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RECONSTRUCTION OF ILLUMINATION DEVICES AT THE MOSCOW METRO

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ABSTRACT

To save the architectural appearance of cultural heritage stations is one of the main problems for the Moscow Metro. Development of station appearances is mainly connected to illumination devices that provide light to every station zone and define a comfort level to passengers and staff. They were designed in the first half of the 20th century. Now they do not meet any modern requirements. Many of these illumination devices are lost or replaced by more efficient illumination devices that totally misrepresent the original appearance of stations. Appearance of LED light sources allows to optimize luminous environments and to save the historical appearance of illumination devices and stations. This paper shows the ways of problem-solving in case of the entrance hall and the inter-escalator anteroom at *Krasnye Vorota* (station).

Keywords: metro, station lighting, architecture, luminous environment, cultural heritage, reconstruction, renewal, LEDs, energy saving, sconces

Fig. 1. Exterior of IDs with a transparent diffuser and an FL

1. INTRODUCTION

Lighting upgrade of spaces at the first stations of the Moscow Metro that are considered to be cultural heritage sites is a complex, multi-variable, and contradictory task. The main problem is that the stations were designed in the early 1930s. The construction of illumination devices (chandeliers, sconces, torchères, platform lights) suggested incandescent lamps (IL) as light sources (LS) that were replaced to fluorescent lamps (FL) in the 1950s. With regard to solutions of that time, there were no restrictions of direct radiant influence on the human eye and they are not exist up to now, if it not related to light emitting diodes (LEDs) as we can conclude from modern lighting requirements for stations [1].

As a result, we see a situation where FL illumination devices (IDs) are used in the Moscow Metro (Fig. 1), which is significantly uncomfortable due to luminous flux pulsations and dazzle created by

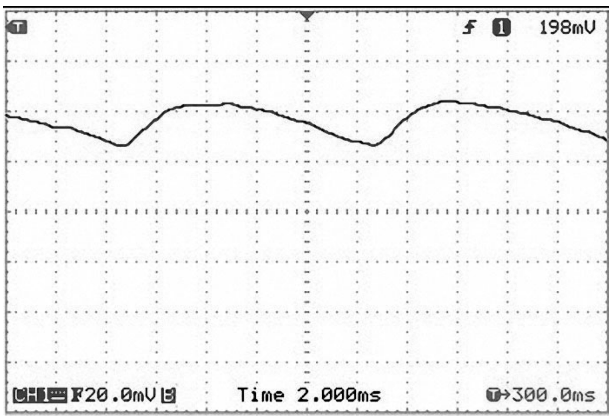


Fig. 2. Specific pulsation level of the FL luminous flux

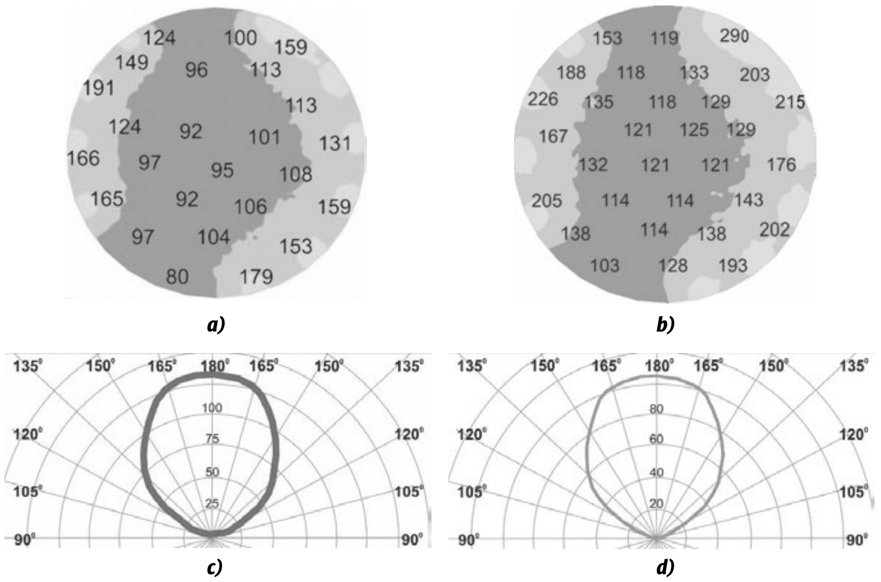


Fig. 3. Illuminance distribution (lx) on the floor of the entrance hall and the inter-escalator anteroom: *a*, *b* – E27 IL and CFL; *c*, *d* – bottle-shaped LIC of ID (sconce), with 100 W IL and 30 W CFL

