Let's assume that the error in determining the area $\delta S = 100$ ha, $\Delta t = 16–10 = 6$ days. We accept the indicator of the fire area growth rate $\alpha = 2$, i. e. assume that the speed of the fire front is constant.

We calculate the coefficient k and its error in the model:

$$K = \Delta S/\Delta t^2 = 770/36 = 21.4 \text{ ha/per 24 hours},$$

$$\delta k = 100/36 = 2.7 \text{ ha/per 24 hours}.$$

An error estimate of the indicator α according to formula (9) yields:

$$\delta\alpha = \frac{100}{21.4 \cdot 6^2 \cdot \ln 6} = 0.07 .$$

As the wind speed is not great, we use the exponential indicatrix. For the wind speed $w = 1$ m/sec, from tab. 1 we determine the factor $P(w) = 1{,}178$ and $Q(w) = 1{,}758$.

In accordance with the formula (5), converting acres into square meters, we get:

$$v_{0S} = \frac{\sqrt{k}}{P(\omega)} = \sqrt{\frac{21.4 \cdot 10^4}{1.178}} = 426 \text{ m/day}.$$

In view of a possible error δk the value of the front velocity will be in the following ranges: $275 \le v_{0S} \le 577$ m/day.

With the help of formula (6) we can estimate the rate of the fire perimeter growth:

$$\frac{dL(t)}{dt} = 2v_0(t)Q(w) =$$
$$= 2 \cdot 426 \cdot 1.758 = 1498 \pm 531 \text{ m/day}.$$

The resulting estimate of the fire front rate together with the selected indicatrix of propagation allows us to form the predictive estimates of the fire contour over time.

A simple method of estimating the parameters of the distribution process presented in the article is based on the use of geometric models and allows to predict the forest fires propagation on the basis of information stored in ISDM-Forestry. The methodology uses the indicatrices of two kinds, depending on the wind speed in the area of fire: the exponential one and the elliptic one. The received formulas were used for the numerical calculation of a real fire parameters, their errors were estimated. The described method of calculation was used to construct the contours of fires on the basis of neural network forecasting in a software package "Taiga-2" and in the development of an information system of forest fires forecasting for ISDM-Forestry.

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A THERMAL VACUUM SPACECRAFT TEST: THE EXPERIENCE OF CREATING SOLAR SIMULATORS USING HIGH PRESSURE GAS-DISCHARGE LAMPS

In this article we have considered a possibility to use the commercial XBO xenon lamps to create a source of radiation, integrated in solar simulators. We have conducted experimental studies of photonic lamp performance.

Keywords: thermal vacuum test, solar simulator, radiation source, light flux, XBO-lamp.

One of the main stages of ground spacecraft testing is considered to be the thermal vacuum test. The tested object is a thermophysical spacecraft model of its elements. Instead of flight devices and blocks, the platform of the thermophysical model has its own thermal simulators – heater sections, simulating thermal dissipation during flight operations. The resistance sensors are installed in the model's elements to read the temperature information during the thermal vacuum test (TVT).

The purpose of the TVT is an experimental test of the thermal mode and thermal schemes of newly developed external spacecraft elements, devices, and equipment during the injection simulation during orbital operations.

There are some tasks that should be fulfilled during the test: verification of a mathematical conducted heat exchange model between the platform structure elements; verification that the temperature of the structural elements and devices meets the requirements for thermal control subsystem, as well as requirements for external elements when simulating extreme external and internal heat loads; determination of temperature fields by external structural elements of the articled parts; verification of sufficient electrical power for heat from external devices and articled equipment; development of recommendations, concerning the updating of technical documentation on heat schemes for the articled external elements.

During the preparation of test results, the temperature parameters registered and controlled during the test shall be assessed if they are in compliance with the permitted values. If required, some recommendations will be given in a report concerning the thermal scheme update. Thermal vacuum tests are performed on dedicated test benches: vacuum units, equipped with cryogenic screens and simulators of external heat and light fluxes. The test conditions are similar to those at spacecraft in orbit. The thermal vacuum test benches comprise: a thermal vacuum chamber, a vacuum pumping system, a cryogenic system, panels of the heat fluxes simulator, and a solar simulator. The vacuum pumping system provides pressure inside the chamber not exceeding $5 \cdot 10^{-5}$ mm of mercury. The cooled cryogenic screens simulate the environment of black space with a temperature not exceeding –180 ºC.

