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Complex assessment of LED tubes

***Abstract**. In this paper, the authors are trying to complexly assess usage of LED tubes as replacement of linear fluorescent tubes. In the first part, advantages of LED tubes deployment are shortly described. Then comparison of its connection from electrical and safety point of view is done. Results of thermal measurement held in dust-proof luminaire follow. Based on this a confirmation of useful lifetime is provided. Light sources were measured in louvre and dust proof luminaires to compare luminances and light intensity distribution curves. With measured data, authors did economic analysis of three different lighting systems.*

Streszczenie.** Artykuł dotyczy wykorzystania tub LED zamiast świetlówek typu T8 zarówno w istniejącym oświetleniu, oprawach oświetleniowych jak i w nowych instalacjach. Na wstępie zostały wymienione podstawowe wady i zalety wykorzystania lamp LED lamp a następnie została przeprowadzona analiza pod względem instalacji elektrycznej i bezpieczeństwa. Wyniki pomiarów temperatury lamp i ocenę ich trwałości przeprowadzono przy ich pracy w pyłoszczelnych oprawach. Przedstawiono również luminancję i bryłę fotometryczną opraw pyłoszczelnych rastrowych z źródłami LED. Na podstawie zmierzonych danych zaprojektowano trzy systemy oświetlenia oraz przeprowadzono porównanie ekonomiczne całkowitych kosztów. **(Kompleksowa ocena tub LED)

Keywords: LED tube, fluorescent lamp
Słowa kluczowe: tuby LED, świetlówka liniowa

Introduction

The European Union and need of economical savings are forcing society to use highly effective light sources with small power consumption and maintenance cost. Linear tubes are widely used for more than 70 years, nowadays the most efficient version on market is T5. But there is still majority of older T8 systems in operation, most of LED tubes are therefore designed to replace them. Usage LED technology provides many benefits for customers, such as:

• High luminous efficacy - LED tubes have integrated driver and their overall lumen efficiency is about 95 lm/W, value for T8 tubes with inductive driver, depending on tube type, is between 70 and 80 lm/W.

• Flicker effect removal - light sources based on LED technology reduce or remove disturbing light flickering caused by low electricity quality, because LEDs are powered by direct current from a stabilized current source.

Fig.1. Measured tubes - discharge, LED transparent, LED diffuse

• Instant luminous flux starts and turns ON/OFF cycle independently - discharge tube's lifetime strongly depends on number of switching and moreover their light output became stable after minimum 5 minutes. LED tubes aren't affected by these phenomenon and therefore their usage with presence sensor to reach energy savings is possible.

• Low temperature operation - LED tubes are capable to work in very low ambient temperature, which increases efficiency and lifetime of LEDs. These tubes operation is independent on working position.

• Long lifetime - lifetime of LED tubes provided by manufacturers or resellers is usually between 25 and 50 thousand hours, based on L80 or L70 calculation. Discharge tubes lifetime on inductive ballast is about 15 000 hours only.

Some other important advantages and disadvantages are closely described in next chapters. The Comparison was made on sample of several 1200 mm long tubes – discharge, LED with transparent and diffused cover.

Electrical parameters

Replacing linear fluorescent tubes by LED tubes is a very simple operation in practice. Modern LED tubes do not require change of luminaires wiring, just a special igniter, which shorts its circuit. This connection prevents electrical shock hazard, while previous could cause an injury when installing new tube.

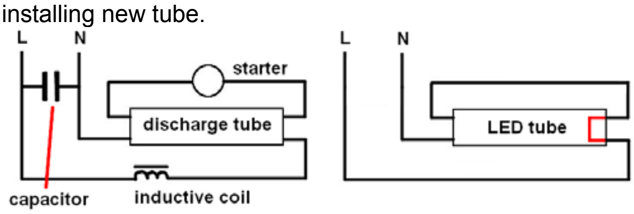

Fig.2. Standard fluorescent lamp connection, recommended connection of LED tube

Some LED tube producers/sellers don't provide installation manual where no further modification is needed except of short-circuit starter installation. After installation of LED tube into luminaire (connection diagram Fig. 2 on the left), very low power factor was measured. It was caused by compensating capacitor, which is involved in some luminaires to compensate low power factor of induction ballast. If capacitor is removed, power factor increases.

Table 1. The parameters of the luminaires

	P (W)	cos φ / λ (-)	S (VA)
fluorescent tube 2x36W	84,6	0,92 inductive	92,0
LED tube 2x18W	32,5	0,23 capacitive	141,3
LED tube 2x18W (capacitor disconnected)	32,3	0,92 inductive	35,1

This overcompensation causes higher losses in supplying line and can cause malfunction of circuit protection devices or resonance phenomenon in local power grid. Moreover LED tubes are not suitable for being used with electronic ballast.