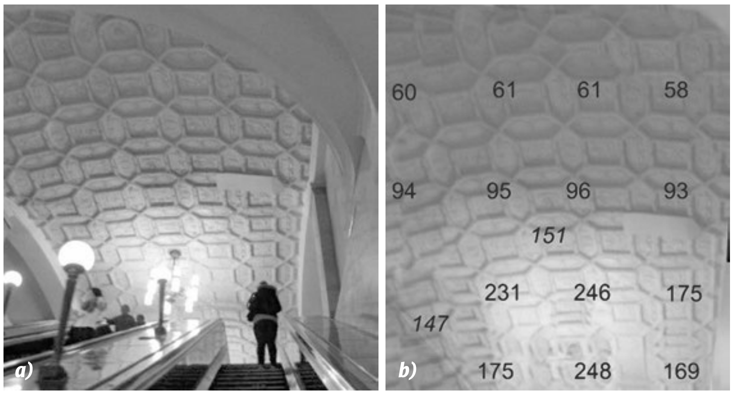


Fig. 4. Exterior of the ceiling in the entrance hall and its lighting principle before ID reconstruction: *a* – exterior; *b* – illuminance distribution

Fig. 5. IDs at *Krasnye Vorota* before reconstruction: *a* – sconce; *b* – chandelier

direct radiation of LSs from these devices on the visual sensory system (Fig. 2). Besides, the attempt to enhance the station lighting with traditional FLs and modern compact fluorescent lamps (CFLs) hardly improves the luminous environment. The Moscow Metro lighting mainly remains below the standard that is shown in Fig. 3, calculated with *DIALux evo 7.0*. The source data were the measured luminous intensity curves (LICs) of 100 W IL sconces and 30 W CFL sconces.

At the same time, the significant dimensions of a luminous element in FLs and CFLs devalue the role of glass diffusers (lamp shades) of these IDs that visually plays with relatively small dimensions of an IL filament. These IDs were designed with regard to such small dimensions [2]. The features of IDs that are mainly used now and especially in the 1930s are not enough for appropriate lighting of such architectural zones as ceilings. The lighting nature of IDs with traditional LSs is shown in Fig. 4.

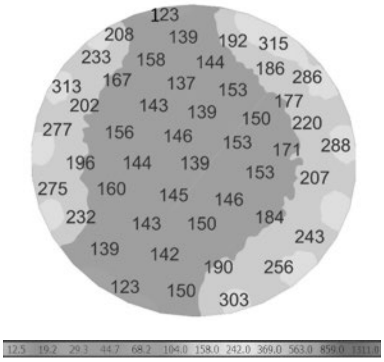
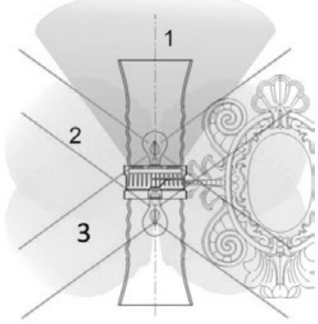
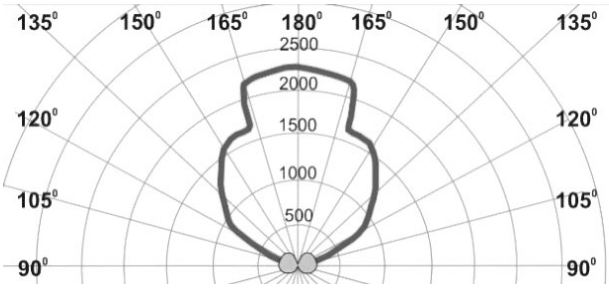