The solar simulator is the main and most complicated element of the thermal vacuum test. The requirements for the solar simulator are so: the radiation energy spectral distribution must be within (0.2–2.5) micrometer wavelength range, close to solar radiation distribution; the radiation flux density must be 1340–1440 W/m^2 with a simulation error not exceeding 10 % from the nominal values; the light spot sizes must be corresponding to the working field size; the light flux nonuniformity must not exceed 10 %.

The solar simulator is a source of radiation and an optical shaping system, directing flux into the working area.

In the recent studies considered is the possibility to apply gas-discharge XBO-lamps with a high-pressure as a source of radiation for solar simulators based on the thermal vacuum chamber TVC-120 (a unique test bench for spacecraft ground tests).

Quite recently (in 2005), during a thermal vacuum test, the solar simulator setup in the TVC-120 was arranged on ДКсРМ-55000 lamps of Russian production. ДКсРМ-55000-УХЛ-4 is a xenon arc lamp with ultrahigh pressure, with power of 55.000 W. The lamp has a metallic water cooling body with internal reflective optics and a domical output quartz window, which is cooled by distilled water. The moveable cathode and copper anode has a slit water cooling system. The lamp spectrum (fig. 1) is close to solar [1]; however, today it is not produced due to its unprofitability. Since the lamp's resource is limited (200 hours) and the available lamps have already been used, there is a necessity to change the source of radiation.

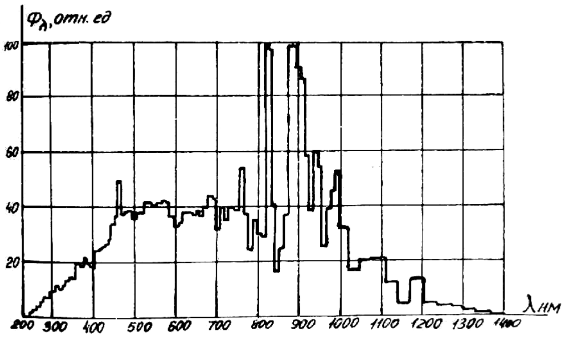

Fig. 1. Radiative energy spectral distribution of the ДКсРМ-55000-УХЛ-4 lamp

A market analysis has shown that XBO lamps can be competitive. These lamps have a reasonable price (since there is a serial production); they are widely applied in film production.

The XBO-lamps belong to the gas-discharge lamp type. In these lamps the light is generated by a discharge arc, which freely ignites in pure xenon between two electrodes. The arc's length is the same as the distance between two electrodes composing several millimeters [2]. The brightness distribution of the lamp arc is shown in fig. 2.

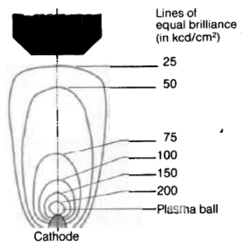

Fig. 2. Brightness distribution in the XBO-lamp arc

As it is shown in fig. 2, the main energy is concentrated inside a plasma ball which is 2–3 mm in size.

This means that the lamps are very close to be an ideal spotlight, which is particularly important for application in solar simulators – the lamp accommodation in optical element focus allows to create and direct the light flux to a desired field with greater accuracy.

In fig. 3 is the XBO-lamp's spectral radiation rate in comparison to black body radiation in given color temperature.

The XBO-lamp has a continuous spectrum of visible radiation range, the intensity of which coincides with solar radiation [2].

The confirmation of the XBO-lamps performance and the possibility of their application in solar simulation in thermal vacuum test were proved during an experimental test bench (fig. 4).