By LED tubes deployment in old luminaires, original EU declaration of conformity from luminaires´ manufacturers is no longer valid, because their parameters and/or wiring were changed by using improper light source. From that point, responsibility for luminaire operation and safety passes from luminaire manufacturer to person who changed sources or LED tubes.

Thermal measurement

Expected result of this measurement was confirmation of declared LED tubes lifetime. For this purpose dust-proof luminaire was chosen because no air exchange is possible thus cooling of LED tubes is complicated.

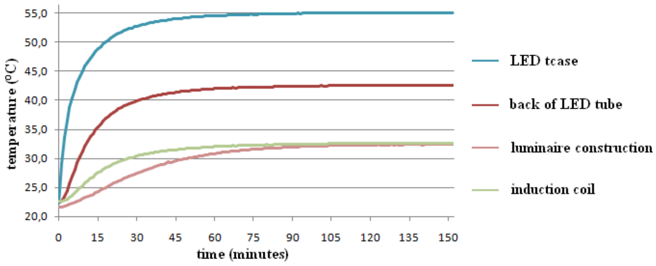

Fig.3. Heating diagram of LED tube in dust-proof luminaire

Measured t-case reached (in ambient temperature 23°C) 55°C, estimated PN junction temperature is about 60°C. Even if ambient temperature was 50°C, maximum temperature approved by LED tubes manufacturer, t-case temperature wouldn't exceed 85°C. Based on similar SMD LED's aging characteristics, estimated lifetime is conclusively above 50 000 hours.

Light output change, when using LED tubes

The most important parameters of light sources are parameters that characterize light output. For these measurements, two surface mounted luminaires were chosen:

- Modus LLX236Al with aluminium louvre, widely used in offices and school classrooms,
- VM elektro VM158A – dust-proof luminaire popular for lighting of car parks and industrial indoor areas.

Luminous intensity curves change

Luminous intensity curves determine illuminance level and uniformity on task plane. Fig. 4 shows significant change in magnitude and directional distribution of light. If LED tubes are installed in existing lighting system, this replacement will cause decrease of monitored parameters and if area was not previously over-lighted, then it would not meet hygienic requirements.

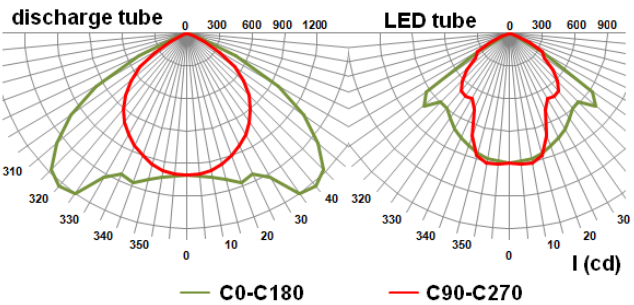

Fig.4. Luminous intensity curves of louvre luminaire with different tubes

Fig. 4 also proves that original data from luminaires´ manufacturer can't be used for project calculation and new measurement with LED tubes needs to be done.

Dust-proof luminaire has a cover to provide needed light distribution for fluorescent lamp. When transparent LED tube is installed light output is very irregular. It may bring better usage LED tubes with diffuse cover, but generally it shows that not all luminaires are suitable for LED tubes installation.

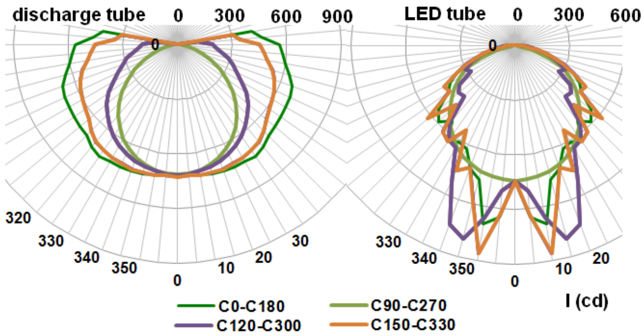

Fig.5. Luminous intensity curves of dust-proof luminaire with different tubes

Luminous flux behaviour

With change of luminous intensity distribution curves there is connected change of luminous flux and related parameters, such as efficiencies.

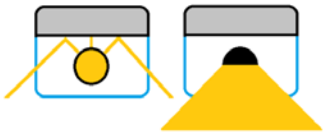

Fig.6. Increase of luminaire optical efficiency

Fig. 6 shows principle of luminaires optical efficiency increase using LED tubes. Rays go directly out of the luminaire and their energy is not decreased by reflections inside the luminaire.

The luminous flux behaviour during start-up can be found at Fig. 7. As temperature of LEDs rises, the luminous flux slightly decreases. It depends on luminaire construction and outdoor conditions. Changes are usually up to 10%.

