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APRON LIGHTING DESIGN INCLUDING AIRCRAFT SHADOWS

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Apron lighting is the necessary part of modern airports lighting. The good apron lighting considerably facilitates the apron maneuverings for aircraft pilots. It also increased safety and speed of maneuverings, the quality of maintenance by comfortable vision conditions for attending personnel. All of these are the important factors for fail-safety and reliable flight service.

The basic requirement for apron lighting stated in International Civil Aviation Organization (ICAO) rules [1]. In accordance with ICAO Riles the apron defined as "area on a land aerodrome intended to accommodate aircraft for the purpose of loading and unloading passengers, mail and cargo; refueling; parking or maintenance". The primary functions of apron lighting are:

- to assist the pilot to taxi his aircraft into and out of the final parking position;
- to provide lighting suitable for embarkation and debarkation of passengers, loading and unloading cargo, refueling and performing other apron service function;
- maintain airport security.

The pilot mainly relies on apron lighting when taxing on the apron. Uniform illuminance of the pavement within the aircraft stand area (parking place) and glare restriction are the major requirements. It is necessary to obtain the following ICAO recommendations:

- an average horizontal illumination should be not less than 20 lx for aircraft stands. The uniformity ratio (average illuminance to minimum) should be not more then 4:1. Average vertical illuminance at a height of 2 meters should be not less than 20 lx in relevant directions;
- in order to maintain acceptable visibility conditions the average horizontal illumination on the apron, except where service functions are taking place, should not be less than 50 % of the average horizontal illuminance of the aircraft stands, within a uniformity ratio of 4:1 (average to minimum). The area between the aircraft stands and the apron limit (service equipment, parking area, service roads) should be illuminated to an average horizontal illumination of 10 lx.

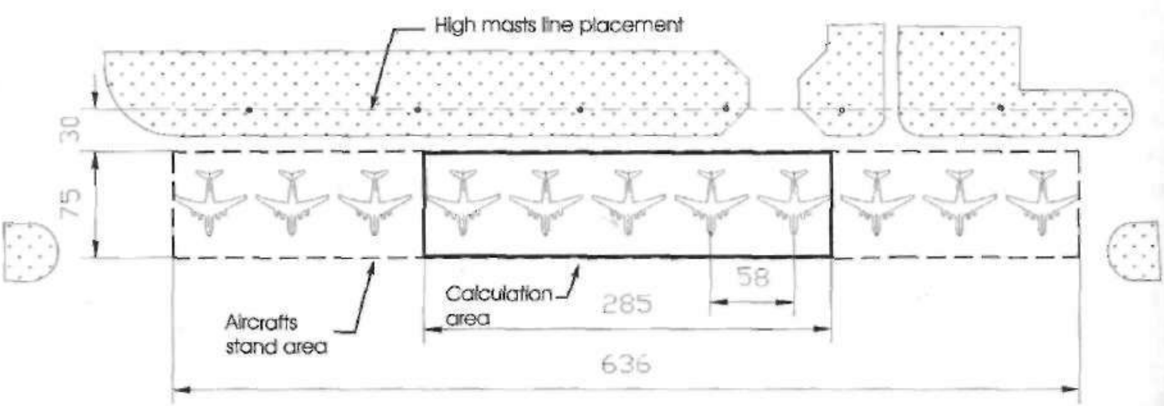
The basic means for apron lighting is high masts floodlighting. In these case very often appear unavoidable sharp shadows from other obstacles, and especially from aircraft's. In order to minimize shadows there is ICAO recommendation: the arrangement and aiming of floodlights should be so that aircraft stands receive from different directions. Better results are obtained by uniform illuminance of the total area than by directing individual floodlights at the aircraft [1]. Unfortunately it is impossible to predict exactly the final result of shadowing following these rules. In order to solve this task more correctly it is necessary to take into account the shadows from aircraft's by design of apron floodlighting. Such method which used in lighting design department of VNISI is proposed in this article.

The lighting design of apron floodlighting including aircraft shadows can be divided on several steps.

