

EQUIVALENCE CRITERIA

FOR SPECIFYING LED SUBSTITUTE LIGHT SOURCE CATEGORIES AS EQUIVALENTS FOR CORRESPONDING FILAMENT LIGHT SOURCE CATEGORIES

1. INTRODUCTION

At the sixty-ninth (GRE-69-41) and at the seventieth GRE session (GRE-70-47), GTB presented their motivation and a possible approach for the introduction of LED Substitute light sources as alternative replacement parts in type-approved devices for Regulation No. 37 filament light sources.

Compared to the tungsten filament technology the LED technology offers the opportunity of highly energy efficient light sources in combination with long lifetime values.

To not compromise traffic safety after replacement of a filament light source according to Regulation No. 37 by an LED substitute light source according to Regulation No. 128, criteria for technical equivalence have to be established. This document describes such criteria and gives guidance for the specification of new LED substitute light source categories in Regulation No. 128.

2. COMPARING FILAMENT LAMPS AND LED LIGHT SOURCES

Several electrical, geometrical, photometrical and thermal parameters shall be specified to describe equivalence between LED substitute light sources and filament light sources of the corresponding Regulation No. 37 category.

- 2.1. Parameters, which are not inherently linked to the light generation technology, shall be the same, for example cap dimensions (IEC 60061), electrical connector, test voltage, luminous flux, colour and light centre length. The maximum outline dimension is linked to the incandescent technology and shall remain the same, too.
- 2.2. In filament light sources densely coiled tungsten wires form the light emitting area, whereof the shape (\approx cylindrical) and the radiation pattern show limited variations in practice. In LED based solutions the light emitting area can be quite diverse in terms of size and homogeneity; as well the radiation characteristics can significantly vary depending on the individual design. Therefore, this type of parameters of LED substitute light sources shall similar to the behaviour of corresponding filament light sources.
- 2.3. In comparison to filament light sources certain parameters of LED light sources are different due to the distinct principle of light generation. With LED technology the same amount of light is usually generated with significantly less energy compared to incandescent technology, and the spectral composition (infrared versus visible radiation, but also within the visible range) differs between both technologies. The internal electrical circuit is different resulting in different failure modes.
- 2.4. Further, the different technology of light generation makes it necessary to consider an additional requirement. In case of LED solutions the photometrical values are usually quantified under initial "cold" and stabilized "hot" conditions in order to control the emission behaviour in changing thermal situations.

Based on these facts the parameters to which these equivalence requirements apply are grouped into four sets of criteria (“same”, “similar”, “different” and “additional”) and described in the following section.

3. REQUIREMENTS FOR EACH RELEVANT PARAMETER

3.1. Parameters with the same values

The following parameters of an LED substitute light source category shall be the same as in the data sheet of the corresponding Regulation No. 37 light source category, including the tolerances:

- 3.1.1. Cap, in accordance with the given IEC Publication 60061
- 3.1.2. Maximum lamp outline dimensions
- 3.1.3. Electrical connector
- 3.1.4. Test voltage
- 3.1.5. Objective luminous flux
- 3.1.6. Colour of emitted light
- 3.1.7. Light centre length
- 3.1.8. Distortion free zone (if any)

3.2. Parameters with similar values

The normalized luminous intensity distribution (“far field”) as well as the emission behaviour and the homogeneity of the light-emitting-area (“near field”) of the LED substitute light source shall be similar to the characteristic of the filament light source of the corresponding Regulation No. 37 category.

3.2.1. Normalized luminous intensity distribution

The normalized luminous intensity distribution of LED substitute light sources shall be specified in directions which are relevant for the light emission of filament light sources of the corresponding Regulation No. 37 category.

Therefore, minimum and maximum intensity values (in cd/1000 lm) shall be given in the category sheet, typically in three different C-planes (C0, C30, C330) and in angular steps of $\Delta\gamma = 25^\circ$, excluding the following distorted areas of filament light sources of the corresponding Regulation No. 37 category:

- transition region of the cap;
- proximity of the filament axis;
- area of strong glass distortions (tips);
- shading area of lead-in wires.

The values shall be derived from measurements of homologated filament light source samples of the corresponding Regulation No. 37 category (see Annex 1). The selection of samples shall include various possible designs of different manufacturers.