Fig. 6. Illuminance distribution (lx) on the floor of the inter-escalator anteroom with a luminous flux increase by 2000 lm



a)



b)

Fig. 7. ID (sconce) engineering solution: *a* – layout for the zone division of the ID luminous flux, its part in zone 1 with an LED module, its parts in zone 2 and zone 3 with *Philips* LED filaments (E27); *b* – LIC of IDs with such light sources

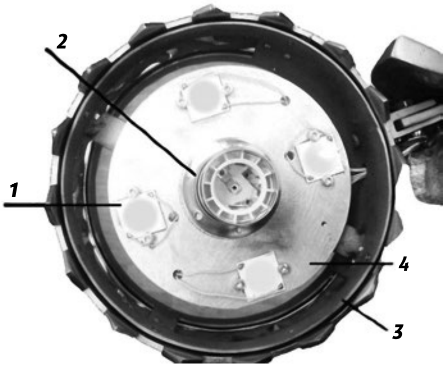


Fig. 8. Exterior of the LED module installed on the radiator: *1* – LED matrix; *2* – E27; *3* – decorative ring with attach fitting; *4* – radiator

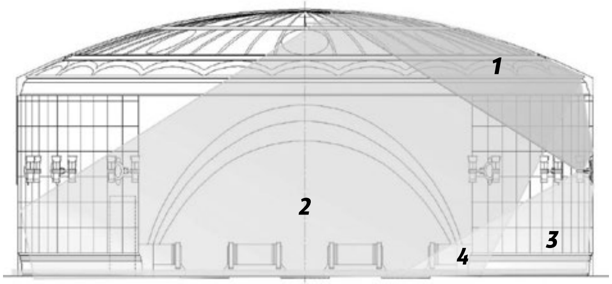


Fig. 9. Lighting layout of the inter-escalator anteroom – lighting distribution zones: main part of the ID luminous flux created with the LED module (*1*) and its reflection (*2*); part of the ID luminous flux created with an LED lamp (*3*); total of parts 2 and 3 (*4*)

Powerful white LEDs enable[1] to reconstruct and renew the given IDs.

As we solve these tasks, we should remember that lighting upgrade should be accomplished with a minimal stock list and with maximally unitred LSs that allow for IDs to operate with regard to their service specifications. Development of a comfortable luminous environment can be more complete with concord of LS correlation in colour temperature to the human circadian biorhythm, e.g. from (4200–3700) K in the morning to (3200–2800) K in the evening [7, 8].

This complex task-solving should be accomplished while developing a common luminous environment that would meet the modern requirements of architectural lighting at a single station (in our case, *Krasnye Vorota* which is a cultural heritage site) and save the historical appearance of IDs presented in the original project of 1935.

2. RESULTS OF RESEARCH

The study subjects are IDs (chandeliers and sconces) with transparent glass diffusers or lamp shades (Fig. 5) that are installed at many stations of the Moscow Metro (with minor differences in their design and construction) such as *Prospekt Mira* (*Koltsevaya* line), *Komsomolskaya* (*Koltsevaya* line), *Kiyevskaya* (*Koltsevaya* line) and *VDNKh*.

[1] Their main disadvantage is blue light that extremely damages the human eye [3–6].