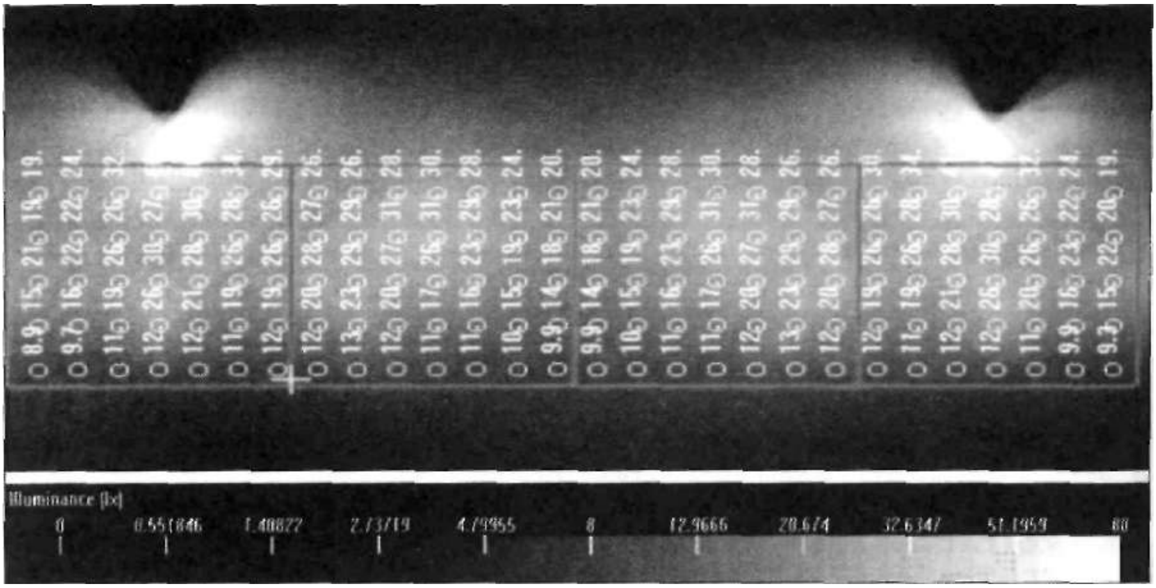
The first step is the calculation of illuminance distribution within apron and glare estimation in accordance with ICAO rules. In this calculations we do not take into account the shadows from aircrafts, we can only follow ICAO recommendation to illuminate aircraft stands from two and more directions in order to minimize shadows. Figure 1 presents an example of such lighting calculations for one part of big cargo apron in airport near Moscow.

There were used two lighting masts with high limit restriction 30 meters and 14 floodlights (7 per mast) with 1000 W high-pressure sodium lamp. The basic ICAO recommendations were achieved in this solution.

The second step is preparing three-dimensional (3D) computer graphics model using special software for 3D modeling (AutoCAD, 3D Studio MAX/VIZ and so on). As a minimum this model should include aircrafts, stands area and lighting masts for floodlights (Figure 2-a). Then the 3D-apron model and floodlights defined on step 1 should be exported into some computer graphics software witch allow to realize physically accurate lighting simulation [2, 3]. On this step materials and lighting distribution curves (LDC) should be added to 3D model (Figure 2-b). It is necessary to have possibility to define correctly LDC and properties of the materials (color, reflectance and transmittance index) for correct lighting simulation.



a) Apron drawing and calculation scheme.



b) The results of the calculation of horizontal illuminance distribution on the apron pavement
E_{min} = 7,1 lx; E_{aver} = 22,6 lx; E_{max} = 63,4 lx; E_{min}/E_{aver} =31,4 % (E_{aver}/E_{min} = 3,2:1)

Fig. 1. Apron lighting calculation for fragment of cargo apron in accordance with ICAO recommendations.

Table **1**

The calculating values of shadowing coefficient kS for several variants of apron floodlighting

Number of masts	Number of floodlights per mast	Comparative total cost (in%)	Average illuminance (Ix)		$K_S=E_2/E_1$
			E_2 (with aircrafts)	E_1 (without aircrafts)	
2	7	38	17.8	22.6	0.79
3	5	53	20.5	25.0	0.82
4	3	68	21.6	26.9	0.80
6	2	100	19.9	21.5	0.93

The next step is lighting simulation, which allow calculating illuminance distribution within 3D model taking into account shadows from aircrafts. We use for this lighting simulation the *Lightscape Visualization System* software from *Autodesk* Company. This software allows simulating light propagation within 3D model using radiosity method for estimation of plural interreflection and the backward ray-tracing technique for correct shadows and mirror reflections calculations [4]. The results are presented in several forms: color visualization picture, numerical grid of illuminance distribution, pseudo-color picture in scaled colors, pseudo-color picture in scaled gray colors. Figure 3a, b presents the results of lighting simulation for our example of cargo apron as full-color visualization picture and illumination distribution picture in scaled color. These results analysis shows that quality of lighting is not acceptable because of big and sharp shadows. Obviously it is necessary to try minimize the shadow's size and intensity, otherwise to optimize shadows.

