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Working conditions for the low location lighting system on passenger ships

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Abstract

An emergency escape lighting system based on Low Location Lighting on passenger ships is required to ensure proper visual guidance to allow safe egress routes for evacuation of the ship's deck, even in very dense smoke. LLL system components must be installed in specific locations of the escape route, as well as exhibiting the required photometric characteristics within a specified time after triggering. The luminance decrease curve for materials used for the surfaces of LLL system components depends on a number of factors, e.g. spectral distribution of light sources and light exposure parameters. Ascertaining the influence of specific factors allows optimization of the proper means of material exposure to achieve the required photometric characteristics.

This article presents the normative requirements for LLL systems installed on passenger ships regarding their placement and photometric characteristics. It presents actual working conditions for LLL systems and laboratory test results for two photoluminescent materials, as well as formulating recommendations to ensure proper working conditions for the LLL system.

Introduction

As per the stipulations of the IMO Resolution (IMO, 1993) and the SOLAS Convention (SOLAS, 1974) of 1997, all passenger ships intended to carry more than 36 passengers are to be fitted with a low location escape route lighting system (Low Location Lighting; LLL). The LLL may utilize an electrically powered self-illuminating design, e.g. a system utilizing light emitting diodes, or use sections of strips made of photoluminescent materials, which mark the escape route after the main and emergency lighting is disengaged. Due to its reliability (electrical power is not required for operation), passenger ships commonly use LLL solutions based on photoluminescent strips for egress path marking. Figure 1 shows a section of the strip made of photoluminescent material, as well as the lighting effect after the main lighting goes out.

The LLL system is the final safety measure to ensure proper visual guidance, so that a safe egress route to leave the ship can be found, even in very dense smoke. Hence, this egress path lighting is located at a low height in relation to the floor level. An example of egress path marking via photoluminescent strips on a passenger ship is shown in Figure 2.

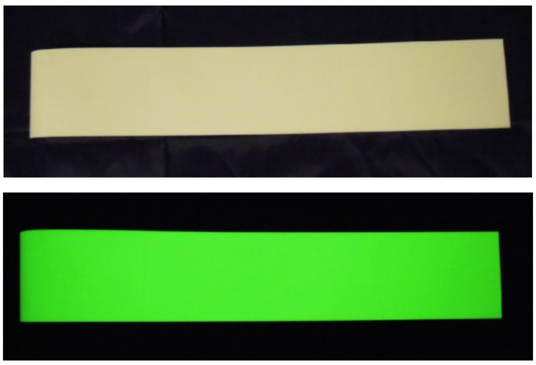

Figure. 1. Photoluminescent material strip view (top) and lighting effect of the strip after main lighting goes out (bottom)

The means of marking egress paths on passenger ships, as well as the required luminance values after the failure of the main lighting, are specified in IMO resolution (IMO, 1993) and ISO standard (ISO, 2010). Moreover, the standard (ISO, 2010) specifies the requirement for the assessment of lighting efficiency of the LLL system as regards field and laboratory testing.

