Research of photoluminescent lighting system

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1. Introduction

The basic method of the escape routes marking on passenger ships is to apply strips made of photoluminescent materials, shining after removal of all existing external illuminating sources. To assure the correct visual guidance of the passengers and crew, these strips must be assembled in determined locations of communication routes and represent the determined photometric parameters after determined time. The strips made of the photoluminescent material create LLL system (low location lighting). The escape routes marking system on passenger ships and required luminance values after 10 and 60 minutes from the illumination removal has been determined by the standard [1]. In accordance with the standard requirements, the strips should be assembled on corridors' walls, stairway walls or stairs or else on the door leading to stairs, exits or dividing corridors' main zones. On corridors, except for the cabins' door, recesses of width under 2 m and connections with other communication routes, the photoluminescent strips should be assembled in such a way that after removal of all the external illumination they must complete the visual information about the escape route. The maximum interruption within the strips continuity should not exceed 2 m. The photoluminescent strips should be installed at 300 mm height above the floor or on the floor plane distant 150 mm from the wall. On the stairways leading to the escape exits, LLL system should be installed on walls at height not exceeding 300 mm from the base or on every stair plane. In any case, LLL system should be installed at least on one side of the communication route when it's width does not exceed 2 m and on both sides when it's width exceeds 2 m. Marking of the door located on the escape routes should unequivocally indicate positioning the handle allowing the door opening.

Fig.1. LLL system before and after removal of all external illumination.

After the removal of all external illumination, the photoluminescent strips should represent the luminance of at least 15 mcd/m^2 after 10 min and 2 mcd/m^2 after 60 min. (tab.1). These requirements relate to the strip of at least 75 mm width. In case of smaller strips, the luminance values can be respectively higher [1].

Table 1. Required luminance values for LLL system strips.

Time from removal of excitation [min]	Luminance [mcd/m^2]
10	15
60	2

The excitation conditions for the photoluminescent strips have been determined only for the laboratory measurements. The excitation source in that case is the fluorescent lamp having the colour temperature of 3000K assuring average illuminance on the examined sample surface of 25 lx. In realty the photoluminescent strips assembled on passenger ships operate in different illuminating conditions. Illumination of the communication routes is normally provided with use of the fluorescent sources of various colour temperatures or incandescent sources (including halogen ones). Taking into consideration the applied luminaires type, their location, applied light sources, method of assembling and interior arrangement, the illuminance values on strips surfaces is from over a hundred lux (e.g. 150 lx) up to several lux (eg. 10 lx). As a result, the photoluminescent strips can represent various photometric properties. Therefore it was necessary to carry out research and determine the influence of individual factors on the strips photometric properties. The measurements results analysis allowed determining the optimum methods for excitation of the photoluminescent strips applied on passenger ships.

2. Examination of photoluminescent strips

The measurements have been carried out for two photoluminescent materials of different photometric properties. The examined materials samples have been taken from two different ferryboats providing connection from Poland to Scandinavian countries. The principal active component of the material number one is zinc sulphide. This material belongs to the material group of average photometric properties and is characterised with the low luminance values after the excitation source removal. The material number 2 belongs to the material group of improved photometric properties. The active components of this material are rare earth compounds. Technologies applied during production of these materials allow obtaining the high level of the luminance and long time of the luminance decay.

The photometric examination of the photoluminescent strips allowing determining the influence of the spectral distribution of the light sources and illuminance on the luminance characteristics, have been carried out in the laboratory conditions in accordance with the appropriate standards [2, 3, and 4]. For the measurement purposes there has been constructed the laboratory station composed of luminance measuring instrument and computer set for data recording. The examined photoluminescent materials have been subject to excitation successively with the light of the halogen bulb ZH 50 W (colour temperature 3000K) and fluorescent lamps with three-band luminophor marked as 830 and 840 (colour temperatures 3000K and 4000K respectively) as well as with two-band luminophor marked as 640 (colour temperature 4000K). The spectral distribution of the luminescent lamps used for the examination has been presented on Figure 2.

