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A STUDY OF THE CLASSICAL ARCHITECTURE FLOODLIGHTING

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ABSTRACT

Designing historic building floodlighting belongs to fairly complicated tasks. Apart from a purely technical imagination and adherence to floodlighting principles and methods, aesthetic aspects should also be taken into account. Predicting the effect, which will be created, is a very difficult thing. It is often impossible for us to check, owing to the dimensions of the illuminated structures, number of the used lighting equipment and its installation capabilities. Here comes 3D computer graphics. The paper presents a case study of floodlighting Palace of the Commonwealth in Warsaw, Poland. A few concepts of illuminating the palace have been described, the analysis of effects has been made and the concept that after some consultations was selected for implementation has been demonstrated. All the floodlighting designs are shown in a form of the photorealistic visualization of lighting with a description of the intended and obtained effects. Apart from the visual evaluation, the level of the building luminance was carefully monitored under the project.

Keywords: illumination, floodlighting, lighting technology, computer graphics

1. INTRODUCTION – BUILDING DESCRIPTION

Palace of the Commonwealth in Warsaw is considered as one of the greatest examples of the baroque architecture in Poland. It is one of the most magnificent conceptions of a French style palace, *entre cour et jardin,* in Warsaw, with its main building called *corps de logis,* situated at the axis between the entrance court (*cour d'honneur*) and the garden at the back of the palace. The building was constructed according to the design by Tylman Gamerski in the years of 1677 and 1695 as a residence of Voivode of Płock, Jan Dobrogost Krasiński. Its structure is based on three avant-corpses as follows: one central five-radial and two side three-radial. Between the main and side avant-corpses there are pillar loggias. Both central avant-corpses, front and garden, are ended with tympana at whose tops there are statues. The basic dimensions of the palace are as follows: width of 76 m, height of 26 m representing 3 floors, roof and statues on tympanum as well as the depth of 28 m. At the back of the palace, there is a garden that was subject to revitalization while designing the palace floodlighting. The front façade is directed at Krasiński Square opposite a modern, glass-structured building of Supreme Court in Poland. Today Palace of the Commonwealth is a part of the Polish National Library's Special Collections Section (Manuscripts and Old Prints).

2. SCOPE OF PROJECT

In 2008, the façades of the palace were renovated, and the existing floodlighting, owing to the technical reasons, was partially disconnected and at present it does not perform (Fig.1). The design was implemented at the beginning of this century, and thus, based on the lighting solutions with economically inefficient light sources. As a result of these factors, there was a need to design a new concept to include and use modern lighting solutions, such as energy saving lighting equipment based on both

Fig. 1. Palace of the Commonwealth in Warsaw, Poland (front façade)

discharge lamps and light emitting diodes (LEDs). The aim of the new design was to floodlight the exterior façades of the Palace of the Commonwealth in Warsaw, meaning highlighting the façades of the building with light.

The conceptual scope of design covered working out a few concepts of the building floodlighting, selecting, positioning and directing the lighting equipment, making the lighting calculations, including the visualization of the floodlighting concept. For every lighting concept, the recommendations and guidelines related to the connection, control and maintenance system for floodlighting were described.

It was agreed that the spatial range of the floodlighting would cover all four façades of the palace: front, garden as well as south and north end walls. During the talks on the design with the building owners, it was agreed that the roof parts of front façade, seen from Krasiński Square, would also be lit.

In the course of designing the lighting solution for the building, the starting point was an analysis of a series of factors related to both palace and its surroundings [1–8]. The basic directions and points of observations, building surroundings in terms of its brightness and capabilities of mounting the lighting equipment were estimated, since its thorough modernisation had recently been carried out. Also, the architecture of the building, its details and function, which it performs, were taken into account. In that way, with the aid of computer lighting simulations, with all aspects of designing with this technique [8] a few concepts of floodlighting the front façade and one for the garden façade were analysed. All these designs were preceded with multiple changes in a type of the lighting equipment and locations of its mounting and directing. All created concepts of the palace floodlighting were complete in terms of design documentation. Apart from the visualization images, every project had the generated luminance distribution on the façades of the building that enabled assessing the design in terms of compliance with the CIE recommendations concerning the luminance of the buildings subject to floodlighting [9]. Also, the projects contained the

Fig. 2. Three-dimensional grid model of Palace of the Commonwealth in Warsaw

guidelines regarding the floodlighting maintenance system, including recommendations on a time period, after which cleaning the lighting equipment and replacing the light sources should be carried out.