3.2.2. Size and position of the light-emitting-area

A similar box definition including the relevant viewing direction(s) of the corresponding data sheet in Regulation No. 37, if any, shall apply for the size and position of the (apparent) light-emitting-area of the LED substitute light source. Depending on the geometrical circumstances [under which the box is defined in the corresponding data sheet in Regulation No. 37] additional viewing directions(s) may need to be introduced.

In addition, a minimum percentage value of the luminous flux emitted from this box into the given viewing direction(s) shall be specified in the data sheet (see parameter DFR in Annex 2). This value shall be derived from measurements of homologated filament light source samples of the corresponding Regulation No. 37 category (see Annex 2). The selection of samples shall include various possible designs of different manufacturers.

3.2.3. Homogeneity of the light-emitting-area

The box defined under 3.2.2. shall be split in three sections (of similar size). A minimum luminous flux emitted from each section into the given viewing direction(s) shall be specified to achieve homogeneity comparable to the filament case, where filaments of typical size and position tolerance per category exist (see Annex 3).

3.3. Parameters with different values

The following properties are inherently different between filament and LED substitute light sources. The equivalence criteria have to be described appropriately:

3.3.1. Maximum electrical power consumption

The maximum electrical power consumption of an LED substitute light source shall be limited to a value of about 30% of the maximum power specified in the corresponding data sheet of Regulation No. 37 in order to limit the heat load in the cap at a level comparable to the corresponding filament light source.

This value may be specified more precisely, for example via comparative temperature measurements. When placed in a typical holder and operated at the properly specified maximum power the cap temperature of an LED substitute light source shall stabilise at similar (or lower) value as for the corresponding filament light source placed in the same holder and operated at objective power.

3.3.2. The minimum voltage range

The minimum voltage range given in Annex 4 of Regulation No. 128 shall be used as a default for electrical and photometrical tests of LED substitute light sources. An additional minimum flux requirement at significant voltage drop shall be given in the data sheet to guarantee a minimum light output comparable to filament light sources (e.g. at 9V at least 20% of the objective luminous flux at test voltage).

3.3.3. The spectral content

LED substitute light sources emitting white light and possibly being used behind red or amber cover lenses shall have a colour temperature of maximum 3,000 K.

3.4. Additional parameters

For all LED light sources one additional requirement shall apply to LED substitute light sources:

3.4.1. Thermal behaviour

The thermal behaviour of the emitted luminous flux after one minute of operation and after 30 minutes of operation shall be in accordance with Regulation No. 128, annex 4. Because LED substitute light sources can be located in the immediate environment of filament lamps, an elevated ambient temperature is added in the datasheet.

4. REQUIREMENTS REGARDING FAILURE

Due to significantly reduced power consumption of LED technology, LED substitute light sources might trigger some failure detection systems even though the light source is working normally. Besides some mandatory failure tell-tales, vehicles may also optionally be equipped with failure detection systems for other lighting or light signalling functions and on-board diagnostic systems, e.g. short voltage pulses to check the function of filament light sources in the off-state.

Failure detection systems and on-board diagnostic systems are not or hardly specified by regulations or by standards from officially recognised international standardisation organisations. In particular the electrical detection threshold is not publicly known or standardized.

Whereas the equivalent of the internal electrical circuit of a filament lamp is just a temperature dependent resistor with coil side-effects, the LED substitute light source electrical circuit is represented by diodes and resistors and may be capacitors and microchips with intelligence. Typical failures are not limited to simple open- or closed-circuit of the light source, although in rare cases also the filament can be partially short-circuited between windings of the coil.

4.1. Failure detection

In order to support the interface to such systems, a lower and upper limit for the electrical current shall be specified per category over a voltage range covering normal application conditions (e.g. 9V-16V DC for a 12V system) and LED substitute light sources shall not flash when a short voltage pulses (e.g. 1 millisecond) is applied.

4.2. Failure behaviour

A criterion per category shall reflect the situation that a LED substitute light source may consist of more than one light emitting element and a clear detection of malfunction is possible. Example: "Either the LED substitute light source complies with luminous flux and intensity requirements, or it stops emitting light and the electrical current drops below a specified limit".