Figure. 2. Marking of egress path with photoluminescent strips

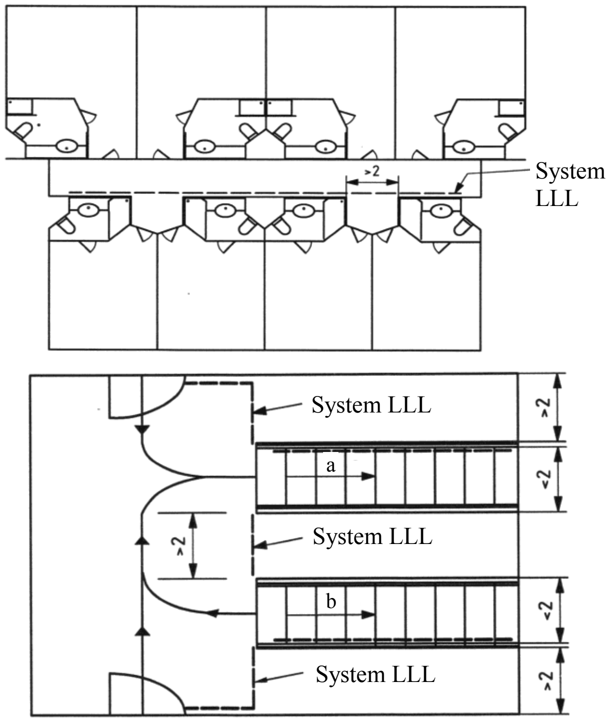

Figure 3. Placement of photoluminescent strips as per the requirements of ISO 15370:2010 (ISO, 2010). Top: Passageway with recesses no wider than 2 m; bottom: staircase wider than 2 m (a – downward, b – upward)

Normative requirements for placement and parameters of the LLL system

Normative requirements for placement of the LLL system

As per the requirements (IMO, 1993) and (ISO, 2010), the LLL system is to be installed on walls of passageways, walls or steps of staircases, as well as on doors leading to the deck exit staircases and separating the main passageway zones. In passageways, apart from cabin doors, recesses less than 2 m wide and connections to other passageways, the photoluminescent strips should be placed so as to provide constant visual information on the direction of the egress route in the event of the failure of the main lighting. The maximum gap between strip sections must not exceed 2 m. Photoluminescent strips should be installed 300 mm above floor level, or on the floor surface 150 mm away from the wall. On staircases leaving to emergency exits, the LLL system is to be placed on walls no more than 300 mm above floor level, or on the surface of each step. In each case, the LLL system should be installed at least on one side of the passageway if its width is less than 2 m, and on both sides of the passageway if its width is greater than 2 m. The labeling of doors located on the egress route should clearly indicate the location of the knob or opening handle. The placement of photoluminescent strips on an example passageway and stairway, as required by the standard (SOLAS, 1974), is shown in Figure 3.

Normative requirements for photometric characteristics of the LLL system

Visual guidance offered by the LLL system should be ensured for the entire time necessary to vacate all the decks and staircases of the ship. For this reason, the LLL system should operate for at least 60 minutes after triggering. Photoluminescent materials used for the strips should give a luminance (L) of no less than 15 mcd/m^2 at 10 minutes, and 2 mcd/m^2 at 60 minutes, after the failure of the main lighting. These requirements apply to strips no less than 75 mm in width. For strips with lower width (d' in [mm]), luminance values (L') must be increased as necessary for the specific operating times, based on the formula (1).

$$L' = L\left(\frac{75}{d'}\right)^2 \tag{1}$$

The required luminance values for strips based on their width for 10 and 60 minutes of illumination time, calculated on the basis of formula (1), are shown on a graph in Figure 4.

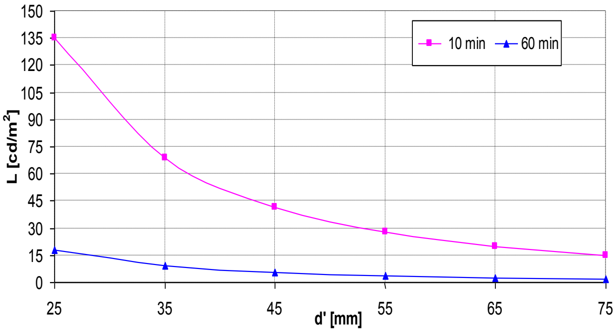

Figure 4. Correlation between the luminance value and width of photoluminescent strip