3. UNDERTAKEN TECHNIQUE OF DESIGN FOR BUILDING FLOODLIGHTING

For such reasons as a prestige of the building, its dimensions, predicted number of the lighting equipment and necessity of analysing a large number of the lighting options, the only way to design the building floodlighting was to use the lighting simulation of its three-dimensional geometric model. There are many methods for designing the virtual 3D models dependent on both used computer application and designer's skills and knowledge in this field. However, the design basics are similar. On the basis of lines, profiles of the building and a series of functions available in the 3D applications, some sets of vertexes, edges and planes representing the virtual rendering of the real building are created. By convention, the authors calls these models a geometric representation of the building (Fig. 2).

Palace of the Commonwealth, as a relatively big building, is not easy to be reconstructed in the virtual space. Its structure is rich in architectural details and façade materials vary. However, in majority, the façade is plastered. As for the created three-dimensional representation of the building, the next step was to define all material features: colour, material texture, reflective properties.

The first two design stages are the most labour-intensive and time-consuming in this method for designing the lighting solution. However, on the basis of such a created virtual scene, the designer can analyse the unlimited number of floodlighting options. It means the options based on the real lighting equipment. Usually, luminaires are defined by lighting manufacturers in a form of luminous intensity distributions in the IES (Illuminating Engineering Society) format. The files uploaded to the software have defined basic lighting parameters: a luminous intensity distribution, maximum luminous intensity of a luminaire and luminous flux of a light source, whereas an appropriate colour temperature of light source should be assigned to them, and as far as a light strip is concerned, its length should be given.

The last stage of designing the lighting with this method is rendering. It is a calculation process, under which the geometry of the building is converted into an image after assigning the reflective and transmissive properties to it, and then, adding the light sources to a scene, as a result of the photometric and colorimetric calculations. On its basis, the designers can see and present their vision of illuminating the building as well as receive the technical, lighting data on their project. The luminance distribution on individual planes, enabling assessing this design should be recognised as the most important data (Fig. 9).

4. MULTI-OPTIONAL DESIGN FOR FLOODLIGHTING

Taking into account the points and directions of observing the building, option 1 was based on a mixed method, general and accent lighting [6]. 16 in-ground luminaires were installed in a distance of 3 m away from the façades evenly illuminating the front façade, with an increase in the luminance in its central part. For the accent lighting purposes, 107 spotlights and floodlights in total were applied. The arcades of the palace were highlighted with the

Fig. 3. Design of floodlighting front façade of palace (option 1 – visualization)

Fig. 4. Simulation of floodlighting garden façade of building

asymmetric light distribution floodlights placed inside them. The tympanum, three statues at its top, banister and pilasters were lit with a light strip system equipped with the light emitting diodes (LEDs). The other lighting equipment predicted for façade floodlighting was based on the metal halide lamps of colour temperature of 3000K. The roof surface of the front façade was illuminated with the rotary symmetric reflector spotlights with glass stretching the light beams horizontally. Due to the patina-covered roof surface, the light sources of a higher temperature (4200K) than for the façade were applied. Fig. 3 demonstrates the floodlighting design.

This option also had a few modifications illustrating an effect of floodlighting with the switched off lighting of the roof, banisters, pilasters and statues at the top of tympanum to show the influence of illuminating them on the final lighting effect.

Due to a different observation perspective, a decision on illuminating the garden and side façades only with the general light [6] was made (Fig. 4). One concept was created as a result of the early multiple changes to the types of lighting equipment and its positioning and directing. The project in this option assumed using 37 asymmetric distribution lighting fixtures equipped with the metal halide lamps mounted at the low bollards at a distance of 4m away from the façade. In order to highlight the depth, characteristic façades recession over the balcony, on their surfaces, 3 asymmetric floodlights each generating a higher luminance levels in these spaces were installed. Additionally, 13 LED linear luminaires to light the tympanum and 7 LED spotlighting fixtures to illuminate the statues at its top were applied.

