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THE RECONSTRUCTION PROJECT OF LIGHTING DEVICES AT THE KRASNOSELSKAYA STATION OF THE MOSCOW METRO

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ABSTRACT

The current state of the Moscow Metro station of the first priority that became operational in 1935 does not allow it to be called a cultural heritage site. This is due to the fact that lighting modernisation carried out by the Moscow Metro was based on fluorescent lamps. Such lamps are more energy efficient compared to incandescent lamps, which were used in original lighting devices specified in the Station Lighting Project developed by architects and designers. However, they significantly changed the station appearance, transforming the originally designed station with entire well-visible architectural tectonics[1] from the standpoint of lighting into a simple, flat, unremarkable, and little loaded station of the Moscow Metro.

This paper describes a method of lighting reconstruction at Krasnoselskaya station by means of original lighting devices that meet modern standards and requirements for cultural heritage sites. The historical analysis on the development of the station lighting environment was conducted during its operation in order to understand what kind of station was conceived by its architects, what changes occurred with its lighting over time, and how it influenced the station appearance and safety of passenger transportation.

Keywords: Moscow Metro lighting, lighting reconstruction, lighting device, illuminance, unified glare rating, lighting installation, dome lamp

1. INTRODUCTION

Lighting modernisation at spaces of the first-priority Moscow Metro stations representing cultural heritage sites is a very special task. In this case, the main problem is that the station appearance should correspond to the original appearance in order to preserve the status of a cultural heritage site (Fig. 1); however, this is rarely seen today: modernisation aimed at improving energy efficiency of lighting installations (LIs) often significantly

[1] The tectonics is a constructional-spatial pattern, a structure, a building installation (a platform hall in this case), and a real relation between a stress-bearing structural unit and a bearing carrier.

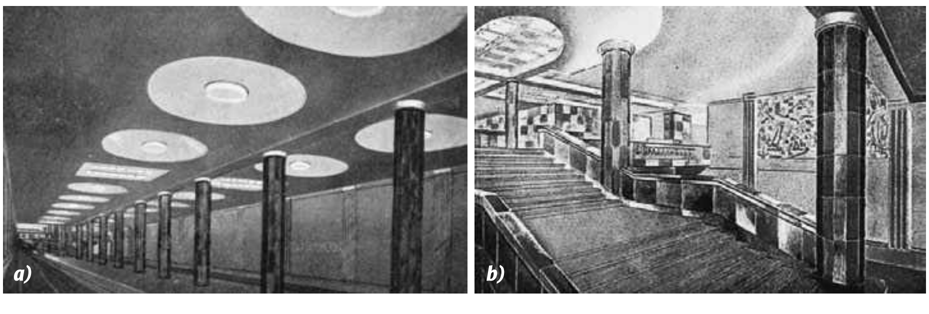


Fig. 1. Project draft of Krasnoselskaya station: (*a*) platform, (*b*) stair flight of the connecting passage

Fig. 2. Appearance of the platform at Krasnoselskaya station: (*a*) 1935, (*b*) 1950, (*c*) 1970, (*d*) 2018

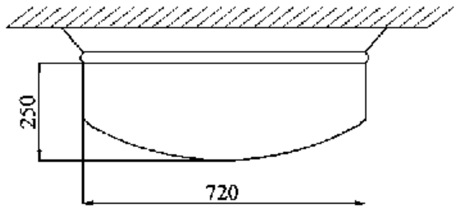
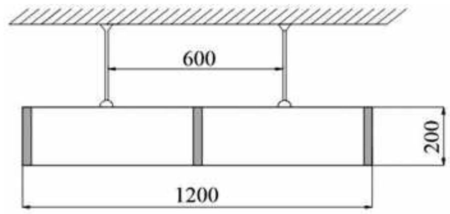
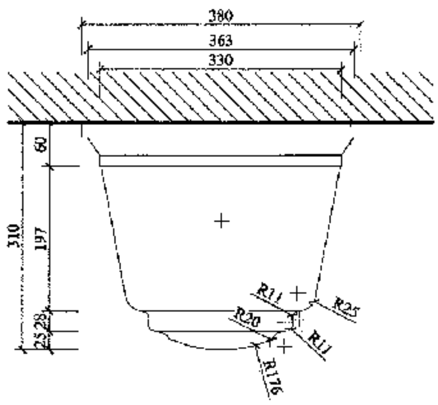
changed the station appearance which was not for the better (Fig. 2). Meanwhile, lighting modernisation has led to the fact that existing LIs do not meet any modern lighting regulations [1], which is absolutely unacceptable. After all, the Moscow Metro today is a space, where thousands of people move every day, and ensuring their safety is the primary task for lighting reconstruction.

