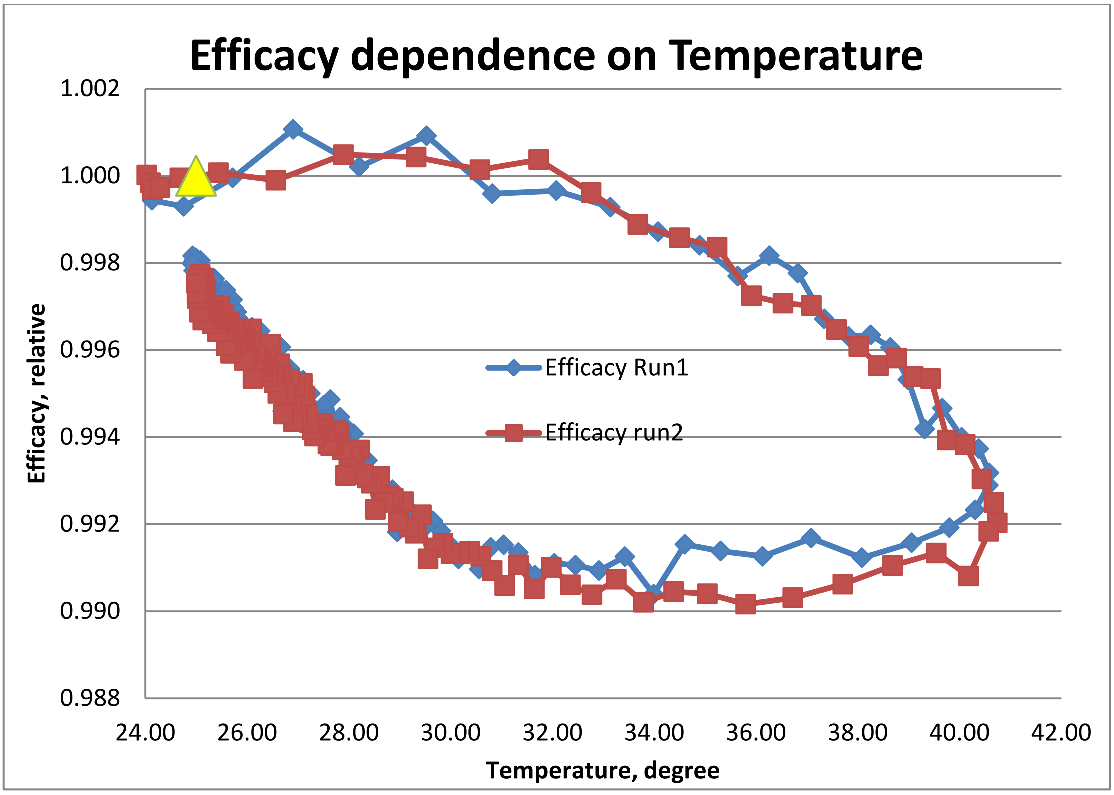

Figure 10. Temperature dependence of efficacy of the SB lamp

Table 3. A hysteresis model of the temperature dependence of the efficacy of SSL lamps

Temperature	**Nominal 25°C**	**Rise 25 -35°C**	**Rise 35 -43°C**	**Drop 43 -32°C**	**Drop 32 -25°C**	**Nominal 25°C**
Lamp of type MB						
Efficacy, rel	**Nominal 1**	**Nominal 1**	**Drop, %/°C**	**Constant 0.996**	**Rise, %/°C**	**Nominal 0.999**
Change %/°C	**0**	**0**	**0.08**	**0**	**0.12**	**0**
Lamp of type SB						
Efficacy, rel	**Nominal 1**	**Nominal 1**	**Drop, %/°C**	**Constant 0.991**	**Rise, %/°C**	**Nominal 0.999**
Change %/°C	**0**	**0**	**0.09**	**0**	**0.15**	**0**

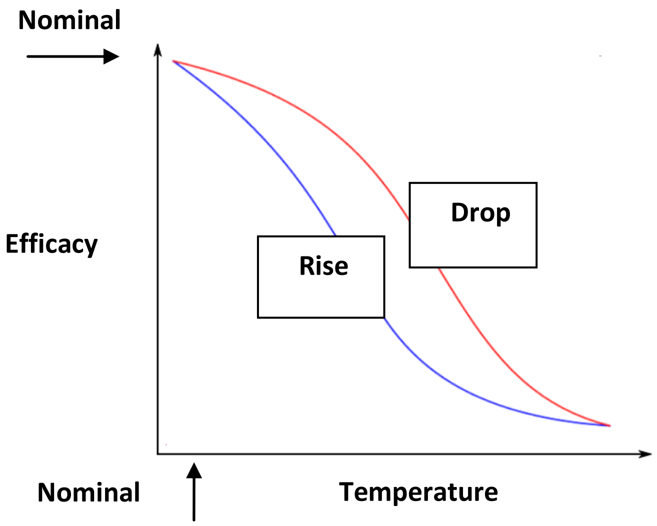

Figure 11. A hysteresis model of the temperature dependence of the efficacy of SSL.

4.2 Outdoor and Street SSL

Three different typologies of luminaires have been tested with the nominal characteristics show in Table 1. The luminaires spread the technological evolution during the three years of the JRP.

Table 1 Type and nominal characteristics of the selected LED luminaires.

Parameter		**Main applications**		
		Road lighting	Tunnel lighting (internal zone)	Tunnel lighting (entrance zone)
Active power	W	70	51	165
Number of LED	-	30	20	72
Luminous flux	lm	3 900	4 100	12 300
Correlated colour temperature T_{cp}	K	6 500	6 000	6 000
General colour rendering index R_a	-	70	70	70
Production year	-	2010	2012	2012

The parameters measured and their expanded (k = 2) measurement uncertainty are summarized in Table 2. The measurement uncertainty of the laboratory temperature is 0,1 °C.

