Energy requirements of common light sources

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***Abstract* —** The paper focuses on energy requirements of light sources generally used in administrative and residential buildings. In buildings for which are properly treated thermally insulating properties, constitute heat gains from light sources proportion of the total heat gains. With the expansion of new technologies, there are new light sources, which could lead to a reduction in energy requirements for lighting. Energy requirements for lighting are not only requirement. There are also demands for the quality of the luminous environment. These parameters mean the color rendering respectively color temperature and glare requirements. These parameters may not be meet when the lighting design is wrong. This paper summarizes the basic requirements for lighting in buildings, means a requirement for environmental quality and energy requirements.

***Keywords*—**Energy requirements, light sources, lighting requirements, quality of the luminous environment.

I. Introduction

LIFE as we know it could not exist without the light. It is necessary for photosynthesis or for visual perception of the world by mankind or other living beings. The best known light source is the Sun, which provides us with daylight. During the day, there is a possibility to use this daylight for lighting work environment. With respect to the requirements for lighting, specifically, uniformity illuminance is necessary to regulate daylight eventually complete it with artificial light. For a correct completing luminous environment with artificial light is needed to know the characteristic of artificial lights, which are used. With this characteristic it is possible to set the right level of artificial light to achieve a right luminous environment with minimal energy requirements. Also, with the right daylight regulation, there are minimal heat grains from the Sun radiation.

II. Standard requirements

Lighting is revised by several standards, which maintain requirements for quality of the luminous environment and energy requirements for lighting [1], [2], [5].

A. Luminous environment requirements

Requirements for illuminance are well known and with uniformity illuminance in place of the visual task and its close area has an effect on speed, safety, and comfort. Measured illuminance and uniformity illuminance depends on specified network. The network is a set of points in which is illuminance calculated and measured. The square network is favored. Maximal dimension of cell is given by [2]:

$$p = 0{,}2 \cdot 5^{\log_{10} d} \tag{1}$$

where d is the longer dimension of the area
p maximal dimension of the cell

Luminance requirements mean especially the luminance distribution that gives eye adaption and also effects task visibility. Balanced eye adaption luminance is important for improve the visual acuity [2].

Color temperature and color rendering give the color quality of artificial sources or daylight. Color temperature is related with the apparent color of light. This color of light could be replaced with color temperature T_{cp}. Daylight during the day changes its color temperature. Artificial light may be sort in one of three categories of white light. Warm white with color temperature under 3300 K, neutral white with a color temperature between 3300 K and 5300 K and cold white with a color temperature above 5300 K. Color rendering means that color of subjects and mankind skin are seen in true color. Color rendering is described with index R_A. The maximal value of R_A index is 100 [2].

Bright surfaces in the field of view, for example, illuminated surfaces, parts of light sources or windows cause glare. For avoiding fatigue, work accidents it is necessary to minimize the glary [2].

These requirements for lighting could be achieved by using daylight, artificial lighting or integrated lighting [2], [3], [4].

In buildings with are determined for people to reside during the day is required adequate daylight. In newly constructed buildings is required adequate daylight for living quarters,

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bedrooms, rooms for preschools, health care facilities. Sources of daylight in buildings are windows, skylight, and a light pipe. This daylight sources must be designed effectively. The requirements for daylight must by achieved with the smallest area of glazing. The spectral composition must not be changed by the glazing [3].

Integrated lighting is more comfortable instead of using only artificial lighting. In newly constructed buildings or theirs, parts could be integrated lighting used only in justified cases. In indoors with integrated lighting must be maintained required part of daylight. This part depends on the difficulty of view task. There are seven difficulties of view tasks. The spectral composition of artificial light sources must be comparable with the daylight spectral composition. The spectral composition of the artificial sources must be also continuous or, at least, maintain significant continuous component. This artificial lighting could be regulated depending on exterior illuminance.

B. Energy requirements for lighting

Standard ČSN EN 15193 [5] describe energy requirements for lighting in buildings. It also provides procedures for energy consumption calculation in buildings. For appropriate calculation of energy consumption is required lighting system, which design is consistent with ČSN EN 12646-1 [2] standard.