A similar situation happened with one of the first stations of the Moscow Metro – Krasnoselskaya. Lighting modernisation of Krasnoselskaya station has led to the fact that the current state of the station does not allow it to be called a cultural heritage site. In order to return the station to this status, a complete lighting reconstruction is required that is impossible without answering the following questions: what kind of station was conceived by its architects and designers? What lighting devices (LDs) and light sources were used? What illuminance values were its designers looked at? How did the station lighting environment change during the whole operation period? The archival documents of 1935 helped to give answers to these and many other questions [2].

Krasnoselskaya station was opened on 15 May 1935 with 12 more first-priority Moscow Metro stations. According to architects from Workshop 2 of the *People's Commissariat of Heavy Industry* – B.S. Vilenskiy, V.A. Yershov, V.F. Skarzhinskiy – and according to the artist Ya. Romas, the station should look as shown in Fig. 1 [2]. The architects sought to visually highlight round and square caissons located on the ceiling of the station hall by setting the tectonics for a long and simple room from the standpoint of the architectural design. The specific emphasis was placed on the connecting passage stairway: the ceiling above was decorated with a ring-shaped hinged structure as if floating in the air due to an original lighting solution. The pictures of 1935 (Fig. 2a) show that architects could not implement their ideas in the station design; although its appearance was close to the original project, it still did not fully correspond to the project (Fig. 1). Today we observe even more differences from the design drafts in the station appearance (Fig. 2d). It is difficult to recognize the old station in the pictures of 2018 despite the fact that all constructive elements of the station (caissons, limestone-trimmed columns, wall tiles, passing zone ring-shaped ceiling) remained in almost perfect condition (Figs. 2, 3). It is obvious that all significant changes in the station appearance are associated with modernisation of illumination installations.

It is known that (60–150) W incandescent lamps (ILs) were widely used as a light source in typical LDs of the first Moscow Metro stations [2]. Two types of LDs were used to illuminate the platform hall at Krasnoselskaya station; their main specifications are presented in Table 1. It was decided to replace round dome lamps with hanging balls in the 1950s; IL LDs were replaced with fluorescent lamp (FL) LDs later in the 1970s. As a result, the plat-

Table 1. Main Specification of Historical Luminaries of 1935

No.	Luminaire name	Luminaire draft	IL quantity and power (pieces × W)	Efficiency (%)
1	Dome lamp *D* = 720 mm		6 × 100 6 × 150	55
2	Hanging cylinder		6 × 60	67
3	Passing zone luminaire		1 × 150	65

form hall has changed out of all recognition: FL luminaries were installed in a line between columns that significantly increased illuminance on the floor of the platform hall but completely distorted its appearance.

According to the original project (Fig. 3), ILs were installed along the contour line of the ring-shaped awning behind the opal plates in the connecting passage; column capitals in the connecting passage were decorated in the same way (Fig. 4a). This design solution allowed creating the effect of light coming out of nowhere and the feeling that the ceiling and columns were floating in the air; however, such a decision was refused due to energy savings after lighting modernisation in the 1970s.

Only 2 luminaries that illuminate the passing zone survived from all first LDs described above; they operate as emergency lighting at the modern station (Fig. 4b); other survivors are several opal plates installed in the upper part of a column (Fig. 4a). All other LDs were lost.

2. METHODS

Krasnoselskaya station was modelled in *Dialux 4.13* based on these data [3]; lighting specifications were calculated for the LI of 1935; all results are shown in Fig. 5. The luminous intensity curve (LIC) of an authentic 60 W IL LD was used to calculate illuminance values [4]. The calculation showed that horizontal illuminance values on the floor surface in the platform hall and in the connecting passage fully correspond to the standards given in Table 2 [2].