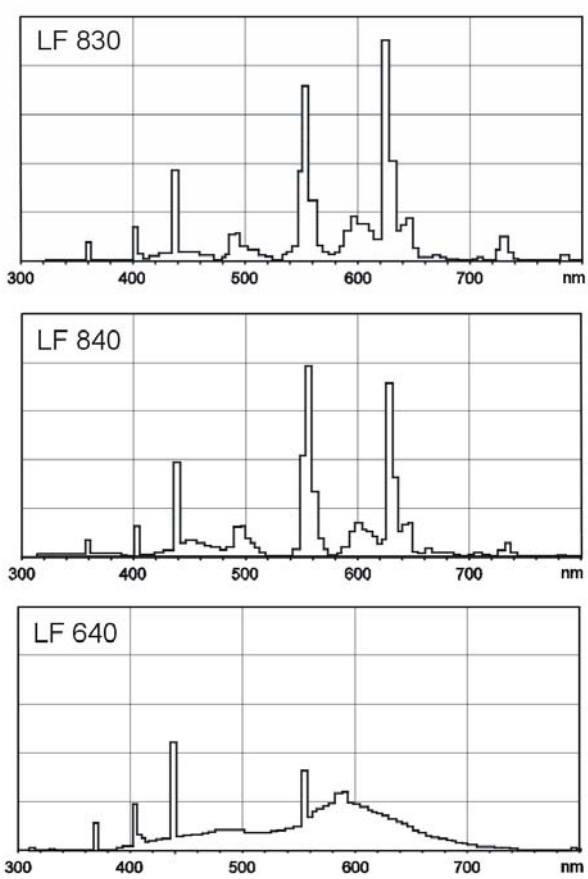


Fig.2. Spectral distribution of the fluorescent lamps used as the excitation sources of the examined photoluminescent materials.

The examination has been carried out for two illuminance levels: 12,5 lx and 25 lx. The level 12,5 lx (50% of 25 lx value), has been selected considering the frequency of such low illuminance levels occurrence at LLL strips surfaces in the ship's real lighting systems installations. In accordance with standard [1] requirements, all measurements have been carried out after 24 hours excitation time (before measurement samples have been hidden in dark for at least 24 hours). In every case, there have been determined the luminance decrease curves after removing the excitation light source and taken luminance characteristic values. The luminance measurement results of the examined photoluminescent material have been presented in Table 2.

Table 2. Results of luminance L [mcd/m2] decrease measurements of the examined photoluminescent materials. The results not meeting standard requirements [1] have been marked.

Excitation source	Time from removal of excitation t	Material no 1		Material no 2	
		Illuminance level E			
		12,5 lx	25 lx	12,5 lx	25 lx
halogen lamp ZH	10 min	[7,3]	[8,7]	16,0	26,9
	60 min	[1,6]	2,0	5,5	7,9
fluorescent lamp 830	10 min	[14,7]	17,3	24,9	38,6
	60 min	2,7	3,2	7,6	10,2
fluorescent lamp 840	10 min	16,7	19,4	27,0	43,4
	60 min	2,9	3,3	7,8	11,0
fluorescent lamp 640	10 min	16,9	19,5	29,5	44,4
	60 min	2,9	3,3	8,6	11,2

The luminance decrease curves have been presented on Figures 3 - 5.