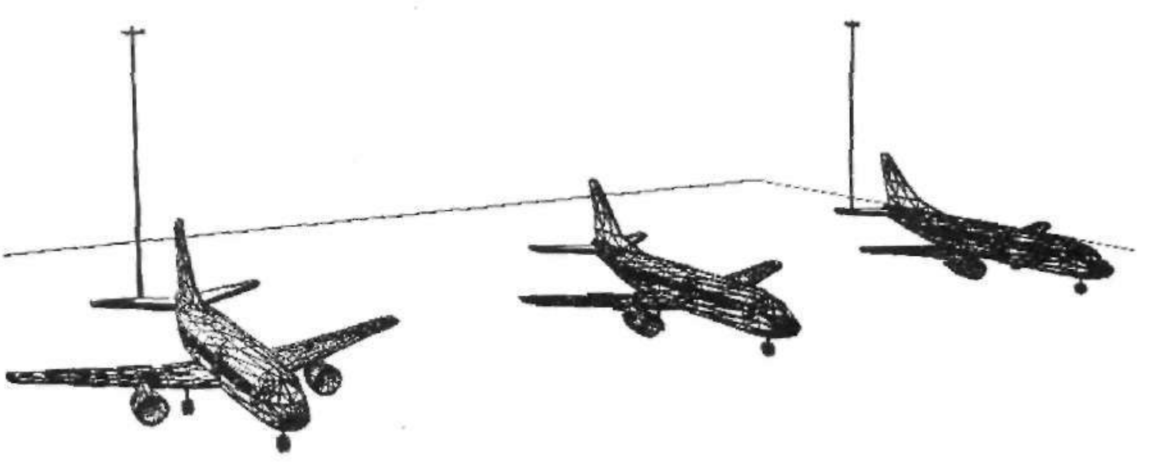
Shadows minimizing is the final step of lighting design including shadows. The shadows minimizing can be achieved by redirections of some floodlights, changing types of floodlights, their LDC and the placement of lighting masts. As common criteria for shadows minimizing could be used the visual estimation of the shadow's size and intensity. The full-color visualization pictures and especially illuminance distribution in scaled pseudo-colors are very convenient for this. Figure 4 demonstrates the shadows variation on the apron obtained by variation of quantity and placement of lighting masts, quantity and redirections of floodlights. As an numerical estimation could be used the a ratio of an average horizontal illuminance on the stands area *with* aircrafts -$E_{hor.aver.\ 2}$,to average horizontal illuminance on the same stands area *without* aircrafts $E_{hor.aver.\ 1}$:

$$K_s = E_{hor.aver.\ 2} / E_{hor.aver\ 1}$$

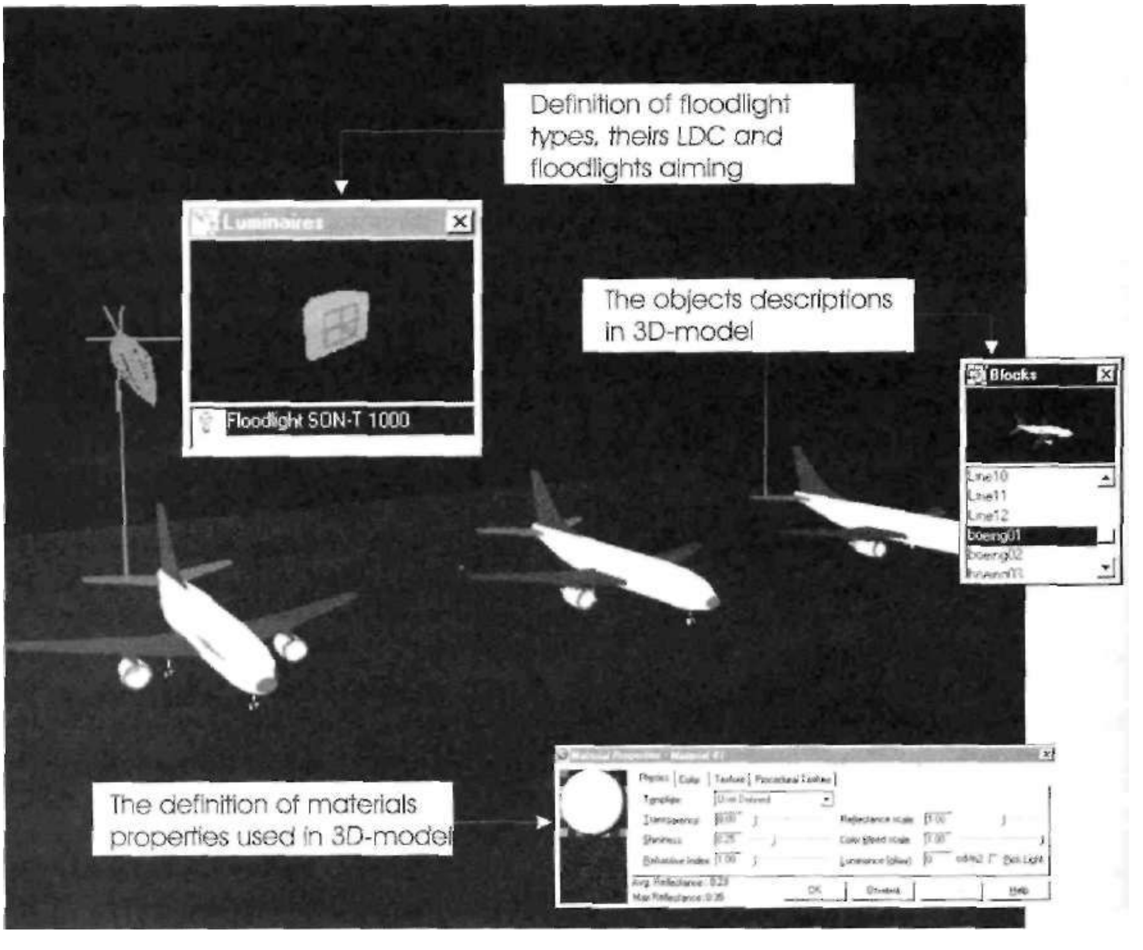
The table 1 presents the calculating values of this numerical criteria for four variants of shadows optimization. Maximum value of this criteria signifies the minimum shadowing. The analysis of lighting visualization pictures and K_s values confirms that well known fact that increasing of quantity of lighting masts decrease the shadow's size and intensity, and illuminance level on the stands area approaches to illuminance level without aircraft's.

From other hand the modern lighting mast especially with mobile crown is quite expensive device. Also the quantity of lighting masts on the apron very often is restricted because of some technical conditions. Because of this the customer usually try to choose the variant with minimum quantity of lighting masts. In this situation using of criteria of shadow minimizing allows to make more valid choose of lighting masts quantity.

Thus in our example of cargo apron lighting the best result is achieved in case of lighting mast arrangement beside every aircraft stand (Figure 4d). But in practice it is very expensive solution, because lighting masts cost can exceed mounting floodlights cost in ten times and more, and the total cost of installation (the foundations building, masts mounting, spending of electrical cable and devices and so on) is high enough. The next variant in minimum of shadowing and almost in two times