In addition to values presented in Table 2, the unified glare rating (UGR) (Table 3) was determined at 4 key points with the most uncomfortable visual conditions, the values of which indicate that LD used in 1935 brought some visual discomfort to passengers and drivers [2]. It should also be noted that the total power consumption of the LI in 1935 was almost 46 kW.

Fig. 3. Appearance of the connecting passage stairway at Krasnoselskaya station: (*a*) 1935, (*b*) 2018

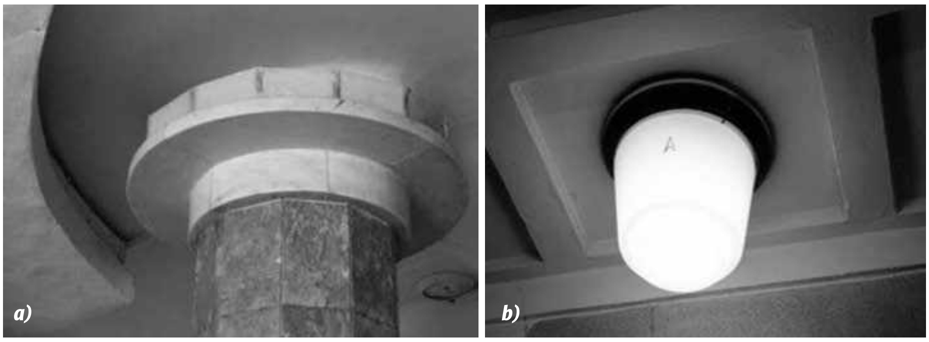


Fig. 4. First LDs of Krasnoselskaya station that survived to date: (*a*) opal plates used for lighting decoration of the stair flight, (*b*) luminaries of the connecting passage

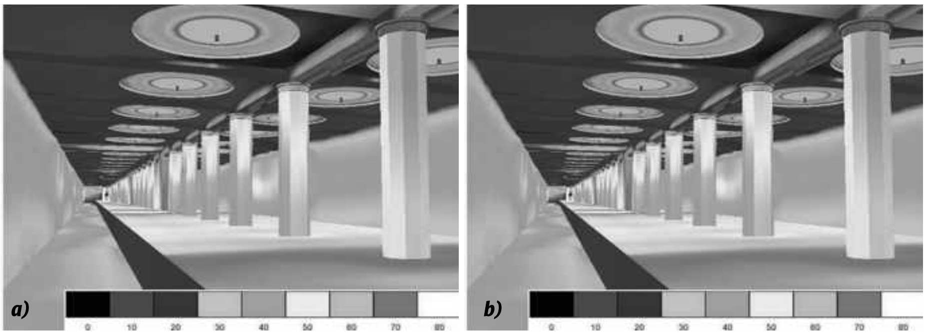


Fig. 5. Results of lighting calculation for the LI in 1935: (*a*) platform hall, (*b*) connecting passage

The same calculation was performed for the current LI at Krasnoselskaya Station, where *Osram* 58 W FL luminaries, which are installed by 3 pieces in a line, were used with the correlated colour temperature of 2700 and 4000 K, the length of 1500 mm, and the luminous flux of 5000 lm. The luminous intensity curve given on the company's website was used to calculate illuminance values [5].

The calculation and measurement results show that the illuminance regulations are met only in the centre of the platform under luminaries. The illuminance rate falls down to 120 lx with more distance from the centre (Fig. 6), which does not comply with the current industry standards of metro lighting (Table 2) [6]. The illuminance calculation and measurements in the connecting passage showed that the illuminance regulations were met in this part of the station. Meanwhile, the values of the unified glare rating given in Table 3 do not exceed the regulations by more than 20 % and therefore meet the standard norms. The total power consumption of LDs of the current LI is 11330 W, which indicates that the efficiency of the new LI is almost 4 times higher than the original illumination installation efficiency.