5. DOCUMENTATION

The proposal for LED substitute category sheet(s) shall be accompanied by information showing the equivalence with the corresponding filament light source category. Measurements of anonymised samples of filament lamps to derive equivalent performance shall be included. See also annex 4.

ANNEXES

Annex 1

Clarification of the requirements to the normalized luminous intensity distribution

The normalized luminous intensity distribution of homologated filament light source samples typically exhibits lamp-to-lamp variations due to the specific design, i.e. due to non-regulated parameters (glass thickness variations, shape of glass bulb, coiling structure of filament, etc.) and/or tolerances (filament position, lead-in wire position). Further, “distorted” areas (design of lead-in wires and their relative position to the filament, proximity of filament axis, transition region of the cap, glass tips) lead to extreme variations in specific angular regions.

However, straight filaments generate quite similar emission patterns in the directions of major light emission, i.e. more or less perpendicular to the filament axis (e.g. +/- 30°).

Therefore, the specification of equivalent radiation characteristics of LED substitute light sources is limited to the directions of relevant light emission of the corresponding filament light source excluding “distorted” areas.

Depending on the specific filament light source category, the excluded areas are different. Figure 1 shows representative examples of transversal and axial filament positions and limitations of the directions where light emission of the LED substitute light source shall be specified.

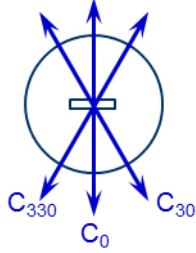
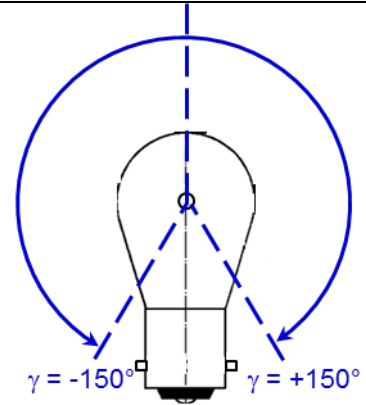
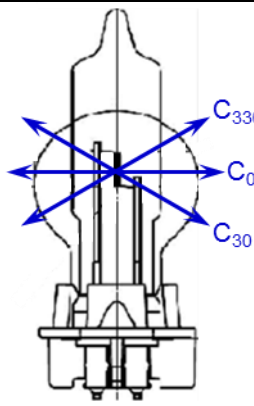
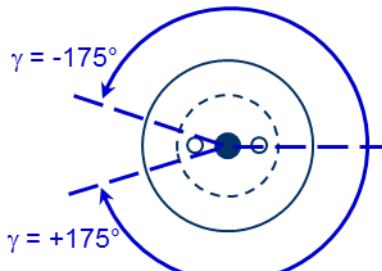
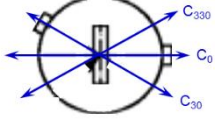
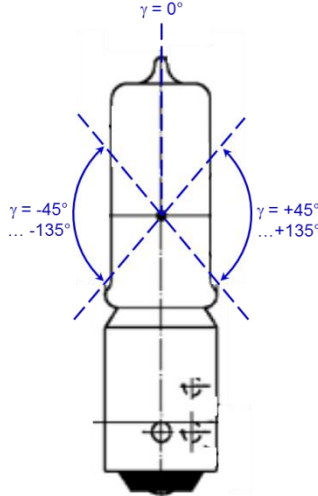
	<i>Orientation of C-planes</i>	<i>Angular limitation of γ in C_0-plane</i>
<i>Example P21W</i>	<p><i>top view</i></p>  <p>A top view diagram of a P21W bulb filament. It shows a central horizontal filament with three blue arrows representing C-planes: C_{330} pointing up-left, C_0 pointing down, and C_{30} pointing up-right.</p>	 <p>A diagram showing the angular limitation of γ in the C_0-plane for a P21W bulb. It features a large blue circle with a dashed vertical line through its center. A smaller circle represents the bulb's outline. Two dashed lines from the center to the bulb's base indicate the angular limits: $\gamma = -150^\circ$ on the left and $\gamma = +150^\circ$ on the right.</p>
<i>Example PW24W</i>	 <p>A cross-sectional diagram of a PW24W bulb. It shows a central vertical filament with three blue arrows representing C-planes: C_{330} pointing up-right, C_0 pointing left, and C_{30} pointing down-right.</p>	<p><i>top view</i></p>  <p>A top view diagram of a PW24W bulb filament. It shows a central horizontal filament with two blue arrows representing C-planes: C_{330} pointing up-left and C_{30} pointing down-left. A large blue circle with a dashed horizontal line through its center indicates the angular limitation of γ in the C_0-plane, with $\gamma = -175^\circ$ on the left and $\gamma = +175^\circ$ on the right.</p>
<i>Example H21W</i>	<p><i>top view</i></p>  <p>A top view diagram of an H21W bulb filament. It shows a central horizontal filament with three blue arrows representing C-planes: C_{330} pointing up-right, C_0 pointing left, and C_{30} pointing down-right.</p>	 <p>A diagram showing the angular limitation of γ in the C_0-plane for an H21W bulb. It features a vertical filament with a dashed vertical line through its center. Two dashed lines from the center to the bulb's base indicate the angular limits: $\gamma = -45^\circ$ to $\dots -135^\circ$ on the left and $\gamma = +45^\circ$ to $\dots +135^\circ$ on the right. The top of the diagram is labeled $\gamma = 0^\circ$.</p>