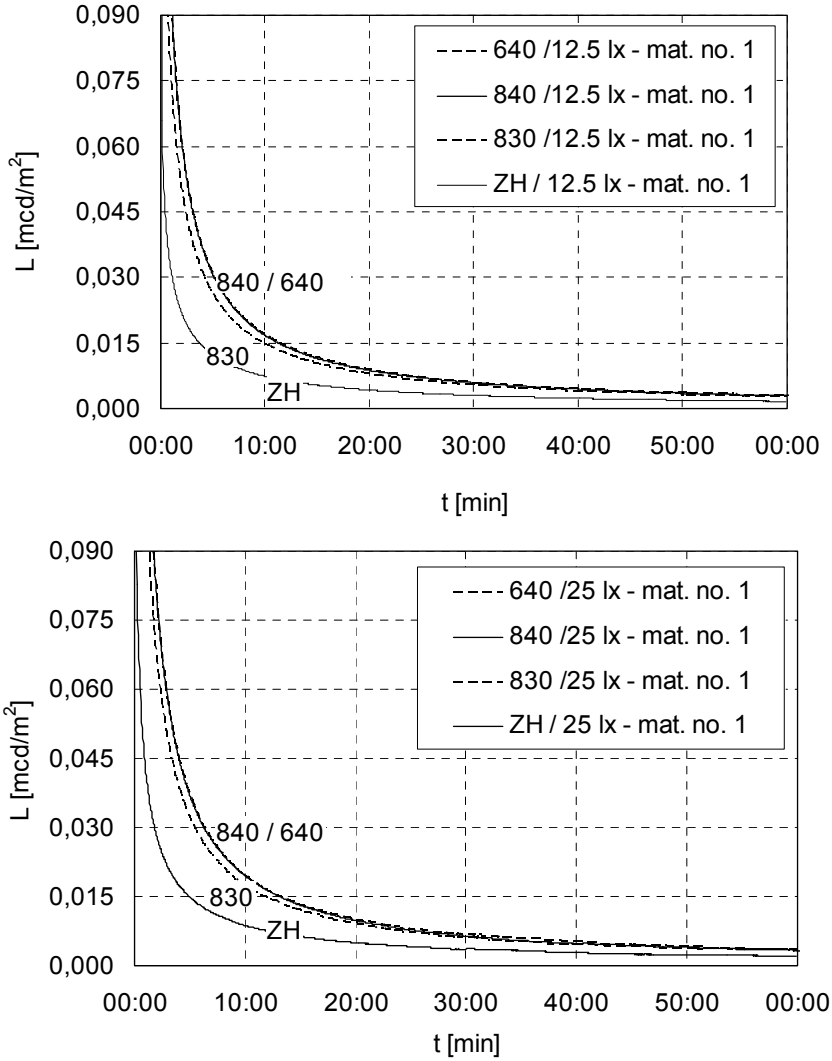
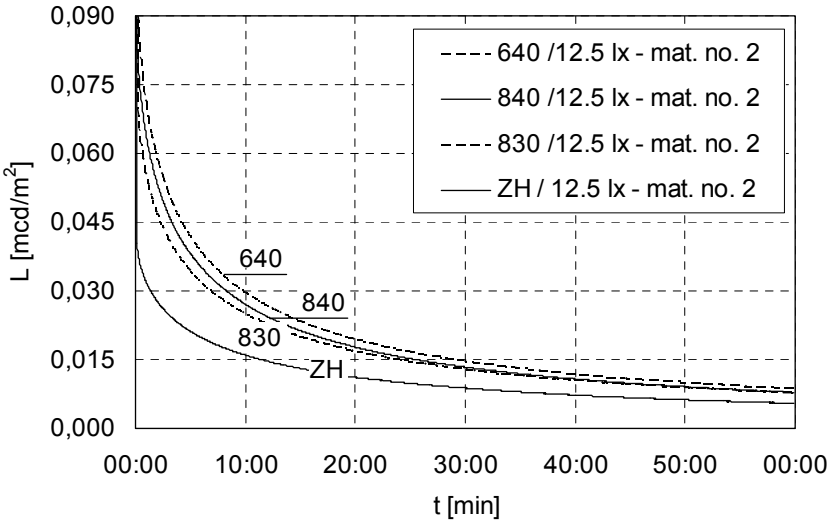


Fig. 3. The material no.1 luminance decrease curves for four excitation sources (fluorescent lamp 640, 840 and 830 as well as ZH halogen bulb) and two levels of illuminance on the material surface (12,5 lx and 25 lx). The luminance decrease curves for fluorescent lamps 840 and 640 obtain very similar luminance values for suitable times.