The given analysis shows that, in the case of reconstruction of the LI at Krasnoselskaya station, the following difficult problems should be resolved:

- Safe illuminance levels in all station zones;
- Elimination of discomfort created by LDs according to the current industry regulations;
- Identification of main architectural elements of the station platform hall (round and square caissons);
- Return of lost lighting decoration of the stairway in the passing zone;

Table 2. Specified and Calculated Lighting Values in Different Zones at Krasnoselskaya Station

Zone	Platform halls			Connecting passages between stations			Escalator combs and stair flights		
	1935 II	2018 II	Proposed II	1935 II	2018 II	Proposed II	1935 II	2018 II	Proposed II
Rate-setting surface	Floor surface			Floor surface			Step level		
Specified value of horizontal illuminance (lx)	50	200		60	100		–	100	
Calculated value of horizontal illuminance (lx)	60	190	200	60	125	100	37	90	120

Table 3. Specified and Calculated UGR Values at 4 points under the Most Uncomfortable Vision Conditions for Passengers and Drivers

Position in space	Specified UGR value	Calculated UGR value		
		1935 II	2018 II	New II
View field of a passenger standing on the floor of the platform hall	20 (excess is allowed by 20 %, i.e. at most 24)	26	22	23
View field of a passenger standing on the stairs of the platform hall		26	23	22
View field of a passenger standing in the connecting passage		22	22	22
View field of a driver entering the station		26	24	22

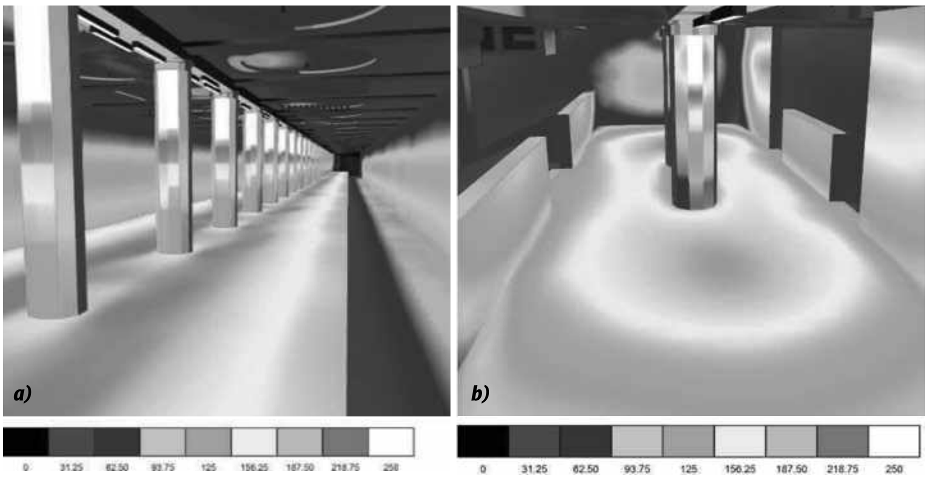


Fig. 6. Results of lighting calculation for the LI in 2018: (*a*) platform hall, (*b*) connecting passage

• Ensuring visual compliance of new LDs with lost luminaries as per the project of the 1930s.

Since illuminance of the platform hall needs to be increased by almost 4 times in comparison with the illumination installation of 1935, it is obvious that a simple increase in the luminous flux of the light source would lead to a higher luminance of LDs and to a higher unified glare rating. Therefore, the solution of the above tasks would require significant structural changes in LDs.

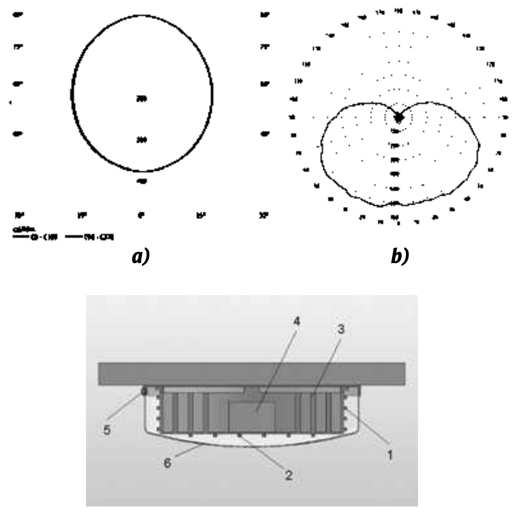


Fig. 7. Redistribution of the luminous flux on the ceiling of the station hall: (*a*) historical luminaire LIC, (*b*) proposed luminaire LIC, (*c*) dome lamp diagram (profile drawing by vertical projection plane) where *1* – Cree XP-L LED, *2* – Cree JK3030 3-V LED, *3* – heat radiator, *4* – LED control device, *5* – hydrophobic filter, *6* – opal diffuser