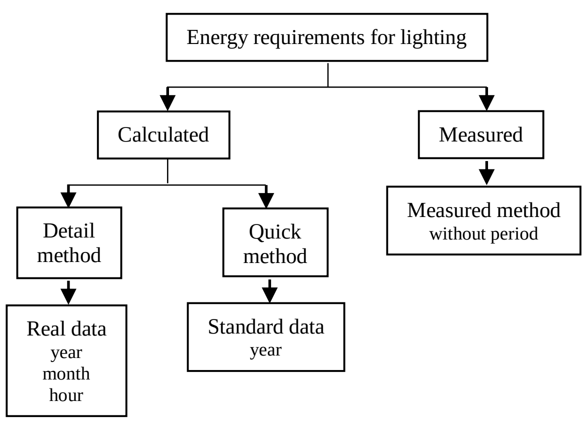


Fig. 1 methods of determining energy requirements [5]

The estimated total electricity consumption of a lighting for room or zones for calculated time is given by [5]:

$$W_t = W_{L,t} + W_{P,t} \tag{2}$$

where $W_{L,t}$ is estimated consumption of electricity in the building to meet the purpose and function of lighting and is given by [5]:

$$W_{L,t} = \sum \frac{\{(P_n \cdot F_C) \cdot [(t_D \cdot F_O \cdot F_D) + (t_N \cdot F_O)]\}}{1000} \tag{3}$$

and $W_{P,t}$ is estimated the loss of electricity in the building, caused mainly by charging emergency lighting and standby lighting control system and is given by [5]:

$$W_{P,t} = \sum \frac{\{\{P_{pc} \cdot \lfloor t_y - (t_D + t_n) \rfloor\} + (P_{em} \cdot t_{em})\}}{1000} \tag{4}$$

where P_n is the total power consumption for lighting in a room or area in watts;
P_c total power dissipation control devices in a room or area in watts;
P_{em} total charging power for emergency lighting luminaries in watts;
t_D hours of daylight in hours;
t_N time without the use of daylight in hours;
t_y standard time of year, fixed at 8760 h;
th_{em} charging time emergency lighting in hours;
F_C constant illuminance factor;
F_O factor depending on the occupation;
F_D factor depending on daylight.

Lighting Energy Numeric Indicator (LENI), indicate year consumption for lighting in building for 1 m^2 floor surface. LENI indicator is given by [5]:

$$LENI = \frac{W}{A} \tag{5}$$

According to Fig. 1 there are two methods for calculating energy consumption. Detail method provides energy consumption for different time schedule. Otherwise quick method calculates data only for one year. Data calculated by one of these methods could be compared with data measured on installed lighting system. Measuring must be done by one of the methods described in standard [5].

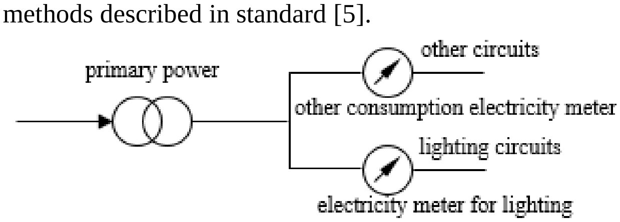


Fig. 2 example of energy consumption measuring [5]

III. Lighting sources characteristics

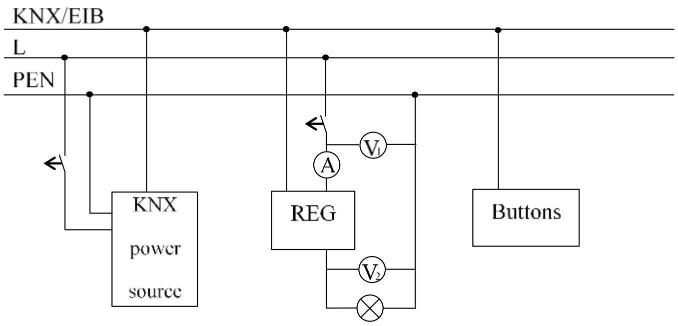
For comparison of light sources, characteristics were determined the most used lighting sources.