Fig. 10. Exterior of operational IDs (sconces): *a* – before reconstruction; *b* – after reconstruction; *c* – location of the power and control gear (for an LED module and standby lighting)

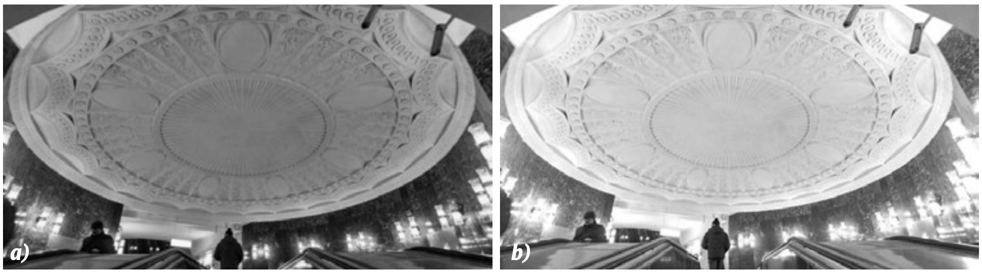


Fig. 11. Exterior of the illuminated ceiling in the inter-escalator anteroom: *a* – before reconstruction; *b* – after reconstruction (installation)

Their work is shown in the case of the entrance hall and the inter-escalator anteroom at *Krasnye Vorota*. According to the 1935 project, the inter-escalator anteroom is illuminated with 11 sconces with 4 prismatic cylindrical glass diffusers, first with 100 W ILs [9], then with 30 W CFLs.

The illumination level (Fig. 3) of these IL and CFL sconces does not meet any modern standards. The analysis shows that the growth of the luminous flux, e.g. by 2000 lm (Fig. 6), does not eliminate all specified disadvantages since the used lighting scheme plan for this station is not quite perfect[2]. So, another lighting scheme for the entrance hall and the inter-escalator anteroom was offered, which suggests the separation of the luminous flux for each ID (sconces, chandeliers) into 3 zones (Fig. 7). Zone 1 includes the 7000 lm luminous flux generated by an LED module with 4 LED matrices that are located at the bottom of a diffuser inside the ornamental ring of the ID in the way to avoid the radiant direction to get within the sight of passengers (Fig. 8). This flux is directed to the ceiling and is reflected from there (Fig. 9). The 800 lm luminous fluxes are formed in zone 2 and zone 3 by *Philips* LED filaments (6 pcs.) that are set at an angle that provides the desired effect of the light on the diffuser cutting and creates an illusion [10] of the main LS, illuminating the whole space without blinding any passengers because of a dull filament luminance. The rest of the ID luminous flux corresponds to the required lighting level of the wall and the floor (Fig. 9).

The offered method is obviously more expensive than just replacement of lamps. The price should be balanced by a decrease in maintenance costs which is possible due to a greater service life of LEDs.

The ID power and control gear is located on the main bracket under the decorative cover that saves the ID historical appearance (Fig. 10) and provides functions that match the modern requirements.

Only lower parts of the ID with appropriate LEDs are operating in a standby lighting mode. That provides the total illuminance of the floor at about 60 lx. The power source comes from a backup circuit with a rated voltage of 100 V DC, and wherein the ID power and control gear feature is a separate polar input.

The offered ID construction totally excludes any discomfort [11] (the average UGR is about 10) and provides the appropriate lighting level and the

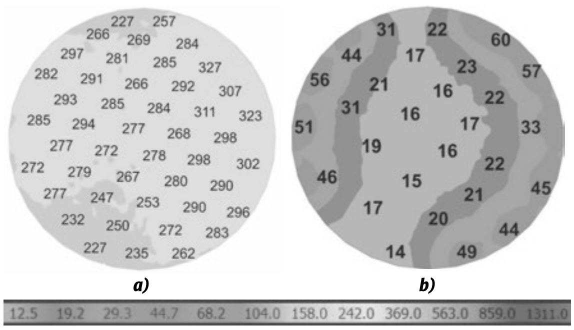


Fig. 12. Illuminance distribution on the floor of the inter-escalator anteroom after reconstruction in operating (*a*) and emergency (*b*) modes

[2] The lighting quality decreases: a bit brighter lighting of the floor causes hard visual discomfort (with non-illuminated ceiling) with increasing power consumption.