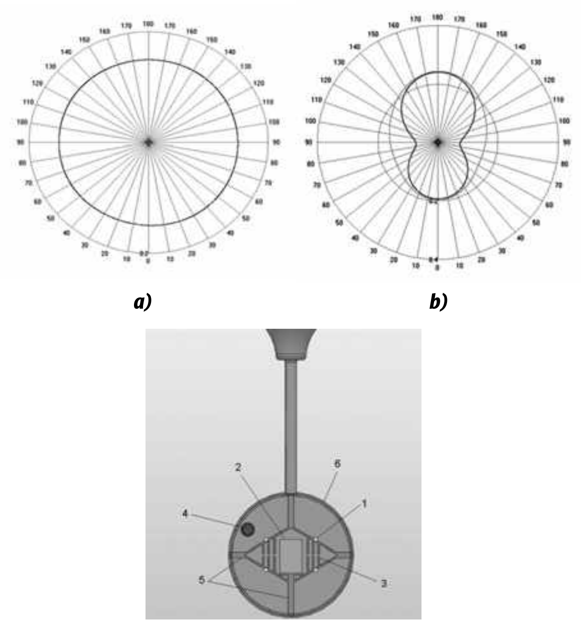


Fig. 8. Redistribution of the luminous flux for a cylindrical luminaire in the station hall: (*a*) historical luminaire LIC, (*b*) proposed luminaire LIC, (*c*) luminaire diagram (profile drawing by vertical projection plane) where *1* – Cree JK3030 3-V LED, *2* – LED control device, *3* – heat radiator, *4* – hydrophobic filter, *5* – holder block, *6* – opal diffuser

The analysis of round dome lamps located along the platform (Fig. 2a) showed that it is necessary to redistribute the flux from the light source to reduce the glare of these dome lamps. A little part of

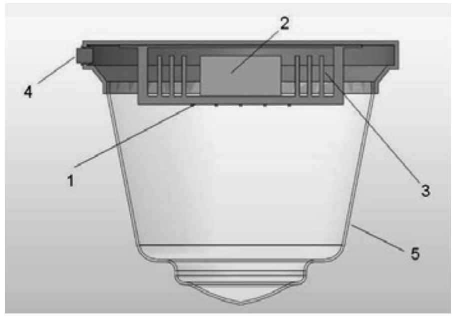


Fig. 9. Luminaire diagram for lighting of the connecting passage (profile drawing by vertical projection plane) where *1* – Cree JK3030 3-V LED, *2* – LED control device, *3* – heat radiator, *4* – hydrophobic filter, *5* – opal diffuser

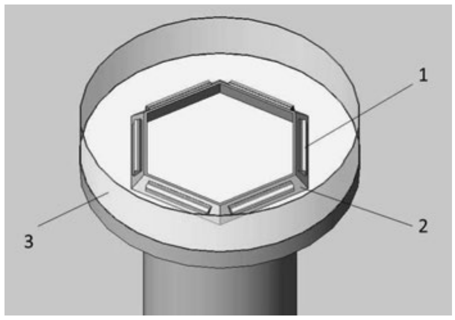


Fig. 10. Lighting decoration elements of column capitals: *1* – Lucendi LED lamps, *2* – brackets, *3* – opal diffuser

the flux should fall down, and a greater part of the flux should go to the upper hemisphere illuminating the platform floor with reflected light. For this purpose, a cylindrical LED module is installed in a dome lamp; the significant part of the luminous flux (90 %) comes from the *Cree XP-L* LED located on the cylinder forming surface; the remaining 10 % are emitted by the *Cree JK3030 3-V* LED mounted on the base of the cylindrical module (Fig. 7c). In this case, the surface and cavity of the cylinder serve as a radiator for convective transfer of excess heat generated by the LED; the total surface area of the radiator is 4355 cm². Besides, there is a room in the cylinder cavity for a control device installation. This solution allows to redistribute the flux in the necessary ratio in order to resolve the problem as shown in Fig. 7.