Actual operating conditions for the LLL system

LLL systems used on ships operate in very different lighting conditions. Measurements (Wandachowicz & Zalesińska, 2015) carried out by the authors indicate that strips made of standard photoluminescent materials, no less than 75 mm in width, are most commonly used on passenger ships. Illumination of passageways and stairways, and hence the light exposure for the photoluminescent strips, uses downlight luminaires, roof mounted louver fittings with milk glass coverings, and wall mounted lights with milk glass coverings. The most often used types of fluorescent lamps are tubular lamps and compact lamps with color temperatures ranging from 2,700 K to 4,000 K; however, incandescent lighting is also observed. The illuminance values on strip surfaces range from approximately 10 lx to over 100 lx. Wall color tones are usually warm. The lighting system, as well as the photoluminescent material, has a direct influence on the achieved luminance values after 10 and 60 minutes of main lighting failure, i.e. the meeting of the normative requirements. The use of standard materials and light sources with low color temperatures (2,700 K, 3,000 K) results in difficulties in achieving the luminance values required by the standard (ISO, 2010), especially at 10 minutes after lighting failure. There are usually no difficulties in meeting the standard requirements for luminance after 60 minutes following lighting failure.

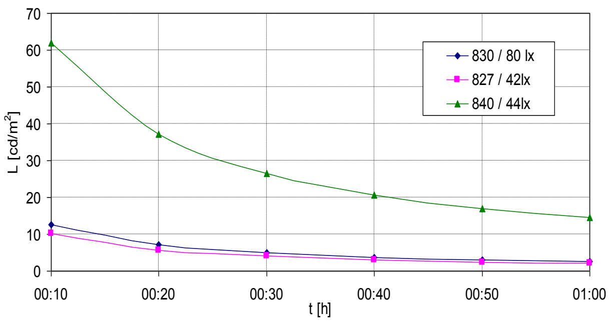

Figure 5. Example luminance decrease curves for different photoluminescent strips in actual operating conditions and exposed to fluorescent lamps with color temperature 4,000 K, 3,000 K and 2,700 K

Examples of luminance decrease graphs for photoluminescent strips in actual operating conditions are shown in Figure 5.

According to the requirements of the ISO standard (ISO, 2010), the correct operation of the LLL system should be tested under normal operating conditions, at least every five years, by persons authorized to perform such testing. The standard (ISO, 2010) requires the use of calibrated luminance meters with the correction error of the spectral photometric head established by the International Commission on Illumination CIE (CIE, 1987) as f_1, which specifies that the discrepancy between the spectral sensitivity curve of the photodetector and the spectral sensitivity of the human eye, $V(\lambda)$, must be no greater than 8%, as well as specifying a range of measurement between 1 mcd/m^2 and 45 kcd/m^2 . Whereas the standard is very precise as regards the specification of parameters of the measuring instrumentation, it does not specify the measurement procedure in any way, both with regard to its technical conditions – the dimming of main lighting, or merely darkening the measuring point – as well as the place of measurement. The standard (ISO, 2010) only specifies the minimum number of measurement points per deck. The number of measuring points should not be less than two. Regarding the placement of measurement points, it is only specified that measurements should not be taken in areas where the material would be exposed to natural light, and that the photoluminescent strips should be exposed for 24 hours before all measurements.

When selecting measurement points, experience and know-how gained during laboratory and field testing are relevant. Based on the measurements of illuminance on the strips, ascertaining the color temperatures of light sources used for strip exposure, as well as the characteristics of the strips, it is possible to select measurement points in which normative luminance requirements may not be met.

Laboratory testing of LLL system characteristics

Achieving the required luminance values 10 and 60 minutes after main lighting failure is primarily influenced by such parameters as: strip material, exposure time, and the spectral composition of strip illumination.

To ascertain the influence of particular factors on the operation of the LLL system, laboratory tests

(Zalesińska & Wandachowicz, 2015) were performed for two photoluminescent materials exposed to illumination with different spectral compositions.

The main active component of the first material is zinc sulfide. It is classified as a material with average photometric properties, featuring low luminance values after the removal of the activator. The second material features improved photometric properties. The active substances in this material are rare earth elements. The technologies used to manufacture these materials allow very high luminance and long luminance fade times to be achieved. The strips were exposed to illumination by fluorescent lamps with color codes 830 and 840, and a 50 W halogen lamp (color temperature 3,000 K). The materials were subject to illuminance ranging from 3.5 lx to 25 lx over a 24 hour period.