The results of measurement are shown from Figure 3 to Figure 14. The measurement of the luminous flux and the measurement of the illuminance in the $C0$ $\gamma 0$ direction, if adequately scaled, are practically coincident. This mean the illuminance value can be used to characterise the luminous flux variation with the temperature, as show in the mentioned figures. In these figures a quadratic interpolation curve is also show:

$$X = a_{\mathrm{X}} + b_{\mathrm{X}}\,T - c_{\mathrm{X}}\,T^2 \tag{1}$$

where:

X	is one of the measured quantities (Table 2);
a_{X}, b_{X}, c_{X}	are the equation coefficient for the quantity X;
T	is the laboratory temperature in degree celsius.

The values of the coefficients for the considered quantities and luminaires are given in Table 3. The variation of the quantities values with temperature is evident but, with the exception of the active power, this variation remains inside the typical measurement uncertainty declared by industrial laboratories, if the temperature is in the considered range. Usually, in the measurement uncertainty evaluation, the calibration uncertainty of the measure instrument is the main parameter. With this consideration the measured behaviours have a consistency and could be used for the estimations of the influence of laboratory temperature discrepancies from the values required in standards [**Error! Reference source not found.**] [**Error! Reference source not found.**] and in the measurement uncertainty evaluation.

Table 2 Measured parameters and measurement uncertainty (at 25 °C).

Parameter		**Main application of luminaires**		
		Road lighting	Tunnel lighting (internal zone)	Tunnel lighting (entrance zone)
Luminous flux	lm	3 880 ± 40	4 085 ± 50	12 090 ± 150
Active power	W	69,02 ± 0,06	51,13 ± 0,06	160,45 ± 0,09
Power factor	-	0,948 4 ± 0,004	0,894 9 ± 0,004	0,984 6 ± 0,004
Luminous efficacy	lm W^{-1}	56,23 ± 0,6	79,87 ± 1,0	75,35 ± 0,9

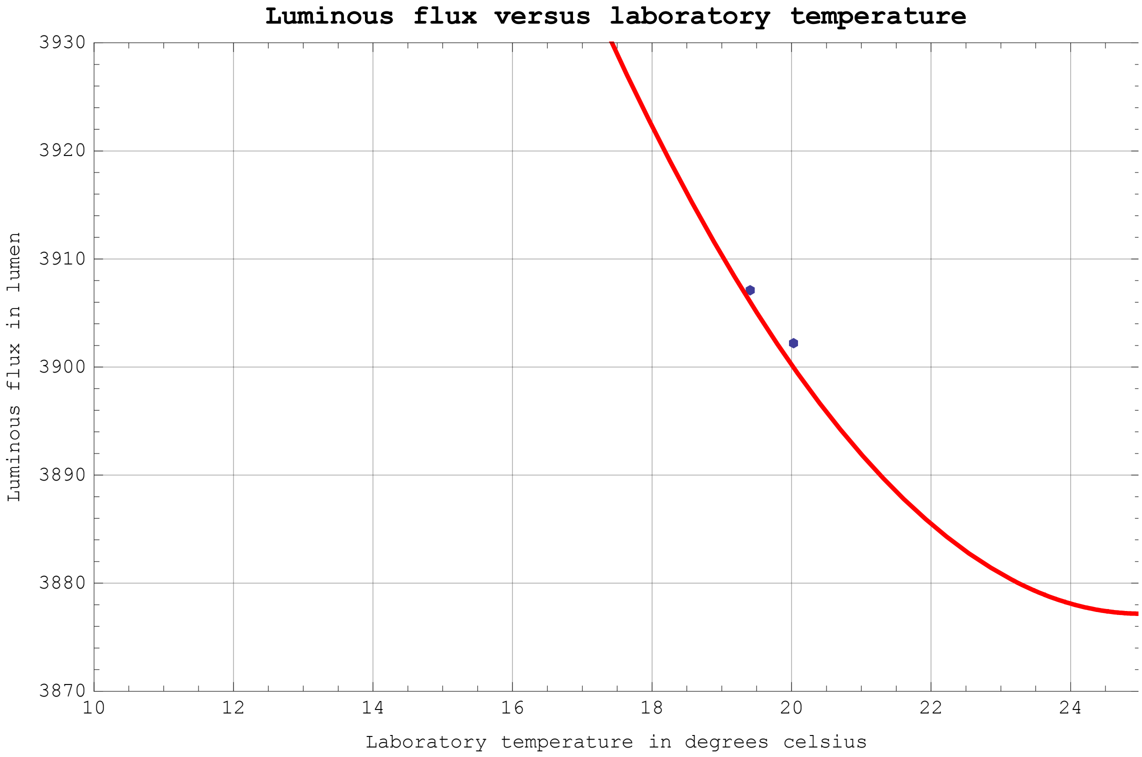

Figure 3 Luminaire for road lighting: luminous flux versus laboratory temperature.