It is necessary to increase the luminous flux in the upper hemisphere and to reduce the luminous flux in the lower hemisphere for square caissons highlighting and for reduction of UGR in the case of cylindrical hanging lamps; it is easily achieved with the use of the *Cree JK3030 3-V* LED lines with different levels of current loads. To achieve this goal, the aluminium diamond-shaped construction is inserted into the lamp shell, which sides and cav-

Fig. 11. Visualisation of Krasnoselskaya station with the proposed LI: (*a*) platform hall, (*b*) stair flight of the connecting passage

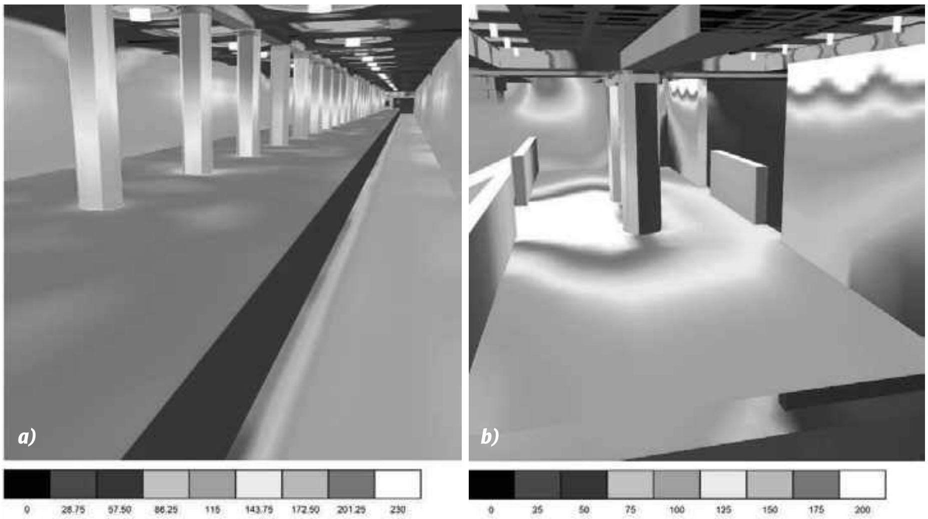


Fig. 12. Results of lighting calculation with the new LI: (*a*) platform hall, (*b*) stair flight of the connecting passage

ity are similar to surfaces of the cylindrical module described above; they represent a heat radiator with a surface area of 1220 cm². In addition, a LED power regulator is mounted in the inner cavity of the structure (Fig. 8).

It is assumed that the connecting passage would be illuminated with LDs that look like modern emergency lights (Fig. 4b); however, the *Cree JK3030 3-V* LED module will be used as a light source instead of 150 W IL (Fig. 9). As in the case of luminaries described above, the control device and a heat radiator of 812 cm² will be placed at the top of the luminaire (Fig. 9).

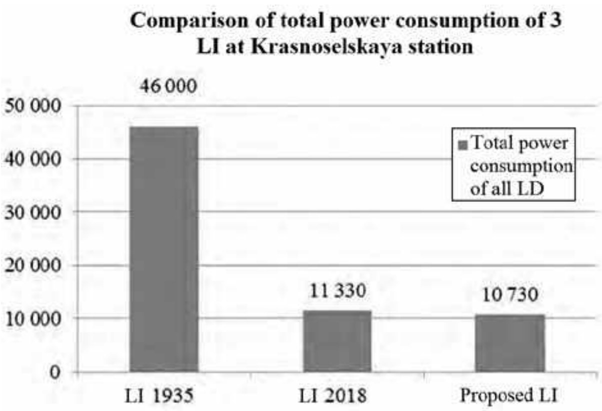


Fig. 13. Comparison diagram of total power consumption of 3 LI at Krasnoselskaya station

It is assumed to use the technique included in the original project by the engineers of *the Russian National Electronic Technical Institute* (Moscow, Russia) in 1935 in order to restore the lost lighting decoration of the stairway in the connecting passage. 6 *Lucendi* LED lamps of 281 mm [7] forming a hexagon will be installed instead of ILs in the projected LI at the top of the column behind the opal diffuser (Fig. 10).