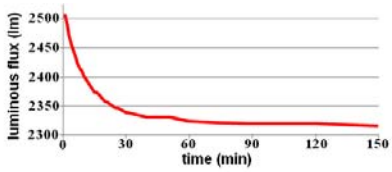

Fig.7. Luminous flux start-up

Table 2. Optical and electrical parameters of different tubes in Modus LLX236Al luminaire

	luminous flux	input power	optical efficiency	luminous efficacy
luminaire with 2x36W fluorescent	3690 lm	84,6 W	0,61	43,6 lm/W
luminaire with 2x18W LED tubes	2330 lm	32,5 W	0,75	71,8 lm/W

Luminance

Despite of lower luminous flux of LED tubes high luminance of LED chips can cause higher glaring. These parameters can't be qualified by valid standards, therefore just results of measurement are provided.

Table 3. Optical and electrical parameters of different tubes in Modus LLX236Al luminaire

	luminous flux [lm]	**maximum luminance [kcd/m^2]**	**average luminance [kcd/m^2]**
fluorescent tube 36W/840	3010	16	13
LED tube transparent 18W	1560	4 400	n/a
LED tube diffuse 18W	1450	200	15

Problem is caused by extremely high maximum luminance of LED chips. Diffuse and transparent tube luminance images are shown on Fig. 8 (on the left).

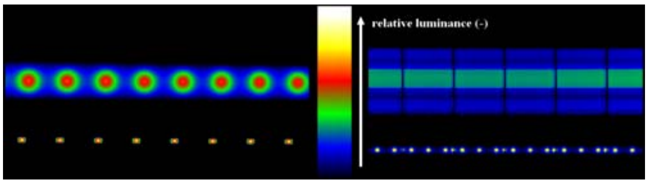

Fig.8. Luminance camera images

Fig. 8 (on the right) shows luminance analysis of fluorescent and transparent LED tube in louvre luminaire. LED tube doesn't use optical system of luminaire, therefore there is visible a high contrast between the reflector and the background.

Economic analysis

Main reason for buying expensive LED tubes is definitely savings in consumed energy. The comparison was made in 3 different projects considering new installation of lighting system:

• Class/office lighting system, average operation time of 4 hours/day, 5days/week

• Warehouse lighting system, average operation time of 12 hours/day, 7days/week

• Underground car park lighting system, average operation time 24 hours/day

As LED tubes´ luminous flux is lower, it was needed to use 30% more LED luminaires in every installation to reach same illuminance.

Financial input data are: price of electricity 4 CZK/kWh, LED tube 120cm 18W (lifetime of 50 000 hrs) 1500 CZK /pcs, fluorescent tube 36W (lifetime of 15 000 hrs) 50 CZK /pcs, price of luminaire 750 CZK/pcs, tube/luminaire replacement/installation 50 CZK /each.

It was chosen lighting system with 100 luminaires with fluorescent lamps, respectively 130 luminaires with LED tubes for comparison.

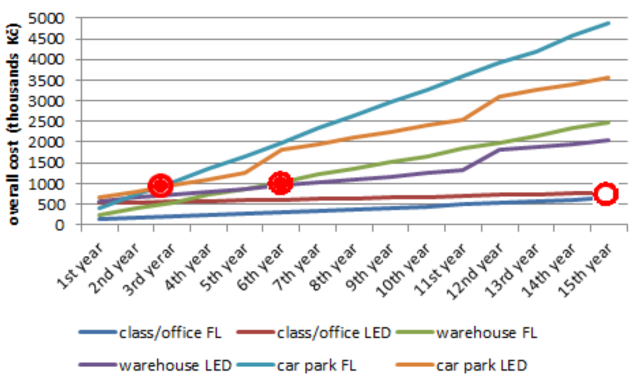

Fig.9. Economic comparison of overall cost

Overall cost (investment, energy, maintenance) comparison between fluorescent lamps (FL) and LED tubes is shown on Fig.9. Investment payback period is the shortest in the third case – nonstop operation for 3 years. Warehouse's payback period is 6 years. In first case payback period has not come in evaluated time period (15 years).

Conclusions

The objective of this article is to assess the LED tubes as replacement of T8 fluorescent ones.

In electrical connection, it's necessary to confirm proper connection, without compensation condenser.

From thermal point of view the cooling of LEDs in tube is sufficient to reach useful lifetime as declared, 50 000 hours. Question is if driver installed in the tube will not cause any earlier malfunction.

The optical properties of LED tubes change completely appearance and light output of the luminaires. Therefore new measurement or project calculations are needed before LED tubes are installed. For interior workplaces lighting, authors recommend only diffuse LED tubes to reduce possible glaring.

Last but not least there is an economic aspect: to reach maximum acceptable payback period of 10 years, minimum 3000 lighting hours per year, resp. 8 hours a day, is needed.

Concluding all facts LED tubes are capable to replace T8 discharge tubes, but further multi-aspect appraisal of each project is needed. Generally it's worth to deploy LED tubes in long time operation lighting systems with lower requirements on quality of light (because of glare).

Acknowledgments

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