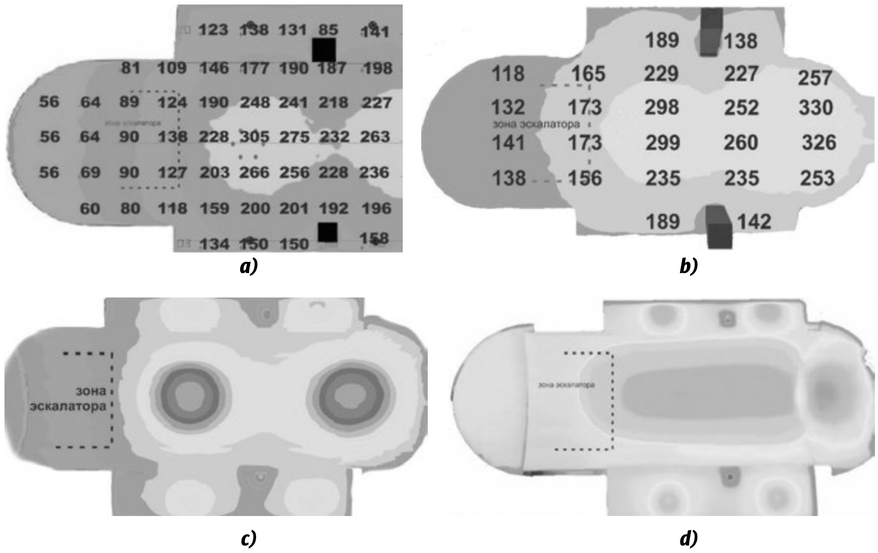


Fig. 13. Illuminance distribution (lx) on the floor and the ceiling of the entrance hall: *a* – on the floor before reconstruction; *b* – on the floor after reconstruction; *c* – on the ceiling before reconstruction; *d* – on the ceiling after reconstruction

necessary uniform illuminance distribution both on the art-treasured ceiling (Fig. 11) and on the floor (Fig. 12) with a decrease of total power consumption by 50 %.

While implementing the offered lighting scheme, the calculations of illuminance and UGR were conducted with *DIALux evo 7.0*, using results of the luminous intensity curves (LICs) of IDs (sconces) with the given LED module and the given LED lamps of 7.5 W (Fig. 12).

Lighting of the entrance hall is implemented in the same way. The only difference is that LED matrices (in an LED module) feature an additional cylindrical diffuser that spreads the light beam along the plasterwork to evenly illuminate the ceiling. The first torchère of the escalator (designed as per the solution described in [12, 13]) is used with the same purpose. The LS of the torchère provides additional illumination of the outer plasterwork.

We can see from the illuminance distribution of the ceiling and the floor in the entrance hall (Fig. 13) that the ceiling "works" after the implementation of the project. The floor is also fully illuminated (in total compliance with the requirements of [1]) with the necessary lighting level and the calculated UGR ≤ 20.

3. CONCLUSION

This work offered the methods for the Moscow Metro IDs with transparent diffusers (lamp shades) reconstruction by replacing weak LSs (ILs and FLs) with LED LSs, which ensure:

- Saving the ID historical appearance;
- Compliance with the illumination level requirements [1], no visual discomfort, energy consumption reduction, and compliance with the requirements for cultural heritage sites.

Unfortunately, during the 2017 renewal of *Krasnye Vorota*, the Moscow Metro has totally ignored the presented result of work. That is why the previous FL and CFL IDs remain at the renewed station with a pulsing luminous flux and a low colour quality that do not meet any modern requirements [1, 14].

REFERENCES

1. Sanitary and Epidemiological Rules SP 2.5.1337–03. Sanitary Rules of Metro Operation.

1. Sanitarno-epidemiologicheskiye pravila SP 2.5.1337–03. Sanitarnye pravila ekspluatatsii metropolitenov.

2. Gorbachov, N. V., Ratner, E.S. Lighting of the Moscow Metro: Preliminary Report // Svetotekhnika, 1935, No. 1, pp. 2–13.

2. Gorbachov, N. V., Ratner, E.S. Osveshcheniye moskovskogo metro: predvaritelnoye soobshcheniye // Svetotekhnika, 1935, No. 1, pp. 2–13.