The second option was a result of modification made to the first version. It assumed withdrawing from using the in-ground luminaires illuminating the front façade in favour of the asymmetric floodlights installed on the low bollards in front of the palace. Unfortunately, it was not a good solution – the lighting equipment was seen during the day time, however, owing to the existing bollards used in the former lighting system and power supply provided to them, a decision on analysing such a solution was made. The amount of lighting equipment was the same. The effects of floodlighting and luminance distribution for this option were similar to option 1.

The palace façade is characterised by the pilaster rhythm along its entire width. Thus, the third important modification to the lighting project assumed highlighting the rhythm of side, outermost avant-corpses, as well as emphasising the balcony banisters in the arcade part, with the light, together with the simultaneous reduction in luminance level in the upper parts of the building (Fig. 5). The effects were achieved thanks to the LED light strips. The number of the used lighting products grew to 160 pieces.

The next analysis was to switch off the arcades on the first floor and to accent the pilaster rhythm along the whole façade width from the palace side. Also, the luminaires illuminating the balcony banisters in the arcade part were left (Fig. 6). The total number of the lighting fixtures installed grew by the next seven pieces.

The last virtual lighting attempt was to emphasise the horizontal façade division by installing the light strips along the entire façade width, at the height of first floor, and to accent the pilaster rhythm in the central and side avant-corpses. The arcades, according to the recommendations regarding the building floodlighting, were lit with the asymmetric light distribution luminaires with the metal halide lamps from the inside. Fig. 7 illustrates the com-

Fig. 5. Visualization of floodlighting Palace of the Commonwealth (highlighting rhythm of pilaster avant-corpses)

puter simulation of the project. This option became the most spectacular, but also expensive. 201 luminaires in total number were installed.

5. FINAL CONCEPT OF FLOODLIGNTING

All the above mentioned concepts of floodlighting the building were initially presented only to its owner who selected option1 for the implementation – with modification meaning eliminating the luminaires mounted directly on the palace façade – on the central pilasters of avant-corps.

The design was also subject to evaluation by the conservation-restoration authorities for the aesthetics point of view [10, 11]. Unfortunately, as a result of the analyses and talks on both achieved effect and possibilities of mounting the lighting equipment, it was rejected. The conservator-restorer recommended using the general lighting method for all the building façades (Fig. 8). The lighting with the aid of two groups of narrow distribution spotlights from a long distance of 40 m away from the façade was recommended. A similar way of floodlighting was also proposed for the garden façade. A vast majority of the lighting products were supposed to be installed on the newly mounted bollards used in the lighting system of the park.

In total, to implement this option 34 spotlights and floodlights of the entire installed 4.2 kW were applied performing the average luminance value about 6 cd/m^2 (Fig. 9), which, thanks to the average surrounding brightness, can be found compliant with the recommendations concerning the building floodlighting [9]. The obtained lighting effect can be considered as consistent, since a nature of the building floodlighting with the general lighting method has hallmarks of rendering effect seen during a day. All floodlighting principles described in the literature of the subject [5, 6] can be also recognised as met. In the final option, 12 luminaires mounted on the three bollards relatively low (4m) were accepted for the installation purposes. In the extreme case there were 5 lighting fixtures of the narrow half-peak divergence of $\delta_{1/2}$ = 16 deg. The luminaire batteries with their size might not be so visible, however, it could be expected that their directing in the plane close to orthogonal to the building façade surface might cause a stronger light penetration into its interior [12, 13].

Fig. 6. Visualization of floodlighting palace (test on highlighting pilaster rhythm along front façade)

Fig. 7. Visualization of floodlighting Palace of the Commonwealth according to option 5

Therefore, there could be a risk of glare to the people walking around it, since the maximum luminous intensities of these luminaires are very high (around 200 kcd). The palace floodlighting with this method is also inefficient. There will also be a strong light pollution and glare to the observers. Yet, it will be possible to verify these parameters only after the implementation. At the current lighting design stage, the methods of discomfort glare risk occurrence evaluation [14, 15] are being worked out for the road lighting in particular, however, it should be expected that these methods can be adapted to the building floodlighting field.

6. ALTERNATIVE TO SIMULATION WAY OF DESIGNING FLOODLIGHTING

The building floodlighting design with the visualization method is a tedious process. The time required to generate a multi-optional lighting project is calculated in tens of working hours. A bigger burden of designing with this method is time needed to create a virtual light scene.