Figure 1: representative examples of filament positions and limitations of the directions where light emission of the LED substitute light source shall be specified

Annex 2

Clarification of the definition of a minimum light emission of the defined box

The luminous flux emitted from a filament light source is not solely emitted from the filament. Scattered and reflected light from coatings, lead-in wires, etc. contribute to the emission characteristics.

Therefore, the definition of an equivalent minimum percentage is defined for LED substitute light sources on the basis of measurements of homologated filament light source samples of the corresponding category.

In figure 2 two examples of an amber filament light source (PY21W) are shown. One sample made of amber glass has a high percentage of direct light emission (~90%; i.e. only minor reflections due to the lead-in structure and the ghost images) whereas the second sample using an amber coating has a lower percentage of direct light emission (~70%; due to additional haze from the coating material). Hence, for the given examples of PY21W filament light sources in figure 2 the minimum percentage value of the luminous flux emitted from the box into the given viewing direction(s), the so-called Direct-Flux-Ratio DFR, shall be 80%.

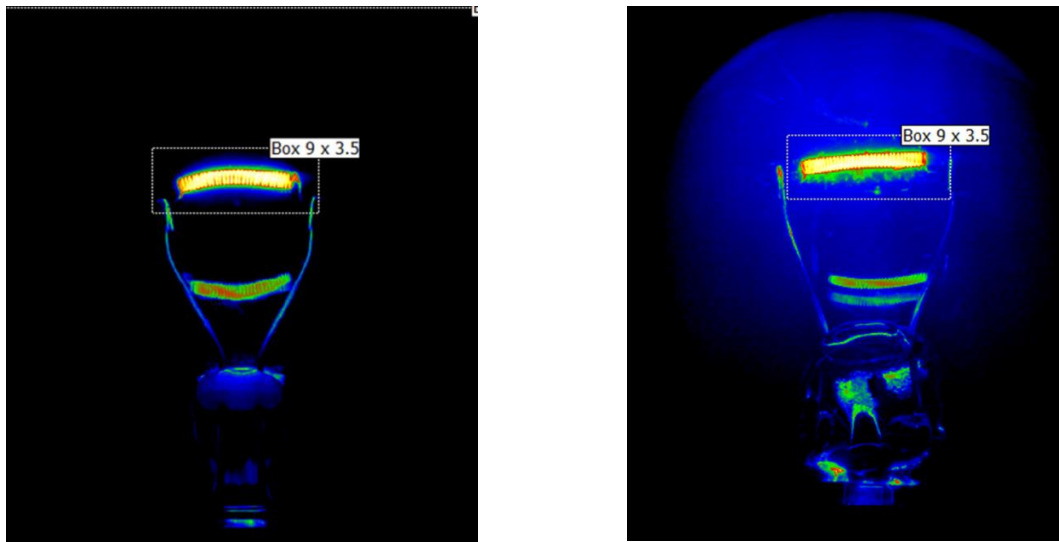


Figure 2: PY21W-samples with amber glass (left) and with amber coating (right)

Annex 3

Clarification of the requirements to the homogeneity of the light-emitting-area

The explanations in this annex are based on the example of PY21W.