Table 1 properties of the light sources

Light source	Power [W]	Color temperature [K]	luminous flux [lm]
Bulb	75	2700	940
Classic ECO halogen	53	2700	840
LED Premium	14	2500	995
Compact fluorescent light	20	2700	1200

All light sources are dimmable and it is possible to determine the regulation influence on characteristics.

Fig. 2 shows schematic circuit for measuring electric parameters of light source regulation. For regulation was used KNX/EIB system, universal dimming actuator specifically. The regulation level was set by push buttons; the level of regulation was determined on 0 %, 25 %, 50 %, 75 % and 100 %. For each level of regulation and light sources was made several measurements. For characteristics were used only current in regulated circuit. Voltmeters were used only as control devices. [2]



L	-	Phase	V_1,V_2	-	Voltmeter
PEN	-	Protective earth, neutral	A	-	Ammeter
REG	-	Regulation element			

Fig. 3 schematic circuit regulation of light sources with measurement electrical values

The first part of this paper does not compare measured values but compare percentage values due to different technologies of light sources. For each light source and level of regulation is calculated percentage level. With regulation set on 100 % the value is 100 % and for others levels of regulation is calculated their percentage value based on this 100 % regulation value.

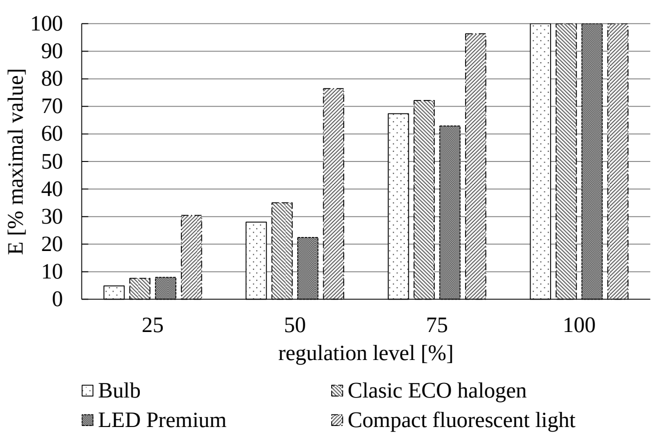


Fig. 4 dependence percentage illuminance on the set regulation

On the Fig. 4 is shown percentage illuminance and its dependence on the regulation level. As could be seen none of the light sources were regulated effectively. In the case of the bulb, classic ECO halogen and LED light sources percentage illuminance was always under required level. But the compact fluorescent light had percentage illuminance above required level.

Fig. 5 provides percentage current and its dependence on the regulation level. Instead of Fig. 4 there is obvious opposite problem. The current in the regulated circuit is almost in every case above regulation level. Only LED light sources current at 50 % and 75 % regulation level were under regulation level.