Carrying out the tests with the use of real lighting equipment under the real conditions is an alternative [16]. Also, for this building, the investor, upon the request from the conservator-restorer, did such a test. Unfortunately, it ended in failure. Despite a relatively small number of the lighting fixtures used for the final concept, none of the lighting companies managed to collect the number of specific types of the luminaires required under the project. However, it should be mentioned that generally, if it were possible to collect such an amount of equipment, the project evaluation during a short show would not be objective either, since it features a lot of disadvantages. It is hard to expect one-off decisions on a way of floodlighting to be made during the show, and it is also risky to rely on the possible analysis coming from the photo documentation of the floodlighting tests [17].

7. CONCLUSIONS

So far three building floodlighting methods have been known: accent, general and mixed. The choice of method mainly depends on a distance and location of the observation points. Taking into account the location of Palace of the Commonwealth, the points and directions of its observation as well as

Fig. 8. Final concept of floodlighting Palace of the Commonwealth (computer simulation)

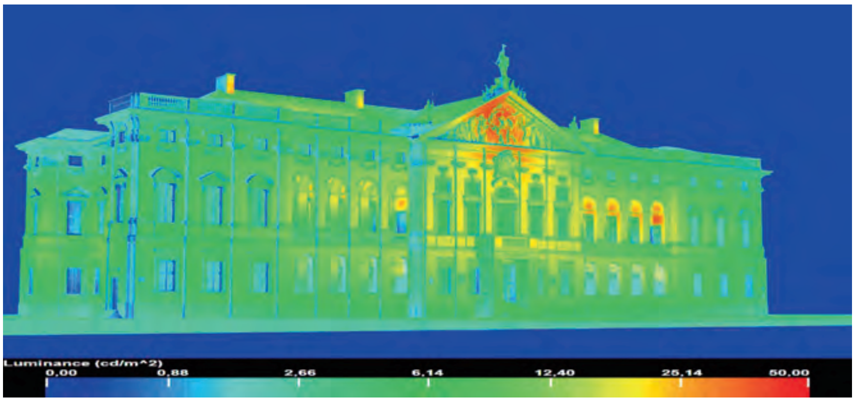

Fig. 9. Luminance distribution for option predicted for implementation

capabilities of its floodlighting, the use of mixed method was recommended from the lighting point of view. All options presented in the project were exactly based on this method. However, it is usually the conservator-restorer who has a decisive influence on floodlighting the building. His or her role is to take care of both building structure (lighting equipment mounting on the façade, drilling the holes, conducting the power supply cables, etc.) and its general appearance in the evening and at night – i.e. an appropriate floodlighting design. Apart from aesthetic reasons that should not be discussed, the final project for the palace to be implemented means, however, a lot of threats. The inefficiency of the final floodlighting option should be considered. After implementing the project, there will be a strong light penetration into the building interior, where there are a lot of collections of old prints and manuscripts. Also, a high light pollution should be taken into account. At present, the new building floodlighting method is being worked out in an attempt to reduce these threats to minimum. It is also possible to verify and change the described project, since while writing this paper the design is still being established.

Designing building floodlighting always requires multilayer approaches, analysing different solutions, both in terms of expected light effects and type of the used equipment. Without computer lighting simulations in 3D model, such an analysis is now difficult to be made. In this case, there are also some thoughts and tests in progress to find out how to solve this problem. It should be expected that in the nearest time the multi-optional floodlighting design on the basis of the real lighting equipment will not be so difficult and time consuming as it is now.

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Fig. 1. Example of visualization of the space-angular luminance distribution by local estimates of the Monte Carlo method for the *Cornell Boxes* reference scene