Figure 3 shows that in Regulation No. 37 the box from the front elevation is defined in three sections. The projection of the filament shall lie entirely within the rectangle and the centre of the filament shall stay within the inner section of the box.

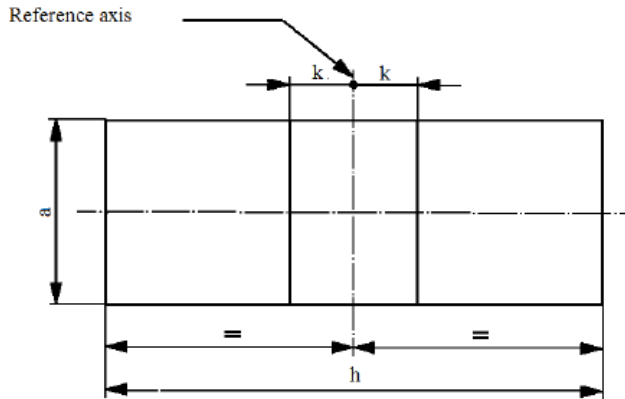
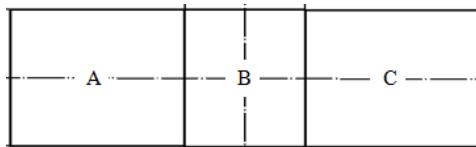


Figure 3: Front elevation of the box specification of filament light source category PY21W in Regulation No. 37

The percentages of the minimum luminous flux emitted from each section into the given viewing direction(s) shall be specified based on considerations done with samples of filament light sources of the corresponding category, i.e. including tolerances of typical filament dimensions and filament position and taking into account that part of the light is emitted from outside the box (ref. value of DFR).

Figure 4 describes the outcome for the example of a PY21W LED substitute light source. The lower limit for each section is derived from extreme values of the filament length ($f = 5.5$ and 7.0 mm), of the filament position (shift of centre $k = -1.0$ and $+1.0$ mm) according to the PY21W filament lamp category and the share of direct light emission from the box ("DRF" = 80%, see Annex 2):

- Section B: $2 \cdot k / f \cdot \text{DFR} = 2.0 / 7.0 \cdot 0.8 = 22.9\%$, rounding up at multiples of 5% to 25% min.
- Sections A and C: $(0.5 \cdot f - 2 \cdot k) / f \cdot \text{DFR} = (2.75 - 2.0) / 5.5 \cdot 0.8 = 10.9\%$, rounding up at multiples of 5% to 15% min.



The proportion of the total luminous flux emitted into the viewing direction from the area(s):

- A, B and C together shall be 80 per cent or more;
- B shall be 25 per cent or more;
- A and C shall each be 15 per cent or more.

Figure 4: Front elevation of the box specification of LED substitute light source category P21W

Annex 4

Checklist for equivalence of parameters

Parameters as in paragraphs described above	Check
3.1. Parameters with the same values	
3.1.1. Cap (as in in accordance with the given IEC Publication 60061)	O
3.1.2. Maximum lamp outline dimensions	O
3.1.3. Electrical connector	O
3.1.4. Test voltage	O
3.1.5. Objective luminous flux	O
3.1.6. Colour of emitted light	O
3.1.7. Light centre length	O
3.1.8. Distortion free zone (if any)	O
3.2. Parameters with similar values	
3.2.1. Normalized luminous intensity distribution	O
3.2.2. Size and position of the light-emitting-area	O
3.2.3. Homogeneity of the light-emitting-area	O
3.3. Parameters with different values	
3.3.1. Maximum electrical power consumption	O
3.3.2. The minimum voltage range	O
3.3.3. The spectral content	O
3.4. Additional parameters	
3.4.1. Thermal behaviour	O
4. Requirements regarding failure	O
4.1. Failure detection	O
4.2. Failure behaviour	O