Example luminance drop curves for tested illumination sources and illuminance on the material surface equal to 12.5 and 25 lx are shown in figures 6–9. Figures 10 and 11 show luminance drop curves for fluorescent lamp color No. 840, for different illuminances on the surface of tested materials.

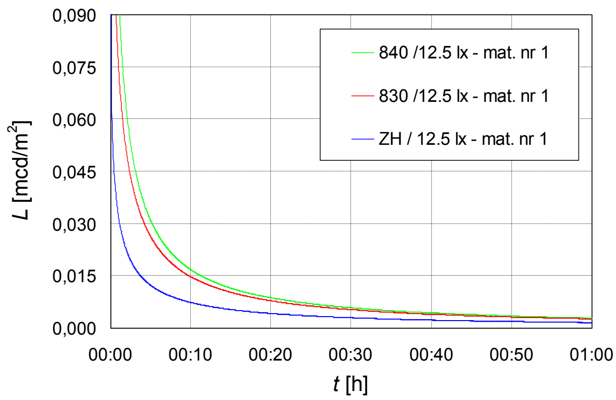

Figure. 6. Luminance drop curves for material 1 and all sources of illumination with illuminance for strip surface equal to 12.5 lx

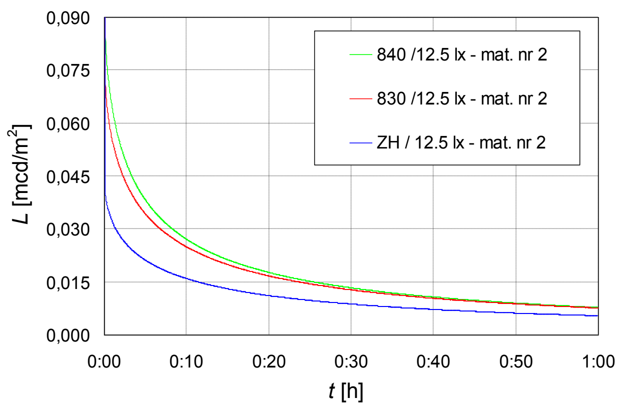

Figure 7. Luminance drop curves for material 2 and all sources of illumination with illuminance for strip surface equal to 12.5 lx

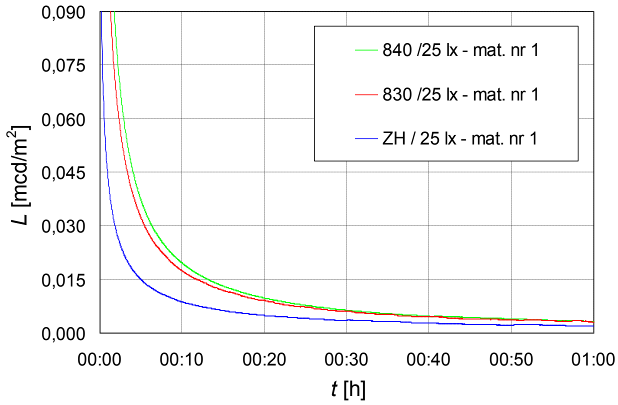

Figure 8. Luminance drop curves for material 1 and all sources of illumination with illuminance for strip surface equal to 25 lx

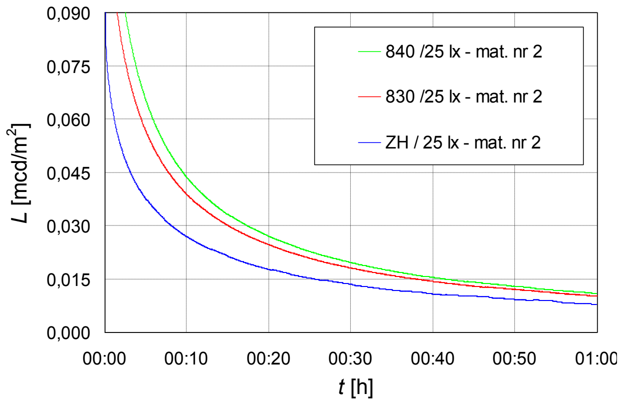

Figure 9. Luminance drop curves for material 2 and all sources of illumination with illuminance for strip surface equal to 25 lx