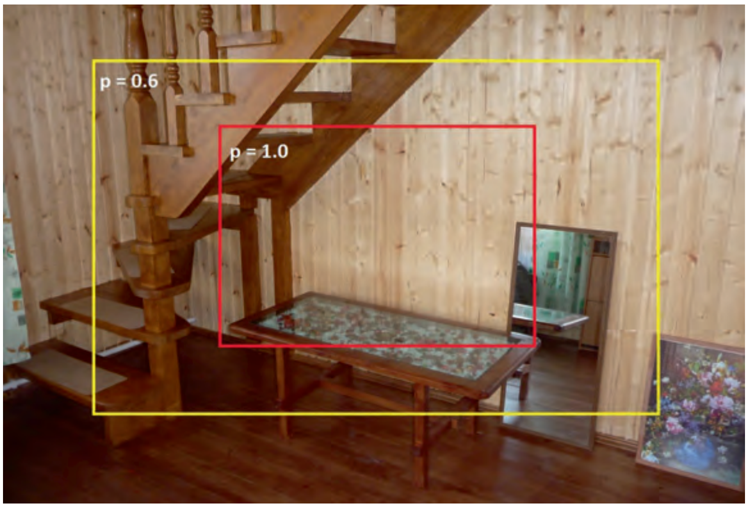

Fig. 2. Example of setting the weight coefficient *p* for different fields of view

Fig. 3. Example of determining the weight coefficient *h*, taking into account the lighting task

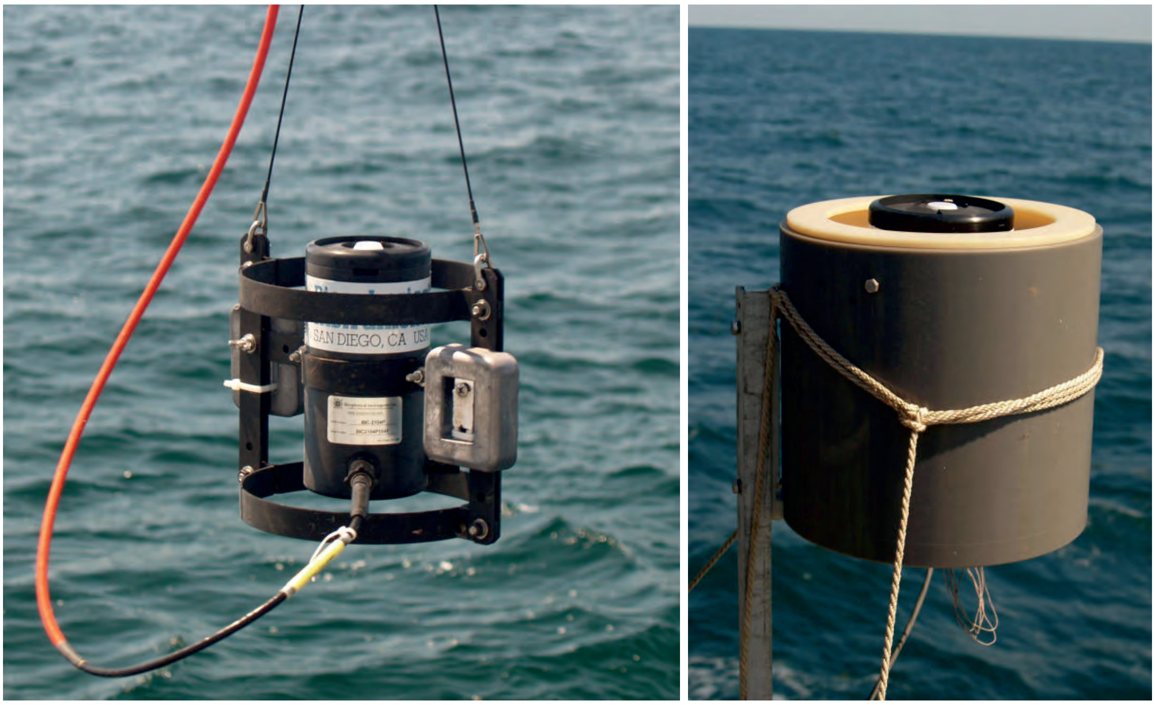

Fig. 4. A measuring instrument of light mode on the sea surface and in water thickness. On the left is an immersed detector, on the right is a deck-based detector