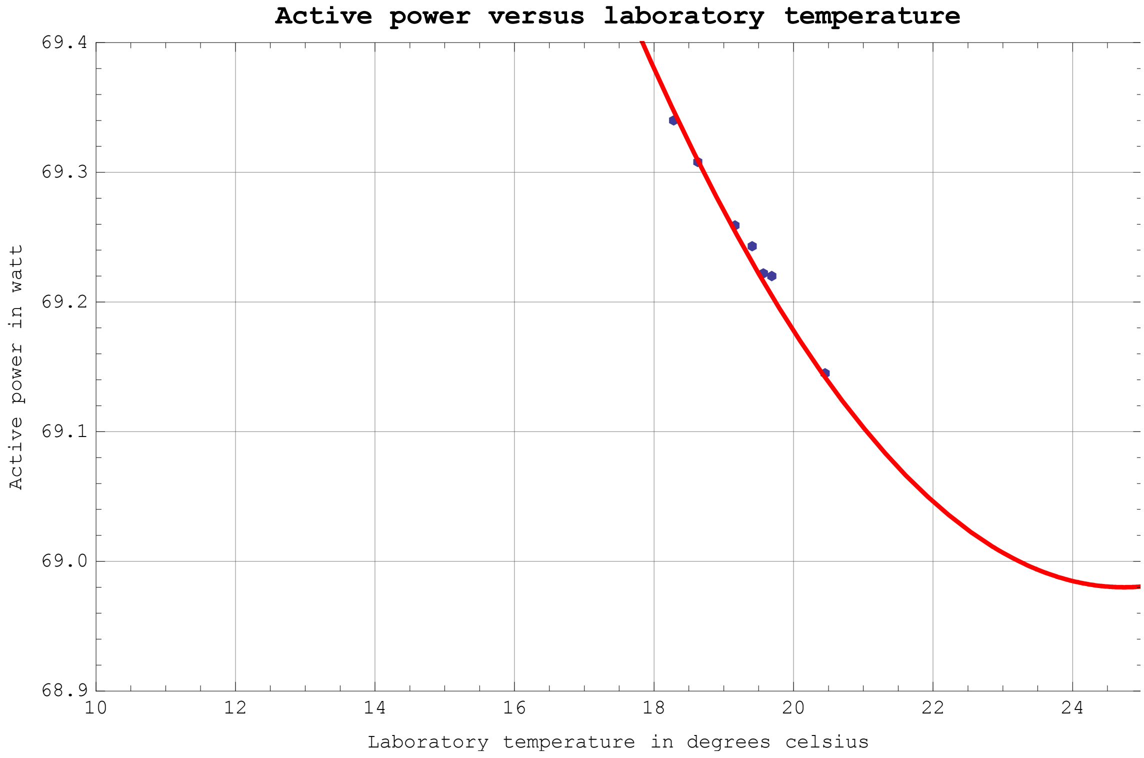

Figure 4 Luminaire for road lighting: active power versus laboratory temperature.

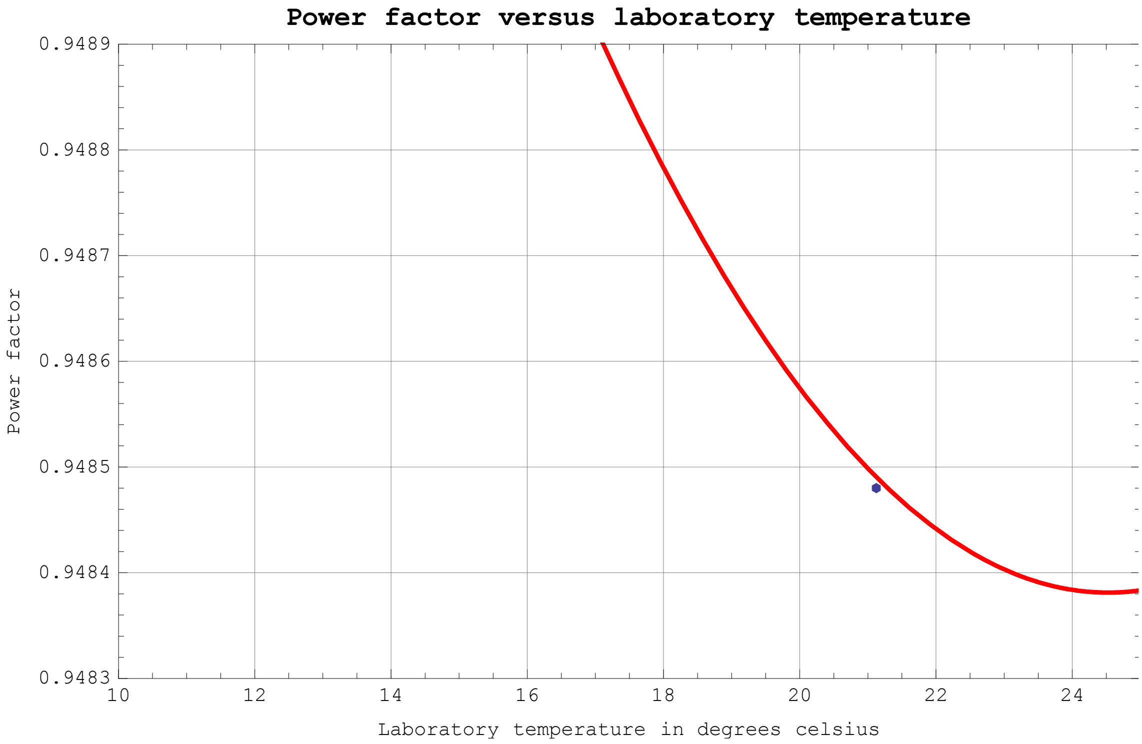

Figure 5 Luminaire for road lighting: power factor versus laboratory temperature.

Figure 6 Luminaire for road lighting: luminous efficacy versus laboratory temperature.