3. RESULTS

The above LDs were modelled in *Solidworks* [8]; *IES* files and luminous intensity curves (Figs. 8b, 9b) were obtained using the *Photopia* plug-in [9]. According to the results of lighting calculation carried out with regard to the properties of the proposed devices and based on result visualisation, it can be concluded that the station appearance with such lighting reconstruction becomes the original idea of the architects (Fig. 11). The new LI allows not only to identify the main architectural elements of the station, but fully meets modern standards for lighting and UGR (Table 3) (Fig. 12). Besides, the total power consumption of the proposed LI will be 10.7 kW, which is almost 0.6 kW lower than the power consumption of the existing LI (Fig. 13).

4. CONCLUSION

We should finally note that the lighting of many metro stations was modernised in the 1960s-1970s since the appearance of fluorescent lamps in the pursuit of efficiency. The first-priority Krasnoselskaya station is not the only one where modern lighting has radically changed its appearance. The appearance of powerful white LEDs radically changes the situation in the reconstruction of the LI of the Moscow Metro. Their relatively small size and high efficiency allow to solve a wide range of problems faced for restorers of cultural heritage; unification of their efforts with the efforts of lighting technicians allows us to expect that passengers will be able to see the first Moscow Metro stations as they were conceived by the architects and designers in the near future.

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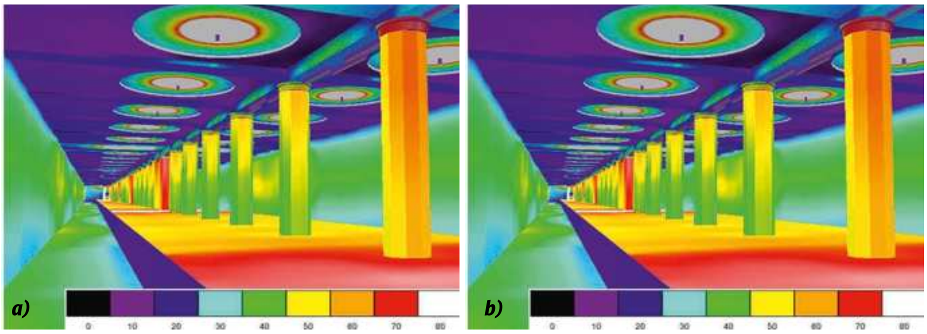

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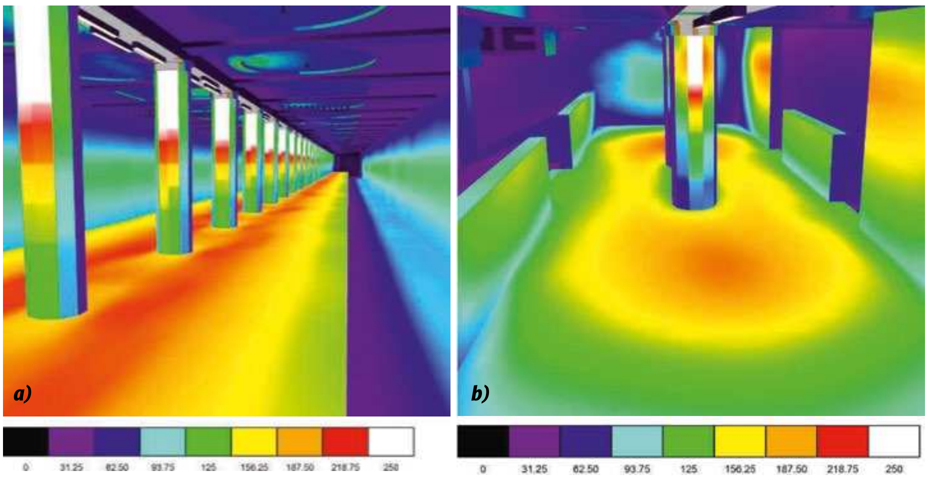

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