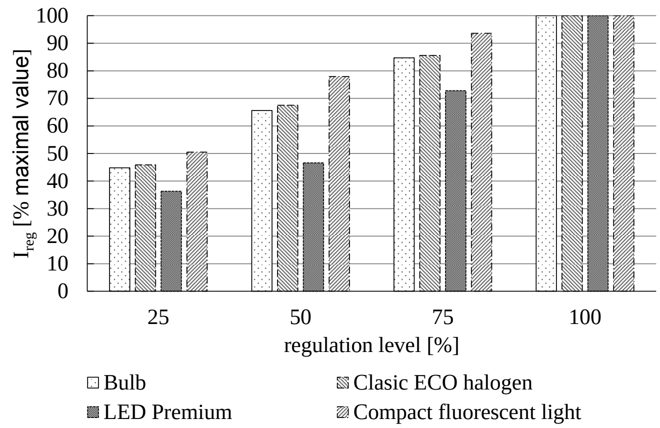


Fig. 5 dependence percentage current on the set regulation

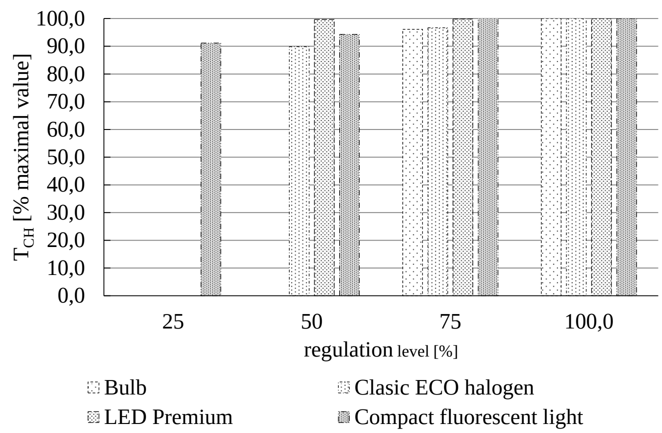


Fig. 6 dependence percentage color temperature on the set regulation

One of the requirements is for color temperature, in Fig. 6 is shown color temperature dependence on the regulation level. As could be seen not for every level set were possible to measure. As could be seen there are missing columns. It is caused by low level of illuminance and measurement element could not measure this low levels. From Fig. 6 could be seen that color temperature dependence on the regulation level is only minimal, the difference is up to 10 % of maximal color temperature, due to chosen light sources it is maximal difference 270 K.

In Fig. 7 are depicted dependencies between percentage current and percentage illuminance. These dependencies provide basic knowledge of what percentage of current is needed for required percentage illuminance. Due to a comparison of percentage values, it is not possible to decide which parts of curves are usable for lighting purposes of fitting standards requirements. Measured values are shown in following part of the paper.

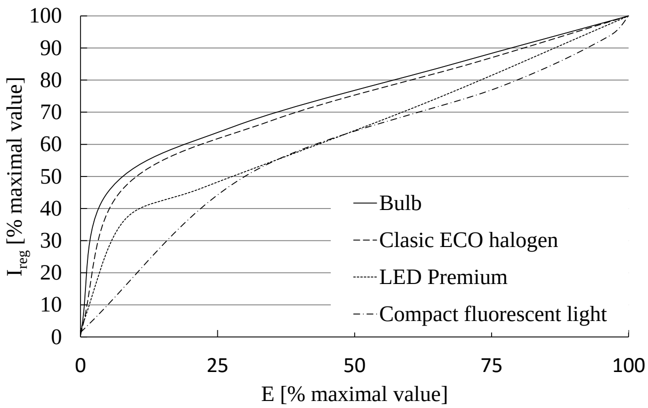


Fig. 8 dependence percentage current on the set regulation

To realize energy requirements and illuminance dependence on regulation level could help following figures.

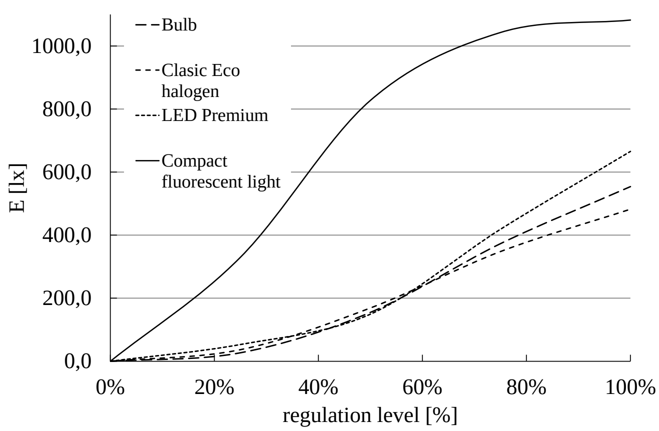


Fig. 9 dependence illuminance on the set regulation

Fig. 8 show illuminance dependence on the regulation level. As could be seen regulation curves for light sources except compact fluorescent light regulation curve are similar. The