3. Kaptsov, V. A., Deynego, V.N. Transport Lighting: Health Risks for Personnel and Passengers // Health Risk Analysis, 2016, No. 3, pp. 4–12.

3. Kaptsov, V. A., Deynego, V.N. Transportnaya svetotekhnika: riski zdorovyu personala i passazhirov // Analiz riska zdorovyu, 2016, No. 3, pp. 4–12.

4. Kaptsov, V. A., Deynego, V.N. Blue LED Light as a New Hygienic Problem // Health Risk Analysis, 2016, No. 1(13), pp. 15–25.

4. Kaptsov, V. A., Deynego, V.N. Siniy svet svetodiodov – novaya gigiyenicheskaya problema // Analiz riska zdorovyu, 2016, No. 1(13), pp. 15–25.

5. Kaptsov, V. A., Deynego, V.N. Disorders in the Melanopsin Effect of Pupil Constriction as a Risk Factor Causing Eye Diseases // Health Risk Analysis, 2017, No. 1, pp. 132–148.

5. Kaptsov, V. A., Deynego, V.N. Narusheniye melanopsinovogo effekta suzheniya zrachka – faktor riska zabolevaniya glaz // Analiz riska zdorovyu, 2017, No. 1, pp. 132–148.

6. Bizhak, G., Kobav, M. B. LED Spectra and Melatonin Suppression Function // Light & Enineering, 2012, No. 3, pp. 15–22.

7. Demidov, V. How We See What We See [3rd edition, republished and complemented], Berlin: Science & Technology. Rare Editions, 2010, 280 p.

7. Demidov, V. Kak my vidim to, chto vidim [izdaniye 3-e, pererab. i dop.]. Berlin: Ni T. Raritetnye izdaniya, 2010, 280 p.

8. Blatner, P. Luminous Environment for a Human: Science, Industry, and Law // Svetotekhnika, 2016, No. 1, pp. 45–49.

8. Blatner, P. Svetovaya sreda dlya cheloveka: nauka, promyshlennost i zakon // Svetotekhnika, 2016, No. 1, pp. 45–49.

9. GOST R52706–2007. Tungsten Incandescent Lamps for Everyday and Similar General Lighting. Operating Needs.

9. GOST R52706–2007. Lampy nakalivaniya volframovye dlya bytovogo i analogichnogo obshchego osveshcheniya. Ekspluatatsionnye trebovaniya.

10. Novakovskiy, L. G., Miras, J.-P. Illumination Tool for Creating a Light Beam // Utility Model No. 159921 RF.

10. Novakovskiy, L. G., Miras, J.-P. Svetovoy pribor dlya formirovaniya svetovogo puchka // PM No. 159921 RF.

11. GOST 33392–2015. Buildings and Structures. Test Method for Unified Glare Rating in Candlelight Conditions.

11. GOST 33392–2015. Zdaniya i sooruzheniya. Metod opredeleniya pokazatelya diskomforta pri iskusstvennom osveshchenii pomeshcheniy.

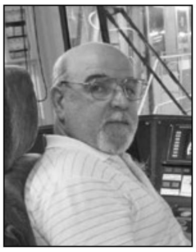
12. Novakovskiy, L. G., Kazakovskiy, N. I., Kanevskiy, A. V., Peselis, Yu.A. Light of the Metro Escalator Balustrade / Patent Decision No. 2017107716 dated March 2017 for a Utility Model.

12. Novakovskiy, L. G., Kazakovskiy, N. I., Kanevskiy, A. V., Peselis, Yu.A. Osvetitel eskalatornoy balyustrady metropolitena / Resheniye ot 03.2017 g. No. 2017107716 o vydache patenta na PM.

13. Novakovskiy, L. G., Feofanov, S. A. A Correct Illumination of an Esscalator is a Set of Radical Solutions // Light & Engineering, 2018, V. 26, #3, pp. 58–65.

14. GOST R54350–2015. Illumination Devices. Lighting Requirements and Test Methods.

14. Pribory osvetitelnye. Svetotekhnicheskiye trebovaniya i metody ispytaniy.



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