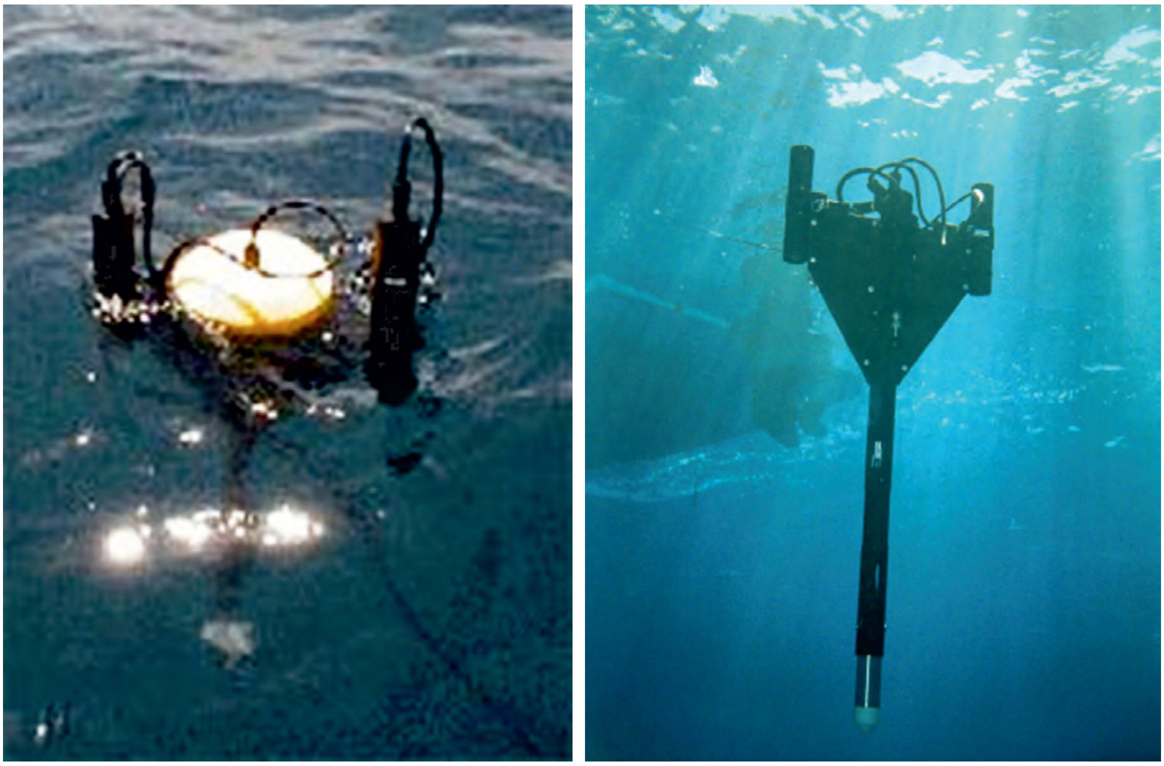

Fig. 6. The *Profiler II* measuring system developed by *SATLANTIC* Company [20] to measure luminance of ascending radiation and irradiance from the top in eight spectral channels. On the left is an example to measure in the buoy version; on the right – to measure in the free fall mode