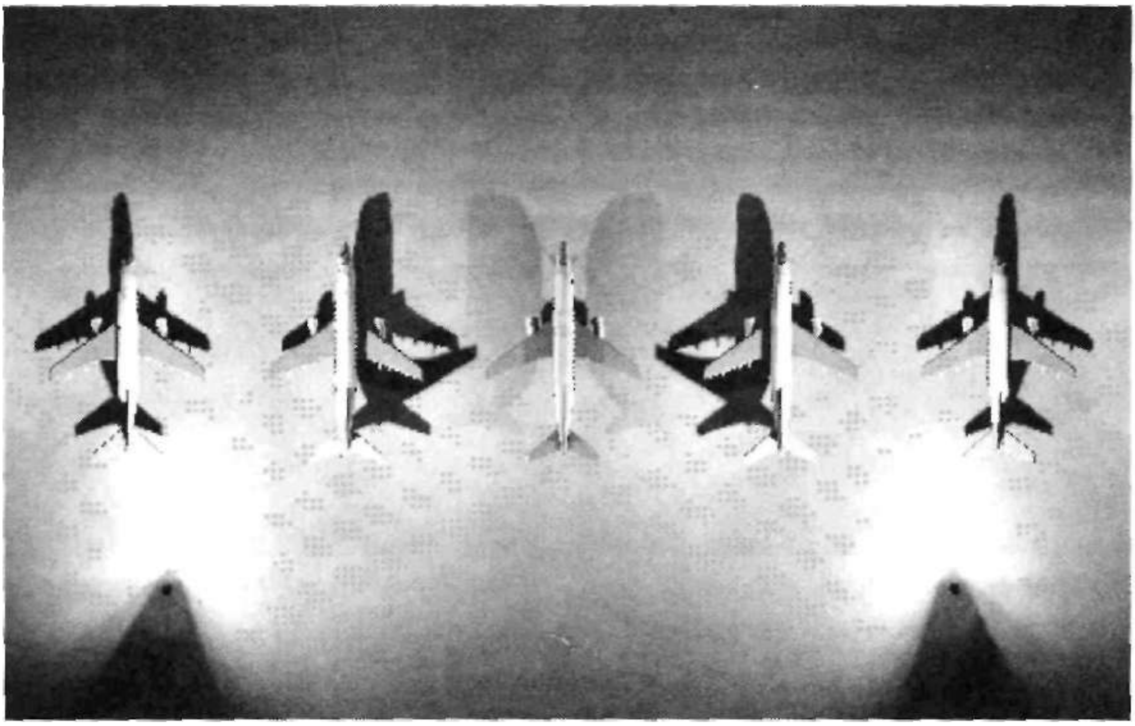


a) 3D-wireframe model of the apron with aircraft's and lighting masts.

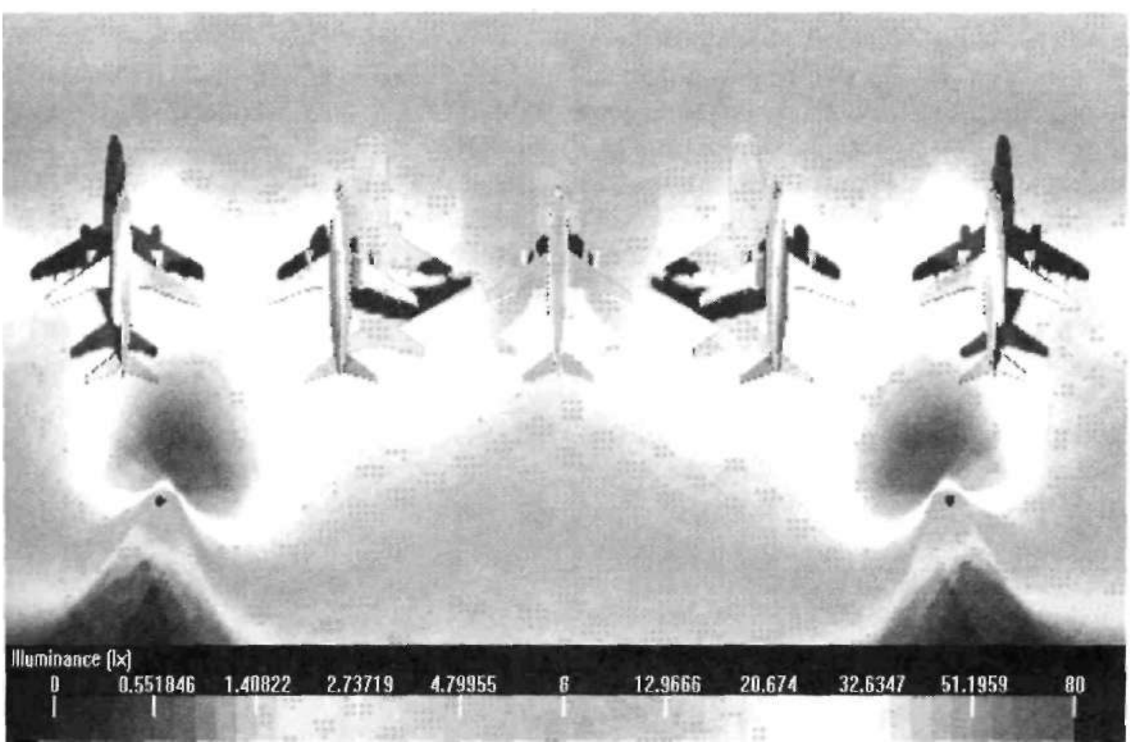


b) 3D model with floodlights and embedded materials.