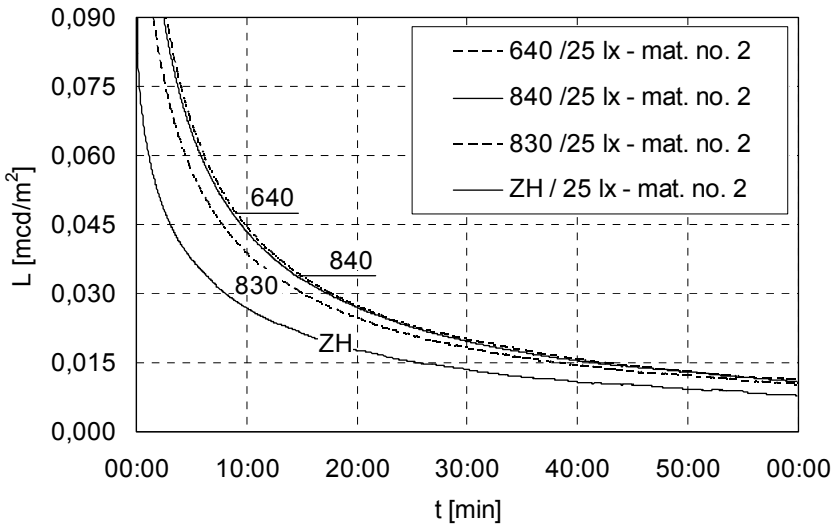


Fig. 4. The material no.2 luminance decrease curves for four excitation sources (fluorescent lamp 640, 840 and 830 as well as ZH halogen bulb) and two levels of illuminance (12,5 lx and 25 lx).

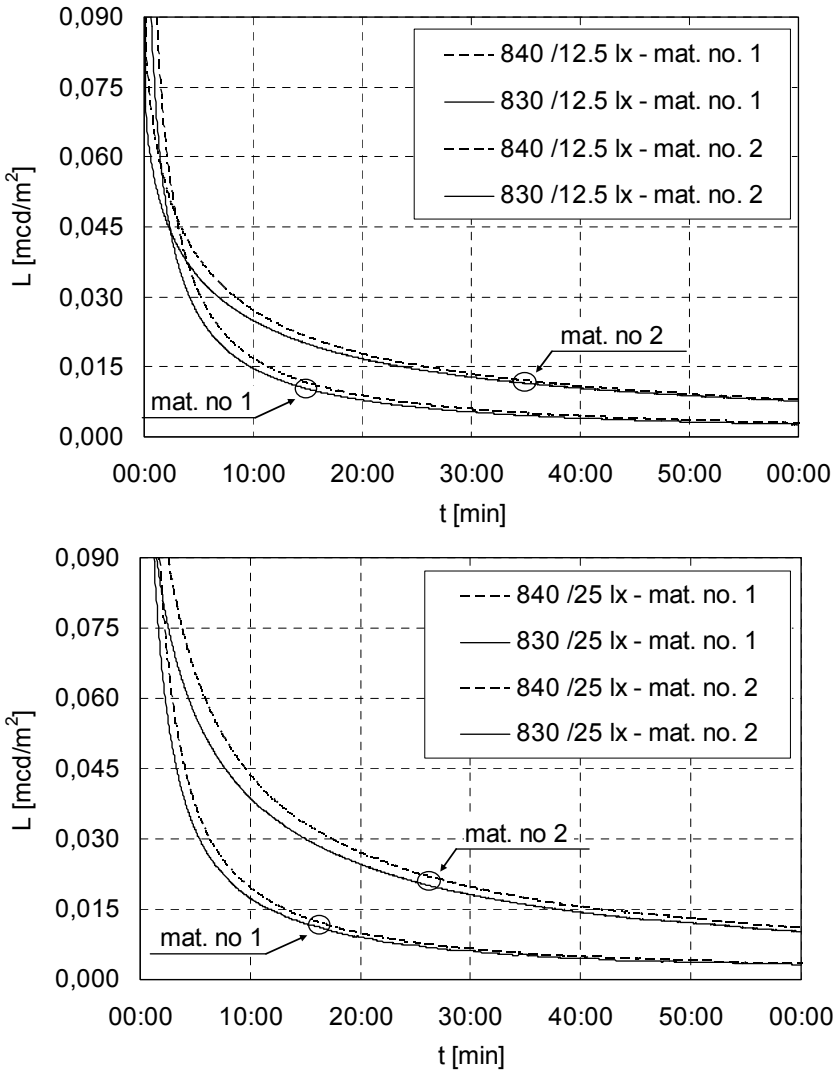


Fig. 5. The material no.1 and material no.2 luminance decrease curves for two excitation sources (fluorescent lamp 840 and 830) and one level of illuminance on the material surface (25 lx).

