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INFLUENCE OF THE SOLAR ECLIPSE ON THE POWER AND OPERATIONAL PARAMETERS OF THE BIG SOLAR FURNACE IN PARKENT OF UZBEKISTAN

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Abstract: *The effect of the total solar eclipse on the performance of the solar concentrator is studied on the Big Solar Furnace (BSF) in the Institute of Material Science Scientific -Production Association "Physics-Sun", Academy of Sciences of Uzbekistan at Parkent of Uzbekistan during the partial solar eclipse of August 1, 2008. It is found that the solar radiation decreased dramatically in the first half an hour from 500 W/m2 at 15:00 to a few Watts per squared meters at 15:35, while it began to increase gradually until reaching about 370 W/m2 at 17:08. The distribution of the heat in the focus of the BSF is tested by measuring the heating power of radiation concentrated by the furnace during that eclipse. Heat energy distribution contours are obtained in the mode of tracking the trajectory of the sun during the eclipse. The divergence of the focus during the eclipse of the BSF doesn't exist and the structure of the spot has no significant change.*

Key words: *solar furnace, focal zone, heliostats, concentrator, solar eclipse.*

1. Introduction

A solar furnace is a structure that uses concentrated solar power to produce high temperatures, usually for industry. Parabolic mirrors or heliostats concentrate light (Insolation) onto a focal point. The temperature at the focal point may reach 3,500 °C (6,330 °F), and this heat can be used to generate electricity, melt steel, make hydrogen fuel or manufacture nanomaterials.

Orientation systems can provide continuous or nearly continuous adjustments, with movement of the collector to compensate for the changing position of the sun. Mechanized orienting systems can be sun-seeking systems or programmed systems. Sun-seeking systems use detectors to determine system misalignment and through controls make the necessary corrections to realign the assembly. Programmed systems, on the other hand, cause the collector to be moved in a predetermined manner (e.g., 15°/h about a polar axis) and may need only occasional checking to assure alignment. It may also be advantageous to use a combination of these tracking methods, for example, by superimposing small corrections by a sun-seeking mechanism on a programmed ‘‘rough positioning’’ system[1].

The largest solar furnace is at Odeillo in the Pyrénées-Orientales in France, opened in 1970. It employs an array of plane mirrors to gather sunlight, reflecting it onto a larger curved mirror.

The second biggest solar furnace in the world BSF with capacity of 1 MW is located in Parkent city in Uzbekistan (φ = 41° 18' 45.93" N and λ = 69° 44' 28.03" E) which is on elevation of 1050 m over the sea level. This furnace belongs to the Institute of Material Science in Parkent of Uzbekistan. It consists of a heliostat field of total area 3022.5 m^2 contains 36 heliostats, a parabolic concentrator of total area 1840 m^2 and a technological tower. The optical parameters and the automatic control system allows this furnace to form a focal zone of energy similar to that produced in that furnace at Odeillo in the Pyrénées-Orientales in France. The concentrator focuses reflected from heliostats solar beams on a focal zone is of diameter 1 m, where 1000 kW of energy is created. The focal area is located in a technological tower, where special devices are established and the equipment allowing investigating the physical and chemical processes proceeding at high temperature influence on substances. A photo of this furnace is shown in Fig. (1), while a photo of the field of heliostats is shown in Fig. (2). To imagine the entire system, Fig. (3) shows a schematic horizontal and vertical diagram of the BSF and the field of heliostats dimensions.

Figure. 1 The second largest solar furnace in the word BSF in Parkent of Uzbekistan.

Figure. 2 The field of heliostats of the BSF.

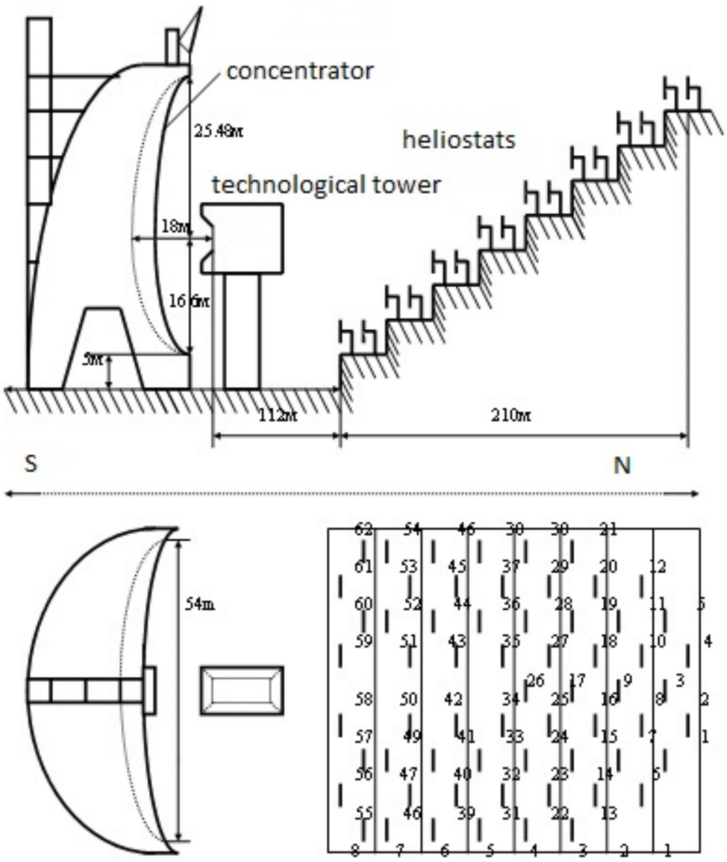


Figure. 3 A schematic horizontal and vertical diagram of the BSF and the field of heliostats dimensions.