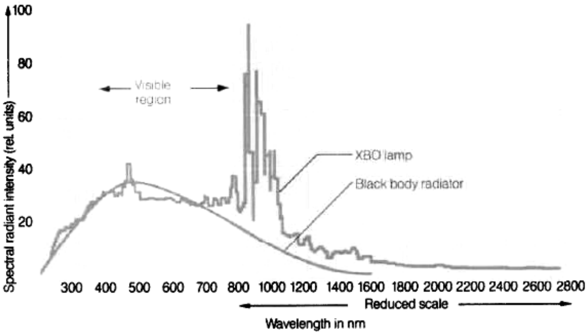

Fig. 3. Spectral radiation rate of the XBO-lamp

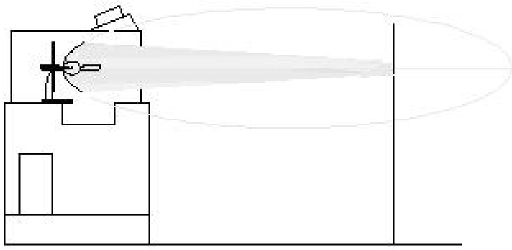

Fig. 4. The scheme of the experimental test bench
for verification of XBO 10000 W/HS OFR lamp performance

The test bench comprises of: film projector Kinoton with a XBO 10000 W/HS OFR lamp (fig. 5) [3]; light flux intensity sensor КФЛП (silicon photocell of radiant flux), attached to a moveable device (fig. 6); a screen for light spot shaping.

Fig. 5. Kinoton film projector with a XBO lamp

The КФЛП sensor consists of a set of silicon plates that convert incoming solar energy into a current. According to the electric signal level it has been defined as light flux power hitting a plate. An ellipsoidal reflector is used for gathering the beams radiated by the lamp in all directions. The XBO lamp installed in the first focus of the reflector radiates the light flux, which then reflects it from the reflector mirror walls to be gathered in the second focus. This occurs in conditions with an ideal spot source. Since the real source had its final sizes, the objective of the experiment was to clarify whether the XBO-lamp is applicable as a source of radiation and what quantity of lamps is required for the desired illumination in the thermal vacuum chamber working area.

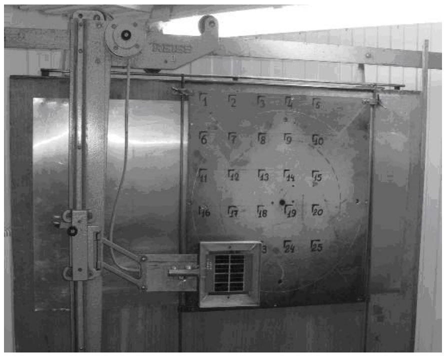

Fig. 6. The screen with marks for flux density scanning

The screen is a flat metallic surface with markings corresponding to dimensions of the photocells' working area and is divided into 25 areas. The screen is placed vertically in the second focus of the ellipsoidal reflector. The central screen area, arc of the lamp, and reflector are located on one optical axis.

In order to verify the compliance with the allowable range of КФЛП values, a rough estimation of power going through this sensor had been performed:

$$P = P_л \cdot K_{кпд} \cdot K_{охв} \cdot K_{отр} \cdot K_{пл},$$

where $P_л$ – power set in the lamp; $K_{кпд}$ – lamp efficiency; $K_{охв}$ – coefficient of light coverage from the lamp by the reflector surface; $K_{отр}$ – reflection ratio of reflector; $K_{пл}$ = 125 considering dimensional equation of КФЛП output value (W/m^2) and its own area (0,008 m^2).

Assuming that $P_л$ = 2560 W , $K_{кпд}$ = 0,6, $K_{охв}$ = 0,6, $K_{отр}$ = 0,85, we get:

$$P = 97920\ (W/m^2).$$

Considering the КФЛП sensor measurement range to be (0–3000 W/m^2), a decision had been made to manufacture mesh from brass with attenuation of approximately about 97920/3000 = 32.6 times.

During the experiment the lamp was switched on at 2 560 W, the light spot on the screen was shaped, and by a КФЛП sensor moving around the screen area, field scanning of 400 × 500 mm had been performed. The average data (illumination values in W/m^2) for 6 sizes are shown in table.