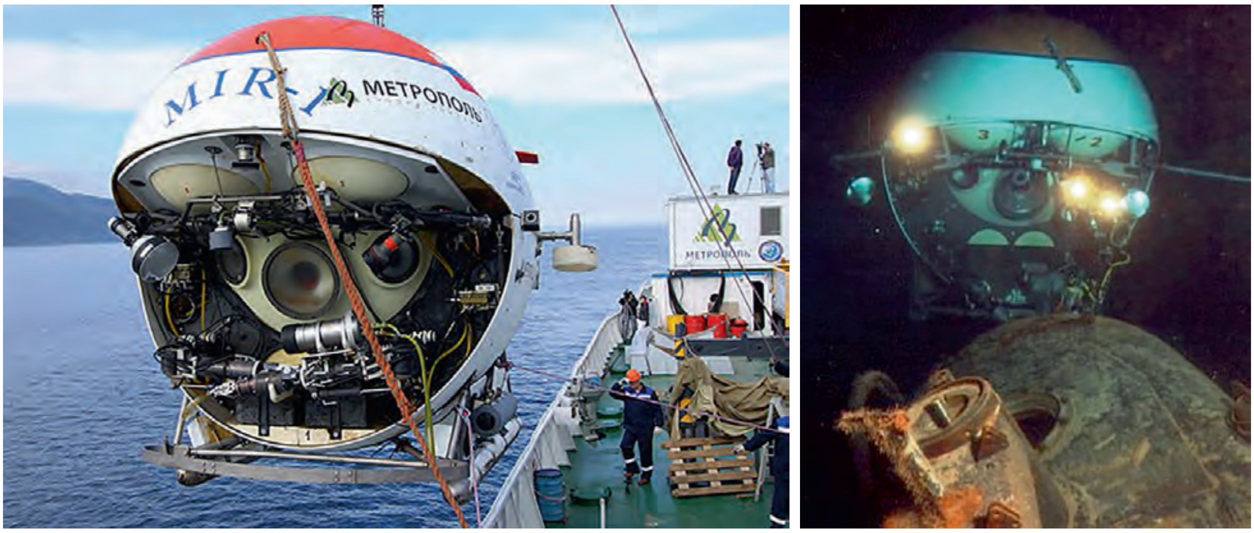

Fig. 8. Deep-water manned vehicle Mir: on the left – before immersion, on the right – investigation of a sunken submarine, Atlantic Ocean, depth is 5400 m

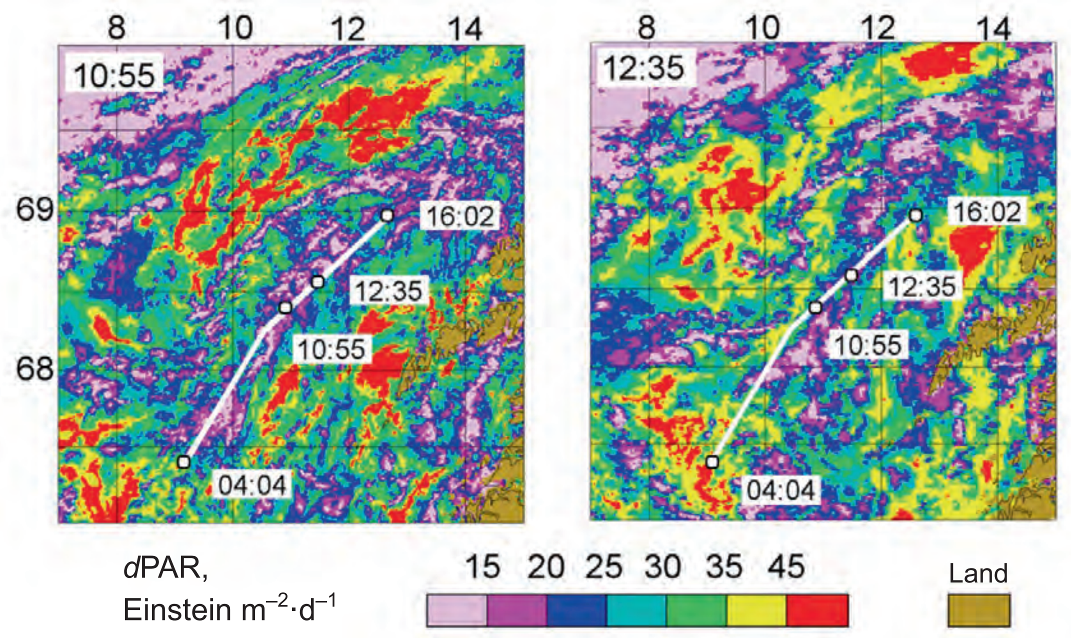

Fig. 10. Comparison of spatial distributions of daytime exposition of photosynthetically active radiation (400–700 nm) computed according to the *MODIS-Aqua* satellite scanner using IO RAS algorithm on August 1, 2014 at 10:55 am *GMT* (on the left) and at 12:35 pm *GMT* (on the right). The white line shows route of the boat, and figures nearby show the beginning (4:04 a.m.) and the end (4:02 p.m.) of the PAR measurements, as well as the boat position during the satellite flight [31]