3. Analysis of obtained results

The carried out examination of the photoluminescent strips showed the influence of the illuminance and light sources spectral distribution on luminance values obtained after 10 and 60 minutes after the excitation source removal.

The requirements of the standard [1] are not met for the material number 1 with the incandescent light source independently of the illuminance value on the material surface. LLL materials examination is carried out in the laboratory conditions in accordance with the standard [1] requirements with the illuminance on the material surface 25 lx obtained from the fluorescent lamp of colour temperature 3000K. The illuminance level 25 lx is however insufficient for obtaining required luminance values with the excitation by incandescent light sources. Especially after 10 minutes from the excitation removal the obtained luminance values do not meet requirements of the standard [1]. In case of illumination with use of the incandescent lamps the illuminance levels on the surface of LLL strips manufactured with use of standard materials (with zinc sulphide as the active compound) should be higher than the illuminance the laboratory examination is carried out with. The increase of the illuminance level above 25 lx may cause obtaining the required luminance values.

In case of the fluorescent light source, the standard [1] requirements have been met for every illuminance level only by the material no.2 (material with rare earth compounds as the active compound). In case of the material no.1, the standard [1] requirements have not been met for the fluorescent lamp 830, illuminance level value 12,5 lx and after 10 min from the excitation removal.

The application of the material having improved photometric properties allows obtaining higher luminance values for every illuminance level and thus meets standard requirements in less advantageous illumination conditions e.g. illuminance lower levels on the LLL system strip.

The performed measurements showed a significant influence of the light sources spectral distribution on the obtained luminance values of photoluminescent materials and on the form of the luminance decrease curve after a determined time from the illumination removal. The light sources that emit bigger energy within the spectrum short wavelength part (fluorescent of colour temperature 4000K) allow obtaining higher luminance values independently of the considered illuminance level on the material surface. For the material marked as no.1 the examination did not show a significant influence on the chemical luminophor compositions (two-band and three-band luminophor), independently of considered illuminance level, on the luminance decrease curves. These curves for the fluorescent lamps 840 and 640 obtain very similar values for suitable times. For the material marked as no.2 the luminophor type was of importance only for the lower illuminance. During the illuminance increase on the material surface up to the value of 25 lx the differences in obtained luminance values were smaller.

For the light sources of low colour temperature values, the illuminance level influence on the obtained strips' luminance value after the excitation removal was more significant than in case of lamps having higher colour temperature values. When increasing twice the illuminance level, for the halogen bulb we obtain the luminance value increase by 19% (material no.1) and 68% (material no.2) after 10 minutes and by 25% (material no.1) and 44% (material no.2) after 60 minutes. For the fluorescent lamp with two-band luminophor of colour temperature 4000K with the same difference in the illuminance levels, there have been obtained relatively smaller increase of the luminance value by respectively 15% (material no.1) and 51% (material no.2) as well as 14% (material no.1) and 30% (material no.2).

The carried out examination allowed also to determine the influence of the excitation sources spectral distribution on the relative luminance changes speed, referring to the initial value present in the moment just after the excitation removal (Fig.6). The carried out

examination showed for the fluorescent lamps quicker luminance decrease in respect of the determined illuminance level and photoluminescent material type. Concerning the incandescent lamps the slower relative luminance decrease occurs. However, there must be pointed out that at the same illuminance level the luminance initial values occurring just after the excitation removal are for the incandescent lamps much lower than for the fluorescent lamps. It is why for the incandescent sources there occur most frequently difficulties with assuring the appropriate luminance for time 10 minutes after the illumination removal with meeting simultaneously the requirements after 60 minutes. The carried out examination has proved also that independently of the applied excitation source and photoluminescent material type, the relative luminance decrease is higher for the lower illuminance level on the strip surface. For the same levels of the illuminance and excitation sources, the standard material (no. 1) has been characterised by lower relative luminance decrease than the material of improved photometric properties (no. 2).