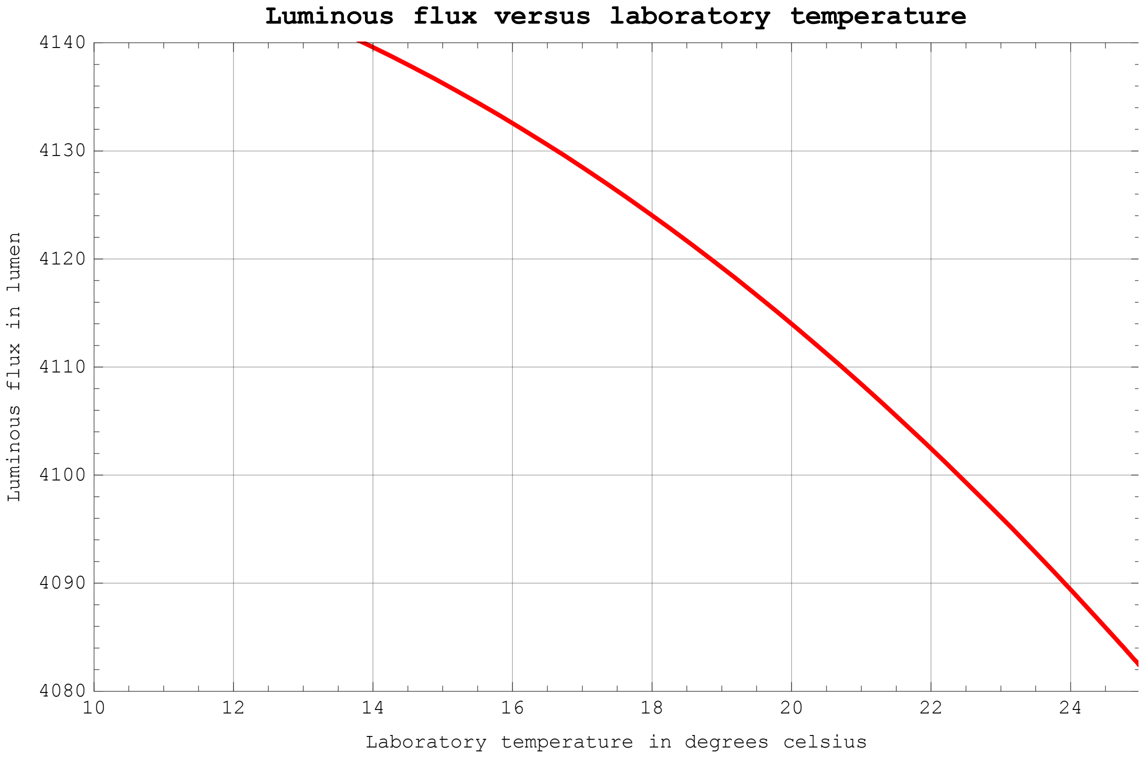

Figure 7 Luminaire for tunnel lighting (internal zone): luminous flux versus laboratory temperature.

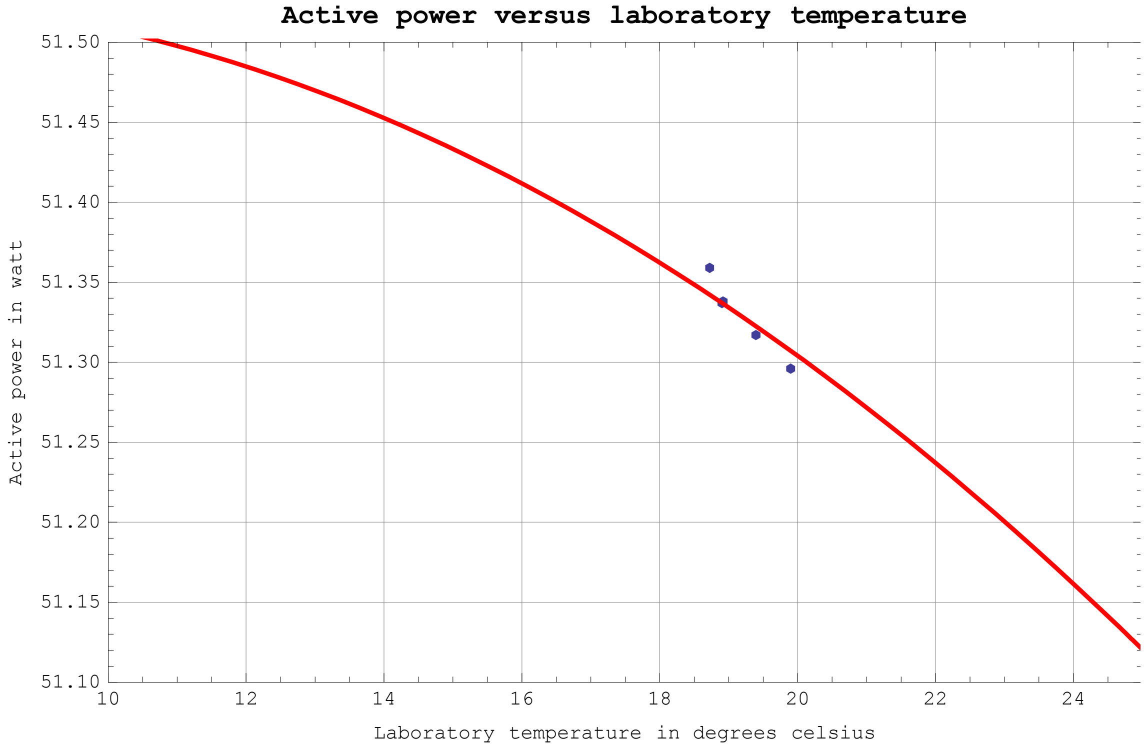

Figure 8 Luminaire for tunnel lighting (internal zone): active power versus laboratory temperature.