Screen illumination in the areas (W/m^2)

984	1 599	1 968	1 722	1 107
1 722	3 321	5 658	4 428	1 845
26 44.5	11 931	24 600	12 423	3 444
2 263.2	6 519	11 070	4 674	2 337
1 107	1 845	2 214	1 845	1 230
			total	114 500

Based on the obtained data, power distribution inside the shaped spot had been created (fig. 7).

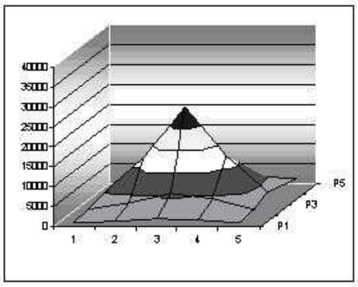

Fig. 7. Power distribution inside the shaped spot

The measurement analysis has shown that in the central area (240 × 300 mm – 9 average elements of the table) 74 % of light energy falling on the screen is concentrated; on the periphery there is only 26 % of energy.

Taking into account the diameter of the thermal vacuum chamber input block (the block through which the light flux passes inside the chamber – 350 mm); for the following calculation it is accepted that energy falling on the input block is on 9 average elements. The total light power coming to the input block is calculated by the formula:

$$P_{\text{сумм}} = \left(\sum_{i=1}^{9} P_{\text{кфлп}}\right)/K_{\text{пл}},$$

Thus:

$$P_{\text{сумм}} = 677 \text{ (W)}.$$

If we consider the way of the light flux through the input block and farther inside the thermal vacuum chamber TVC-120; it also has certain losses.

The input block comprises a mixer and light port, providing hermiticity in the vacuum chamber during the test. Here, there are 4 quartz surfaces. By defining losses on one quartz surface as 4 % [4], we will have losses on the input block of 16 %.

Inside the vacuum chamber there is a collimating mirror. After the mixer, the light flux passes to this mirror, and then it is reflected and goes inside the thermal vacuum chamber, shaping the light flux with section 2 × 1 m^2.

Assuming that the reflection ration of the collimating mirror is 0.85, we get losses inside the chamber of 31 %.

So, according to the experimental data, in the 2 m^2 area there is 467.13 W of light power from one lamp (under the set lamp power of 2.560 W); in the working area of the thermal vacuum chamber there is a light flux density of:

$$467.13 / 2 = 233.6 \text{ (m}^2\text{)}.$$

Based on the requirements for the solar simulator (flux density of 1.340–1.440 W/m^2), it is calculated that the quantity of lamps, needed for generating desired flux density is:

$$N = 1\,440 / 233.6 = 6.2 \text{ (pieces)}.$$

In order to generate the light flux of a desired density during the thermal vacuum test it is sufficient to sum up the fluxes to 7 lamps.

Considering that the experiment was carried out for the lamp with power of 2.560 W, and the maximum lamp power is 10,000 W, we must speak about additional lamp sources. This allows using the lamps in a partial load mode that can provide longer operational lifetime.

This way, the experimental results confirm that it is possible and desirable to use the OSRAM XBO 10 000 OFR lamps in solar simulators. At the same time it is necessary to carry out calculations and make a light optical scheme for summing up the fluxes to 7 XBO-lamps.

If we compare the operational performance of lamps previously used in solar simulators (ДКсРМ-55,000 lamps and OSRAM XBO 10,000 OFR lamps), it is necessary to mention the following: the ДКсРМ-55,000 lamp has an electric power of 55 kW, the optical power is approximately 15 kW, the lamp requires water cooling (too expensive), the average lamp resource is 200 hours. The OSRAM XBO 10,000 lamp requires electric power of 10 kW, provides optical power of approximately 6 kW, and requires only air cooling; the average lamp resource is 500 hours.

Considering other lamp performance (stable light arc; operation under direct current; the possibility of a repeated ignition in a hot state; the full light flux immediately after ignition), it is possible to state that these lamps are quite suitable for application.

A broad application of the XBO-lamps in medicine and film production, pointing to mass production will make them financially available.

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