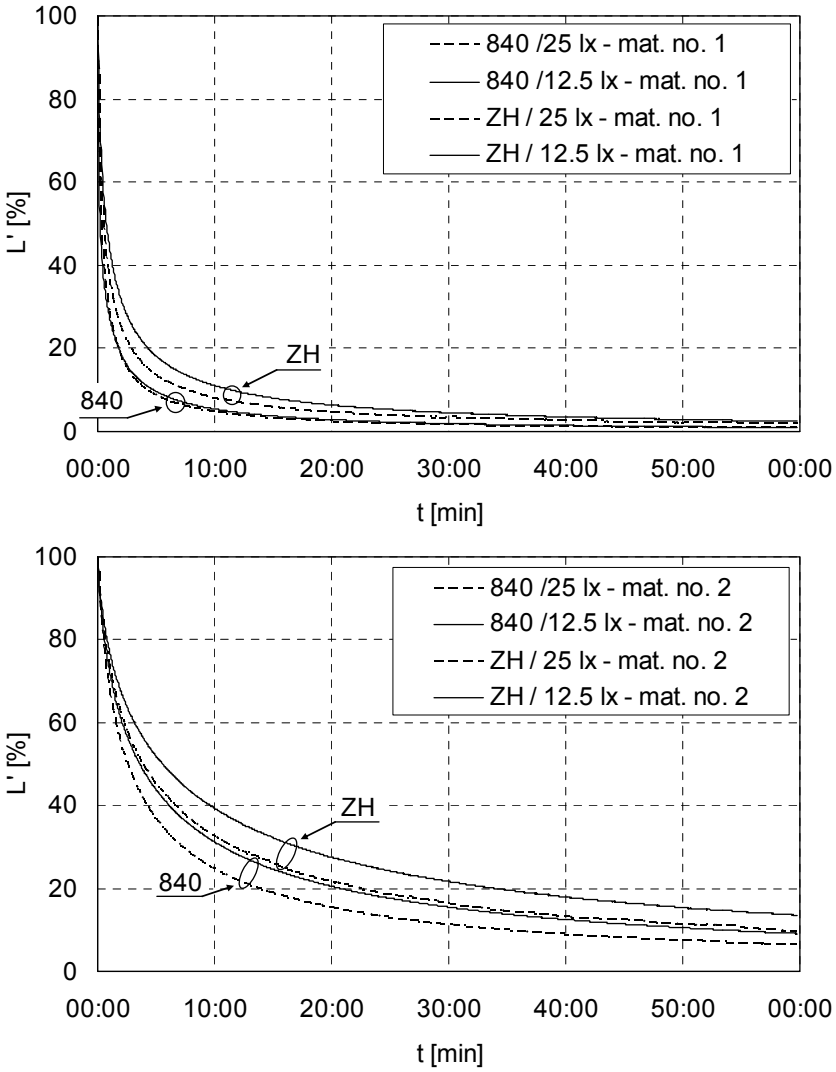


Fig.6. The luminance relative changes curves L' of the material no.1 and material no.2 for two excitation sources (halogen lamp ZH and fluorescent lamp 840) and for two illuminance levels on the material surface 12,5 lx and 25 lx.

4. Conclusions

The carried out examination shows the influence of illuminance level and spectral distribution on LLL strips photometric properties. The application of materials belonging to the group of materials of average photometric properties and characterised by small luminance values occurring after the excitation removal causes in many cases that the LLL

system installation does not meet the standard [1] requirement. The presented description of the materials properties does not include changes occurring within the exploitation. Carrying further enlarged examination could allow acquaintance with the exploitation characteristics of materials and determining on this base the LLL system maintenance factor.

Literature

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[2] PN - 89/E-04040.00 – Pomiary promieniowania optycznego. Pomiary fotometryczne. Wymagania ogólne
[3] PN - 83/E-04040.03 – Pomiary fotometryczne i radiometryczne. Pomiar natężenia oświetlenia
[4] PN - 83/E-04040.04 – Pomiary fotometryczne i radiometryczne. Pomiar luminancji
[5] Wandachowicz K., Zalesińska M., Optymalizacja parametrów naświetlania pasów fotoluminescencyjnych, Materiały XII Konferencji Naukowo-Technicznej "Zastosowania Komputerów w Elektrotechnice", Poznań 2007