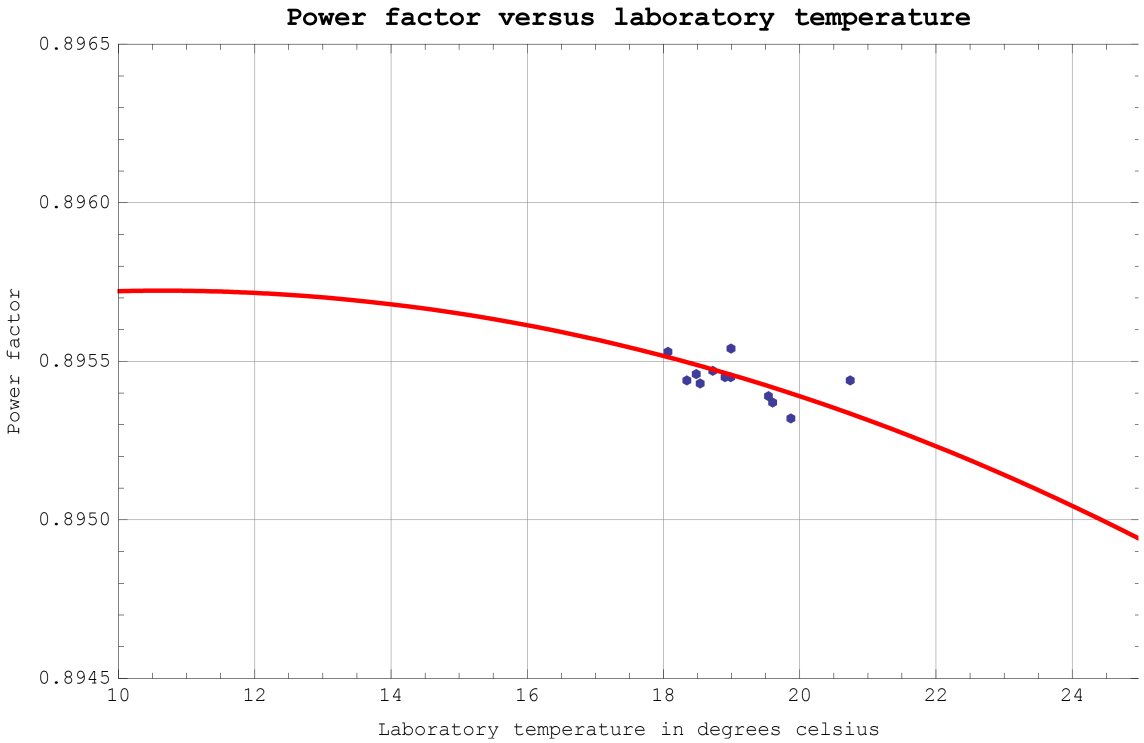

Figure 9 Luminaire for tunnel lighting (internal zone): power factor versus laboratory temperature.

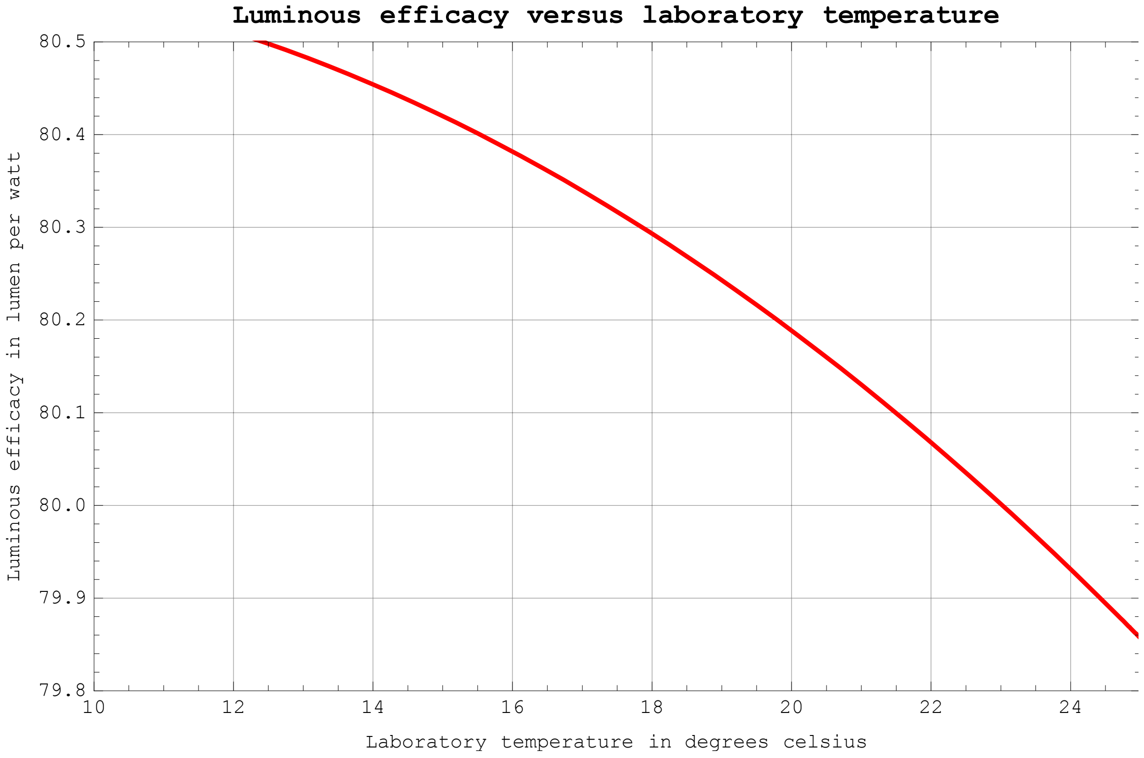

Figure 10 Luminaire for tunnel lighting (internal zone): luminous efficacy versus laboratory temperature.

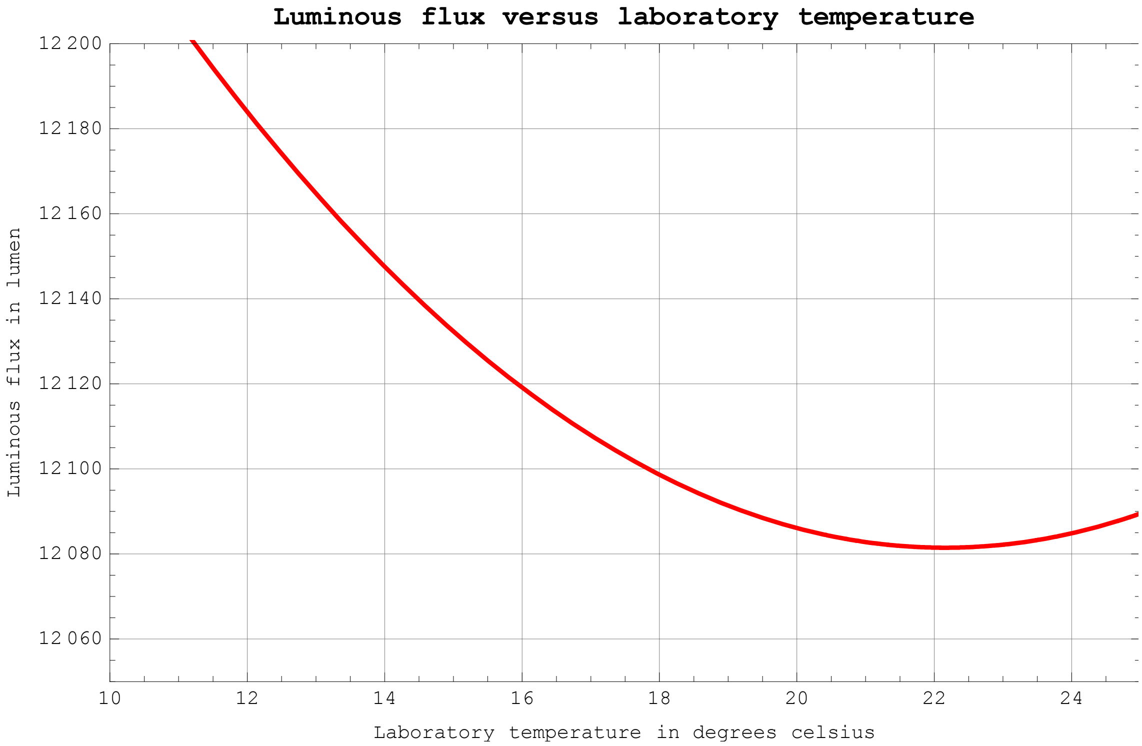

Figure 11 Luminaire for tunnel lighting (entrance zone): luminous flux versus laboratory temperature.