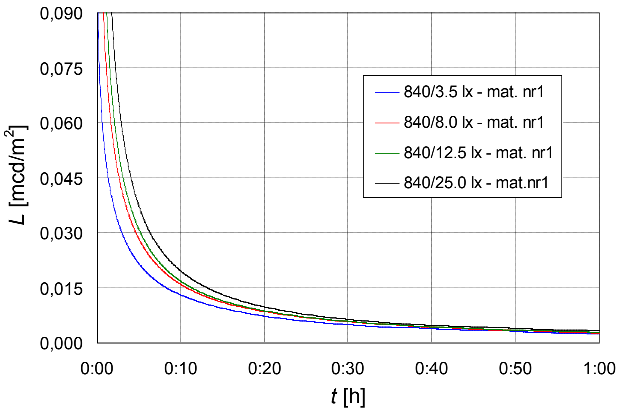

Figure 10. Luminance drop curves over time after removal of activator for material 1 exposed to fluorescent lamp color 840 and different illuminance

The completed laboratory measurements show that the photometric characteristics of materials are influenced by: the spectral distribution of the source of illumination, the illuminance value on the surface of the tested sample, and the chemical composition of the material. For material No. 2, with

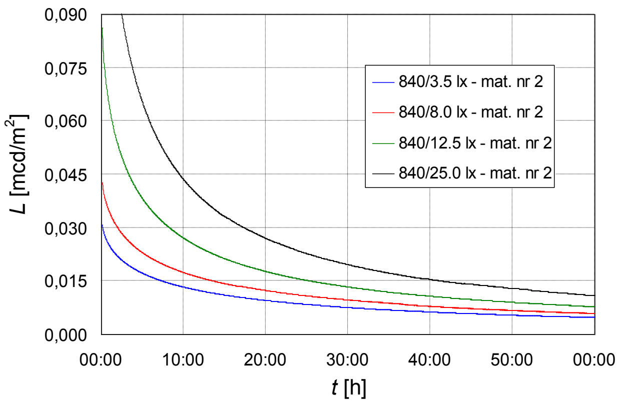

Figure 11. Luminance drop curves over time after removal of activator for material 2 exposed to fluorescent lamp color 840 and different illuminance

improved photometric characteristics, the influence of illuminance was greater than for material No. 1. The differences between the measured luminance of tested material samples increased along with the measured illuminance on the material's surface. For fluorescent lamps and an illuminance of 25 lx, after 10 minutes after exposure had ceased, the luminance of material No. 2 was approximately 2.2 times greater than the luminance of material No. 1, and after 60 minutes it was approximately 3.2 times greater. For the halogen lamp, the values were: 3.2 and 4.6, respectively. At an illuminance level of 12.5 lx, the material luminescence after 10 minutes for fluorescent lamps was approximately 1.7 times greater, while it was 2.2 times greater for the incandescent lamp. After 60 minutes, the same values were 2.8 and 3.5 respectively. For material No. 1, illuminance had less influence on the shape of the luminance drop curve in time after illumination had ceased. Material No. 1 was also characterized by a quicker decrease in luminance over time after illumination had ceased.

Optimal working conditions for the LLL system

The aim of the LLL system is to ensure proper visual guidance after disengaging the main lighting, by achieving proper lighting of photoluminescent surfaces evaluated on the basis of luminance measurement after 10 and 60 minutes of illumination. To create optimal working conditions for the LLL system, basic principles regarding the selection of the lighting system, photoluminescent materials and interior colors should be followed, and periodic maintenance of the system should be carried out. To ensure the best possible working conditions of the LLL system, the authors of this article recommend:

- Use a lighting system for passageways and stairways that ensures the maximum possible illuminance of the strip surface. The illuminance value of strip surface is influenced by: the luminous intensity distribution of the luminaire illuminating the strip, the luminous flux of the luminaire, i.e. the luminous flux used in the luminaire of the light source, the number of luminaires, as well as the placement of the luminaire. From the standpoint of optimum exposure conditions for the LLL system, it is necessary to use luminaires with a broader light distribution, and to allow to them to illuminate the walls on which the strips are installed, as well as the floor of the passageway. Luminaires should be mounted on the ceiling or on the opposite wall in relation to the location of the LLL system. Light sources used in luminaires should provide sufficient luminous flux to achieve the required illuminance. It is no longer recommended to use incandescent lighting for passageways and stairways.
- Carry out periodic maintenance of the lighting system. The maintenance of the lighting system is very important for keeping the required illuminance levels. It is necessary to periodically clean the luminaires and replace the light sources. The entire set of light sources should be replaced (all light sources replaced at the same time). The luminous flux of all light sources decreases with use. It is assumed that the lamps should be used until their luminous flux decreases to no less than 80% of the initial value (for tubular lamps with a tri-band luminophore, e.g. color No. 840, the time frame is approximately 15 thousand hours). If the passageway lighting system works continuously for 24 hours, the total illumination time per year is 8,760 hours. This means that all tubular lamps should be replaced after two years of operation at the latest. Compact lamps usually have lower lifetimes.
- Use light sources with cooler light color. The photoluminescent strip luminous intensity is influenced, apart from illuminance, by light color. Higher intensity is observed after exposing strips to sources emitting white, cool white, or daylight colored light (e.g. fluorescent lamps color No. 840). The strips show lower luminous intensity when exposed to incandescent lamps or fluorescent lamps emitting a warmer tone light (e.g. fluorescent lamps color No. 827 and 830). This may possibly lead to a situation where, even at comparatively higher illuminance, standard requirements are not met. From the

standpoint of the LLL system operation, it is recommended to use white fluorescent lamps (color code 840, color temperature Tc = 4,000 K).

- If possible, use photoluminescent materials with improved photometric characteristics. Using such materials allows, even at worse exposure conditions, at lower illuminance and lower color temperature of light sources, the achievement of higher luminance and longer luminance fade times than standard materials. Given the commonly used photoluminescent materials with average photometric properties, it is of particular importance to ensure a sufficient level of illuminance, and to use light sources with a higher color temperature (min. 4,000 K). The use of materials with improved photometric characteristics ensures that the required luminance is achieved at lower illuminance and makes for a much broader selection of lighting and interior colors, especially for the hotel section of the vessel.
- If possible, use cooler color tones for the walls and floor.
- Perform maintenance on the photoluminescent strips as per the manufacturer's recommendations.

Conclusions

Proper visual marking of egress routes is a basic condition for effective and quick evacuation of ship decks after the failure of main and emergency lighting. Due to the placement of the marking in close proximity to the floor, it is possible to find the escape route even in heavy smoke. Ensuring proper lighting of the photoluminescent strips which form the LLL system, evaluated by means of measuring the luminance of strip surfaces after specific times of illumination, requires using appropriate photoluminescent materials, as well as selecting proper means of light exposure for the system, focusing on the achieved illuminance and the spectral composition of the strip illumination.

Thus, to obtain a high efficiency LLL system operating in real world conditions it is important to:

- Use a lighting system for the passageways and stairways that ensures the maximum possible illuminance of strip surfaces;
- Carry out periodic maintenance of the lighting system;
- Use light sources with cooler light color;
- Use photoluminescent materials with improved photometric characteristics;
- Use cooler color tones for walls and floors;
- Perform maintenance on the photoluminescent strips as per the manufacturer's recommendations.

The authors' research of the efficiency of LLL systems in the laboratory and in real conditions was related only to photoluminescent strips exposed to incandescent and fluorescent light sources. Improvements in LED technology mean that LEDs are commonly used today for lighting. With time, they will also be commonly used as passageway and stairway lighting on passenger ships. Therefore, the future research of the authors of this paper will focus on assessing the impact of this type of light source on the efficiency of LLL systems.

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