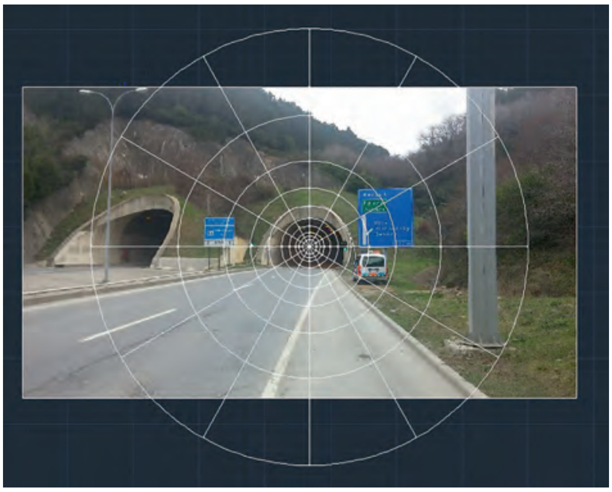

Fig.2. Circles drawn on the photograph of the Istanbul Beykoz tunnel entrance

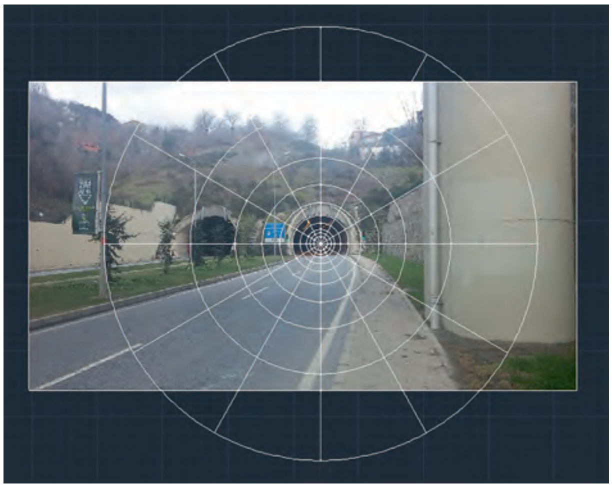

Fig.3. Circles drawn on the photograph of the Istanbul Kavacık tunnel entrance

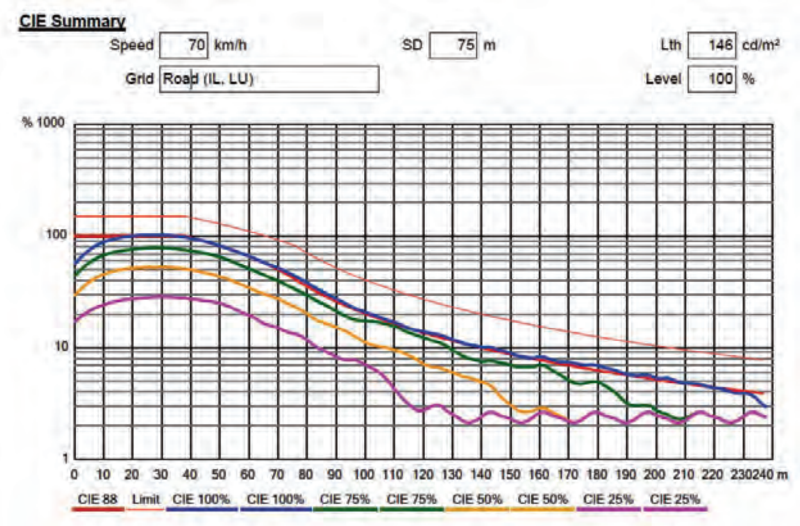

Fig.4. CIE088 curves for first tube

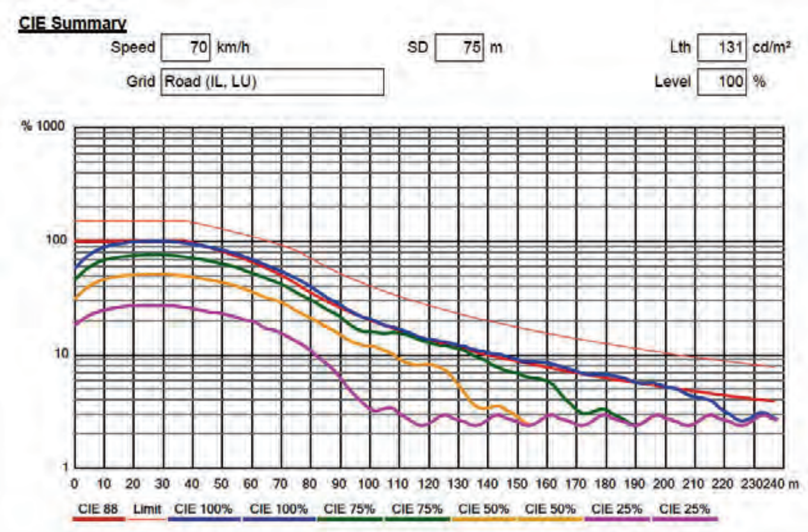

Fig.5. CIE088 curves for second tube