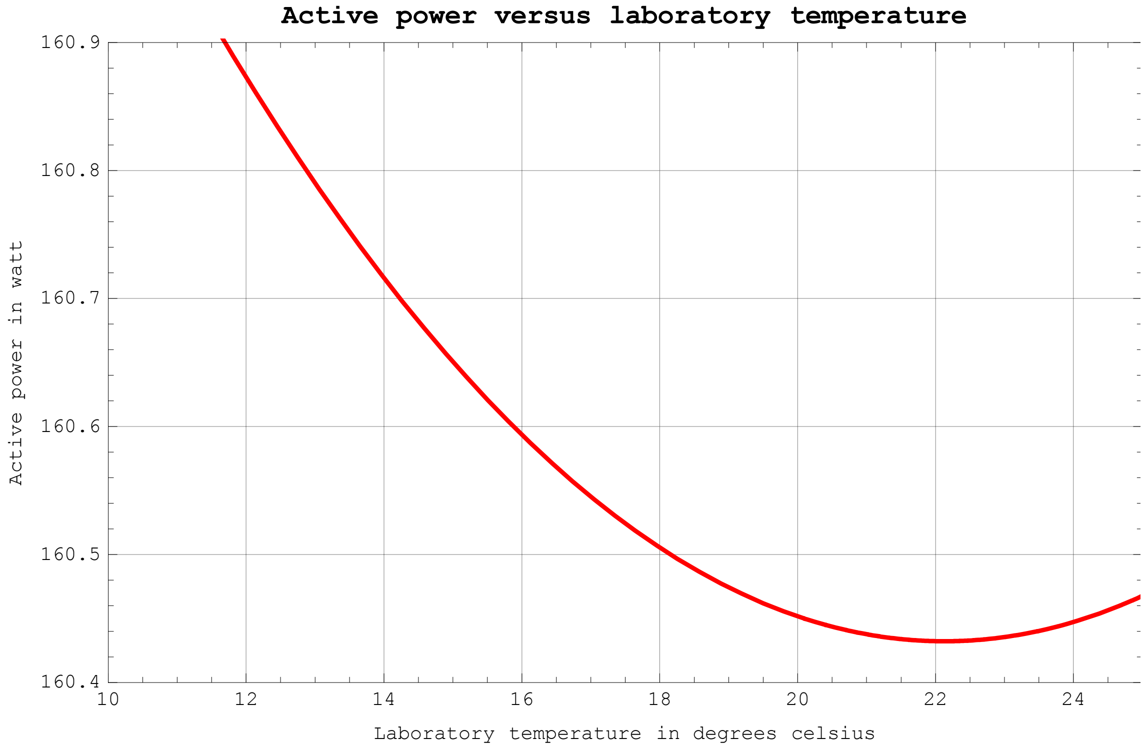

Figure 12 Luminaire for tunnel lighting (entrance zone): active power versus laboratory temperature.

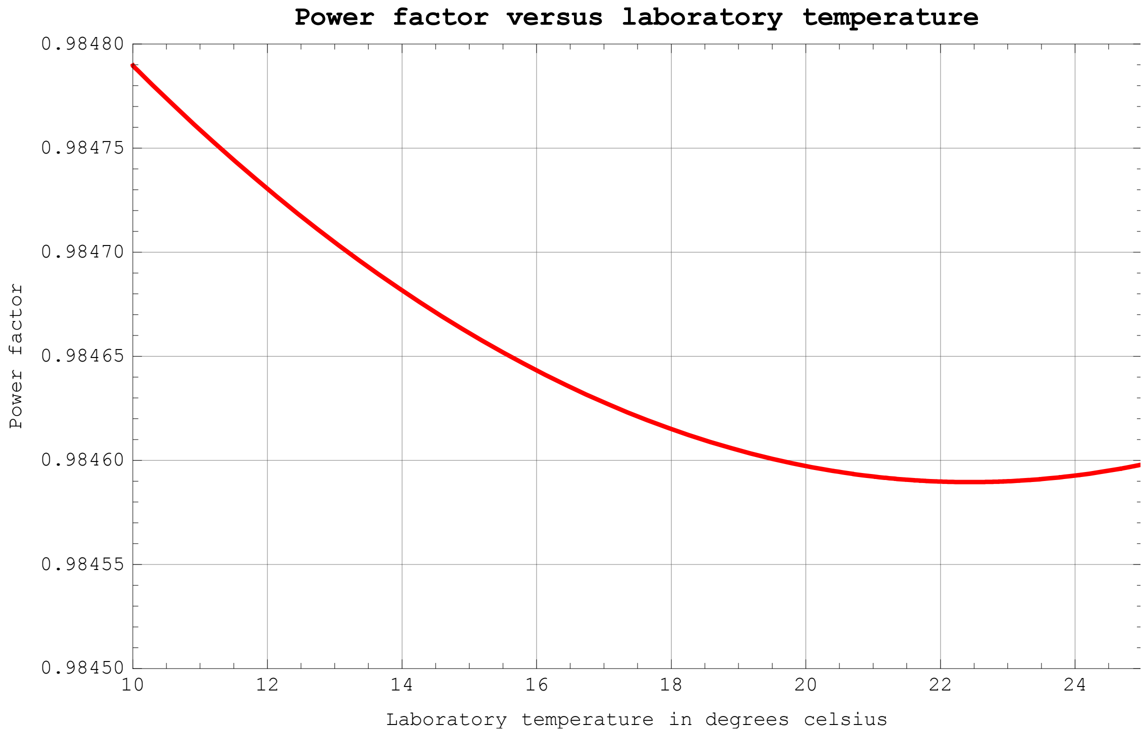

Figure 13 Luminaire for tunnel lighting (entrance zone): power factor versus laboratory temperature.