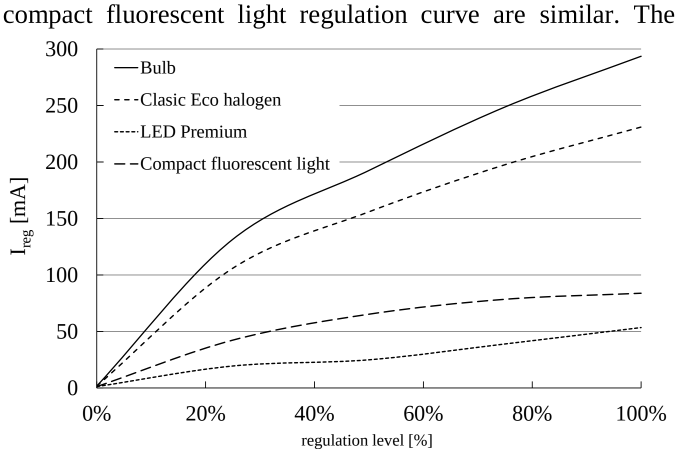


Fig. 10 dependence current on the set regulation

different curve is caused by control electronic inside light source which is very difficult to regulate.

Fig. 9 provide us with current depending on regulation level. With knowing grid voltage, 237 V, it indicates power consumption of each light source.

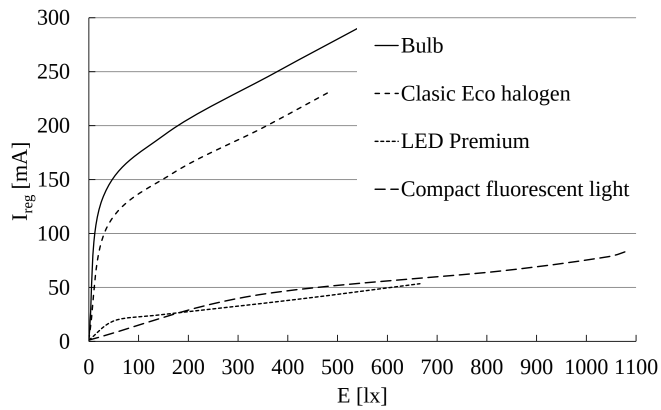


Fig. 7 dependence current on the illuminance

In Fig. 10 are depicted dependence between current and illuminance. These dependencies

Fig. 11 and Table 2 show energy consumption during fifty minutes cycle for each light source. The first cycle was calculated for the regulated light source. The second cycle was calculated as energy consumption without regulation.

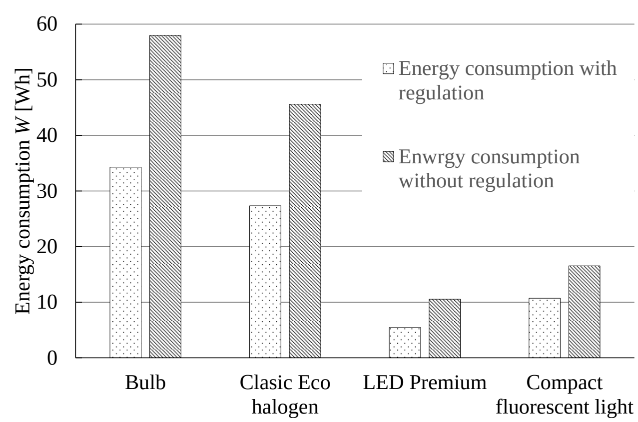


Fig. 11 energy consumption with and without regulation

Using Table 2 could be assumed that LED premium light source was able to save 48.8 % energy during the cycle with regulation. Instead compact fluorescent light was able to save only 35.3%. The explanation could be found in Fig. 5 which shows percentage current and it is obvious that percentage current of compact fluorescent light was in every step over percentage regulation level.

Table 2 energy consumption with and without regulation

	Bulb	Clasic Eco halogen	LED Premium	Compact fluorescent light
Energy consumtion with regulation [Wh]	34.3	27.3	5.4	10.7
Energy consumtion without regulation [Wh]	58.0	45.6	10.5	16.6
Percentage savings [%]	40.9	40.1	48.4	35.3

IV. Conclusion

This paper summarized standards used for lighting solutions. Energy consumption optimization required knowing characteristics of used light sources. The regulation system could be adapted according to these characteristics.

The next step of the research is identifying light sources used in administrative buildings. Also, the different regulation will be tested.

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