Fig. 2. 3D computer modeling of the cargo apron.

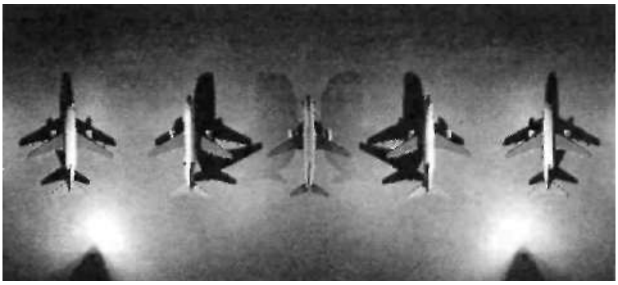


a) 3D lighting simulation full-color picture with ray-trased shadows.

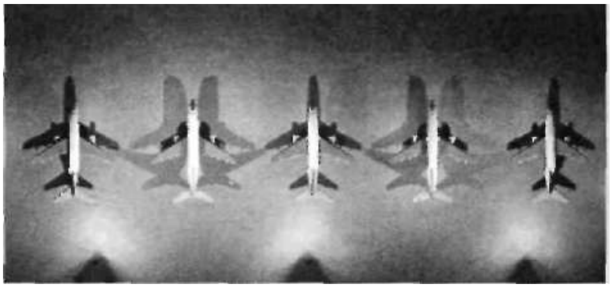


b) 3D lighting simulation picture in scaled pseudo-colors.

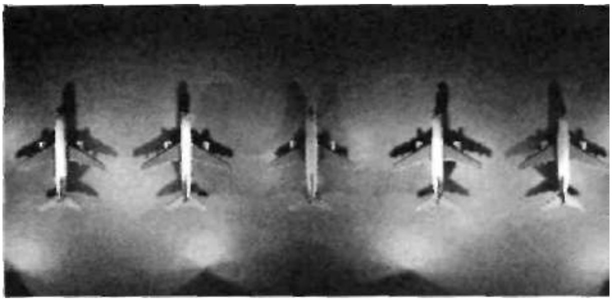
Fig. 3. Apron lighting calculation with aircrafts on stand areas.



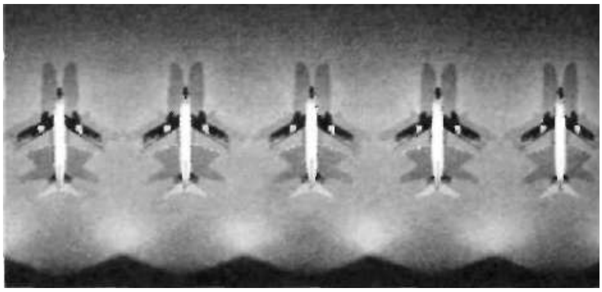
a) 2 lighting masts, 14 floodlights.



b) 3 lighting masts, 15 floodlights.



c) 4 lighting masts, 12 floodlights.



d) 6 lighting masts, 12 floodlights.

Fig. 4. The shadows variation for several variants of apron floodlighting.

cheaper is the variant with three lighting masts for every five aircraft stands (Figure 4b). The variants with two and four lighting masts (Figure 4 a, c) are very closely by K_s values, and in this situation the variant with two masts is preferable because of lower cost of installation. By this way the priorities in the variants of lighting from the point of view of shadows minimizing (by other equal conditions) are the following: six, three and two masts. In this way the customer can make valid chouse proceeding of quality of lighting, technical means and financial resources.

CONCLUSION

The method of apron lighting design proposed in this article allows to choose more validly the variant of lighting masts arrangement and control more exactly the quality of apron floodlighting that increase safety of flight service.

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