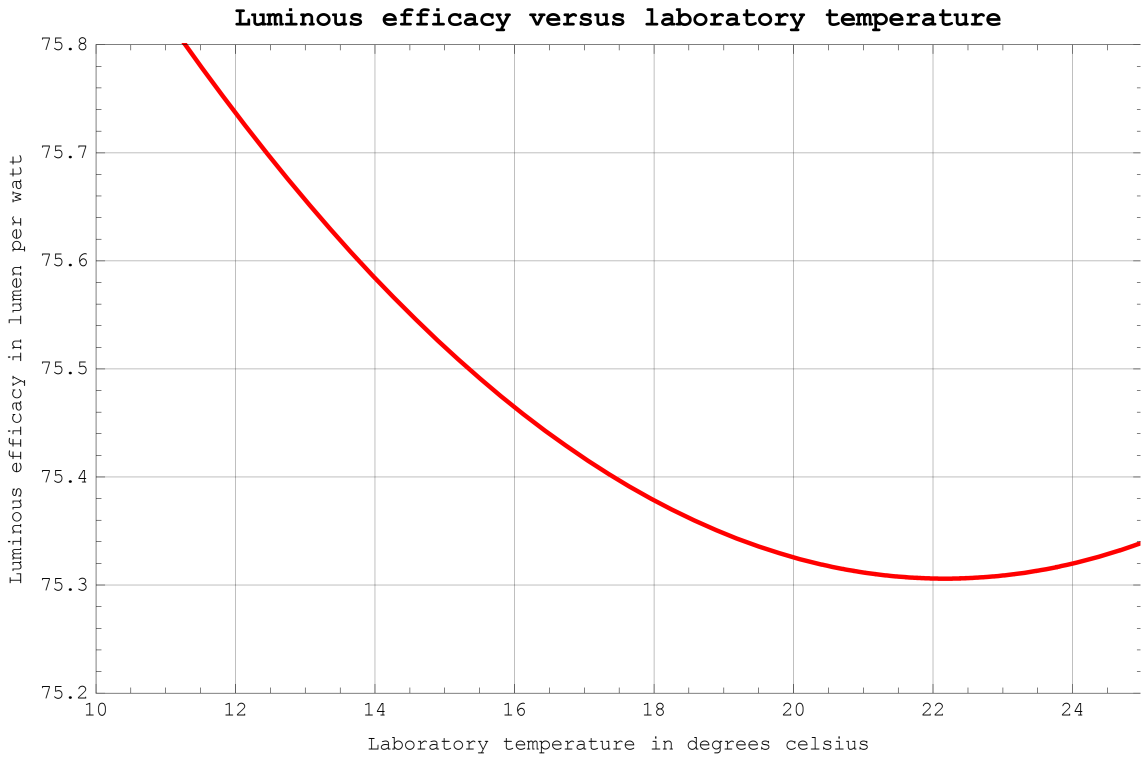

Figure 14 Luminaire for tunnel lighting (entrance zone): luminous efficacy versus laboratory temperature.

Table 3 Coefficient of the quadratic interpolation functions.

Parameter		Main application of luminaires		
		Road lighting	Tunnel lighting (internal zone)	Tunnel lighting (entrance zone)
Luminous flux	a	4 451,8	4 146,6	12 569
	b	- 45,961	2,137 5	- 44,032 4
	c	0,918 96	- 0,188 34	0,993 68
Active power	a	74,369 8	51,495 8	162,536
	b	- 0,435 72	1,210 3 10^{-2}	- 0,190 13
	c	8,805 9 10^{-3}	- 1,084 6 10^{-3}	4,295 9 10^{-3}
Power factor	a	0,954 06	0,895 29	0,985 24
	b	- 4,630 4 10^{-4}	8,103 6 10^{-5}	- 5,801 76 10^{-5}
	c	9,440 1 10^{-6}	- 3,805 6 10^{-6}	1,292 62 10^{-6}
Luminous efficacy	a	60,108	80,512	77,354
	b	- 3,079 5 10^{-1}	2,398 4 10^{-2}	- 0,184 73
	c	6,075 1 10^{-3}	- 2,007 8 10^{-3}	4,165 9 10^{-3}

5. Conclusions

5.1 Indoor SSL

In this study the temperature dependence of the efficacy of two chosen SSL products has been identified and a hysteresis model has been suggested as the best fit. The main conclusion is that the efficacy of SSL drops with the temperature on around 0.08-0.09% per degree Celsius with increase of temperature and rises on around 0.12-0.15% when temperature is decreased.

Hysteresis behavior is clearly pronounceable for both lamps. The difference between two runs though is quite large and within 0.09% for the lamp of type MB while only about 0.01 % for the lamp of type SB. This can be either related to the particular change in the properties of the lamp or an error in the estimation of average temperature of 7 sensors due to inhomogeneity of the warming process by flow.

Moreover, the results of the dependency of the **luminous flux** of SSL on temperature considered in this study as well and given in figure 12 confirm the conclusions given in [4] which are also shown on figure 13. A drop of luminous flux on about **0.5%** is observed in the range between 25°C and 45°C.

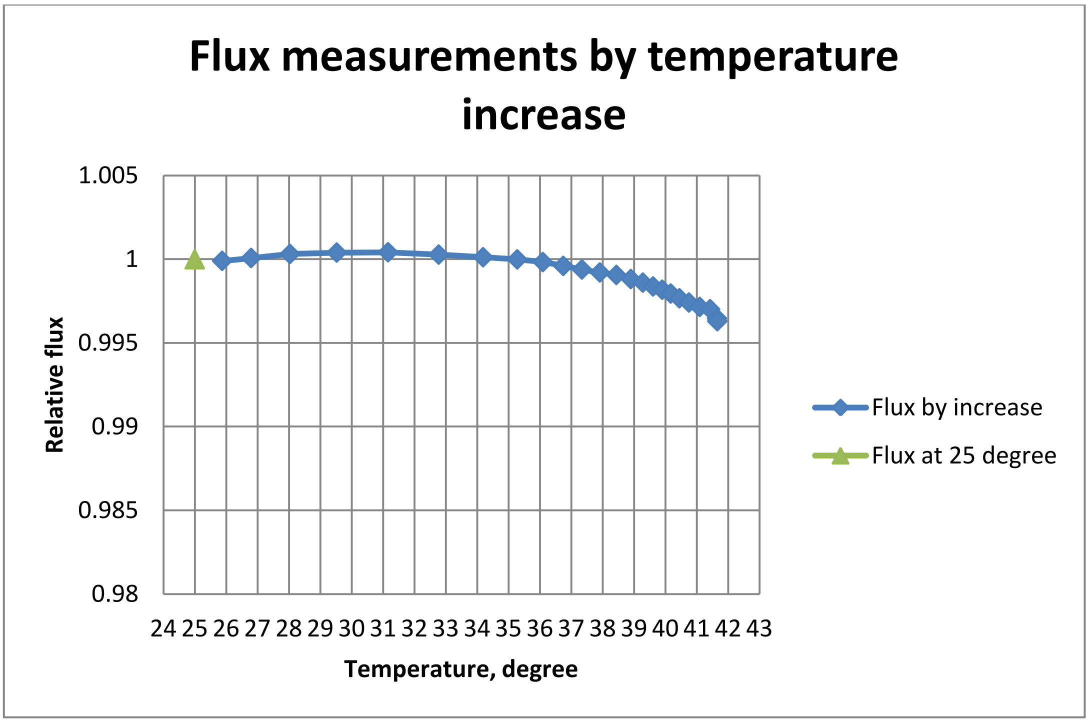

Figure 12. Flux decrease with temperature of MB and SB lamps

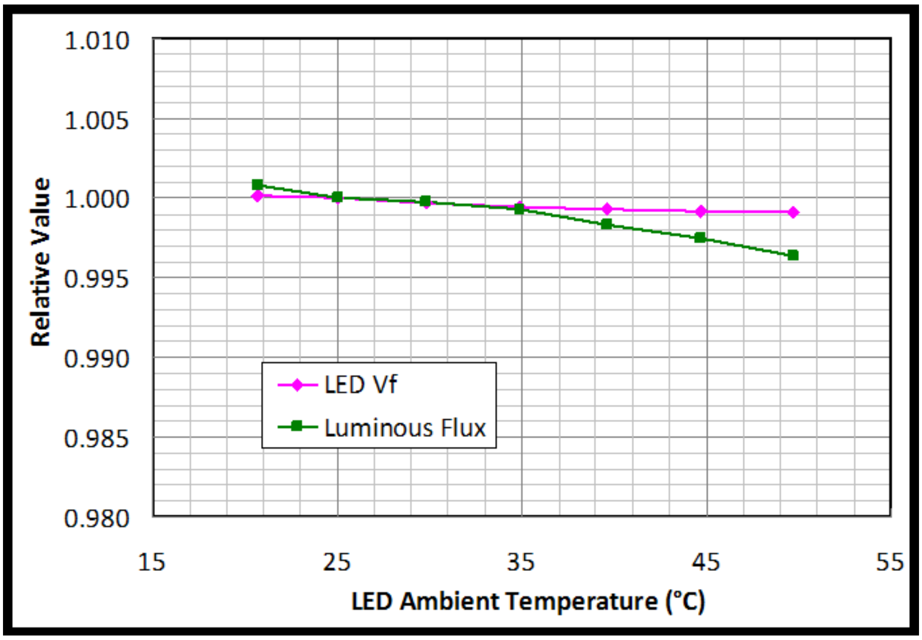

Figure 13. Flux decrease with temperature of a LED from NIST research [4]

5.2 Outdoor and Streetlight SSL

The characterization of luminaires near the standard temperature of 25 °C highlights the following point:

- The time required to reach an environmental thermal equilibrium could be very long especially because the temperature that influence the light output is the LED junction temperature and not the temperature of the luminaire case.
- The tolerance condition required by the last draft of the European standard [7] and CIE technical report [9] to start the measurement when "*the relative difference of maximum and minimum readings of light output and electrical power observed over the last 15 min is less than 0,5 %*" does not mean that the thermal equilibrium is reached.
- The tolerance condition in the ambient temperature (25 ± 1 °C) required by the last draft of the European standard [7] and CIE technical report [9] could be too restrictive for some luminaires, if the measurement uncertainty is correctly evaluated.
- The last draft of the European standard [7] and CIE technical report [9] suggest the luminous flux of a temperature controlled LED chip has a typical relative sensitivity to ambient temperature of 0,1 %/K. This values could be used for luminaires too.

The influence of the internal power supply characteristics in stabilizing the LED current with the temperature could influence the behaviour of the tested luminaires but this aspect need more investigations.

6. Reference

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[3] IEC 61000-4-7:2002/A1:2008 Testing and measurement techniques: general guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto.

[4] Luminous flux and color measurement of high-power LEDs, Yuqin Zong, presentation, NIST, CORM 2009 Annual Conference and Business Meeting, Workshop on Solid State Lighting Measurements and Standards, May 5-8, 2009, Gaithersburg, Maryland, USA, http://www.cormusa.org/uploads/4_CORM_Workshop_YZ.pdf

[5] Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products, LM-79-08**,** IES, 2008

[6] EN 13032:2004, *Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 1: Measurement and file format.*

[7] prEN 13032, *Lighting Applications — Measurement and presentation of photometric data of lamps and luminaires — Part 4: LED-lamps, modules and luminaires* (draft March 2013)

[8] UNI 11356:2010, *Light and lighting - Protocol for the measurement of LED luminaires photometric data,* (in Italian).

[9] CIE TC 2-71, *CIE Division 2 Draft International Standard Test Method for LED Lamps, Luminaires and Modules* (working draft 5 March 2013)