The effect of solar eclipses on the solar energy systems such as photovoltaics and solar furnaces became important since some applications need a continuous operation, which means that the stopping of the performance of such systems may cause some industrial and economical problems. Therefore, some researchers began to study the performance of such systems during total as well as partial solar eclipses.

Ghitas studied [2] the effect of partial solar eclipse on the behavior of solar cell parameters. The partial solar eclipse observed from the Faculty of Electrical Engineering and information Technology at Bratislava, Slovak Republic at latitude 48°10′ N and longitude 17° 07′ E with a surface elevation being about 150 m above sea level was a good chance for such a study. The variation of solar radiation with the current of mono-Si and a-Si solar cells sensors during the partial eclipse has been studied. Accordingly, the phase change of voltage-current of mono-Si cell during the short period of that eclipse has been plotted.

Also, Ghitas and Sabry [2] studied spectral behaviour of silicon solar cells under total solar eclipse of 29 th March 2006. The effect of variation of both intensity and spectrum of solar radiation during the total solar eclipse on the output response of the monocrystalline and amorphous silicon solar cells was investigated. An experimental set up was fixed above Salloum observation plateau located in the western border of Egypt at latitude 31°34´ N and longitude 25°7´ E, during that eclipse. The surface elevation is about 200 m above sea level. The ultimate goal was to explain some of the interesting natural phenomena by using a new procedure. The setup included 8 metallic interference filters in a circle wheel covering parts of UV, visible and IR spectral bands. The comparison between the open circuit voltage of monocrystalline and amorphous silicon solar cells during the total period of eclipse and around center of eclipse were recorded and plotted. There was an identical diminishing occurring for the V_{OC} of both solar cells owing to the depression of radiation in the two wings of eclipse, except a small noticeable difference in the knee curve referred by the two opposite arrows near to the second and the third contacts referred to the apparent begin of and the end of the real contacts between the lunar and solar discs respectively. The measured data from that eclipse have yielded significant variation of spectral behavior of monocrystalline and amorphous silicon solar cells, which explains spectral prediction of many observations at solar eclipse.

1.1. Solar Eclipse of August 1 2008

A total solar eclipse occurred on August 1, 2008. A solar eclipse occurs when the Moon passes between Earth and the Sun, thereby totally or partly obscuring the image of the Sun for a viewer on Earth. A total solar eclipse occurs when the Moon's apparent diameter is larger than the Sun's, blocking all direct sunlight, turning day into darkness. Totality occurs in a narrow path across Earth's surface, with the partial solar eclipse visible over a surrounding region thousands of kilometers wide. The eclipse of August 1, 2008 had a magnitude of 1.0394 that was visible from a narrow corridor through northern Canada (Nunavut), Greenland, central Russia, eastern Kazakhstan, western Mongolia and China. Occurring north of the Arctic Circle, it belonged to the so-called midnight sun eclipses. The largest city on the path of the eclipse was Novosibirsk in Russia[4].

The total eclipse lasted for two minutes, and covered 0.4% of the Earth's surface in a 10,200 km long path. It was the 47th eclipse of the 126th Saros cycle, which began with a partial eclipse on March 10, 1179 and will conclude with a partial eclipse on May 3, 2459[4].

A partial eclipse could be seen from the much broader path of the Moon's penumbra, including northeastern North America and most of Europe and Asia. It was described by observers as "special for its colors around the horizon". There were wonderful oranges and reds all around, the clouds lit up, some dark in silhouette, some golden, glowing yellowy-orange in the distance. One could see the shadow approaching against the clouds and then rushing away as it left.

The eclipse began in the far north of Canada in Nunavut at 09:21 UT, the zone of totality being 206 km wide, and lasting for 1 minute 30 seconds. The path of the eclipse then headed north-east, crossing over northern Greenland and reaching the northernmost latitude of 83° 47′ at 09:38 UT before dipping down into Russia. The path of totality touched the northeast corner of Kvitoya, an uninhabited Norwegian island in the Svalbard archipelago, at 09:47 UT[4].

The eclipse reached the Russian mainland at 10:10 UT, with a path 232 km wide and a duration of 2 minutes 26 seconds. The greatest eclipse occurred shortly after, at 10:21:07 UT at coordinates 65°39′N 72°18′E (close to Nadym), when the path was 237 km wide, and the duration was 2 minutes 27 seconds. Cities in the path of the total eclipse included Megion, Nizhnevartovsk, Strezhevoy, Novosibirsk and Barnaul[4].

The path of the eclipse then moved south-east, crossing into Mongolia and just clipping Kazakhstan at around 10:58 UT. The path here was 252 km wide, but the duration was decreased to 2 minutes 10 seconds. The path then ran down the China-Mongolia border, ending in China at 11:18 UT, with an eclipse lasting 1 minute 27 seconds at sunset. The total eclipse passed over Yiwu, Juiquan and Xi'an. It finished at 11:21 UT[4].

A partial eclipse was seen from the much broader path of the Moon's penumbra, including the north east coast of North America and most of Europe and Asia. In London, England, the partial eclipse began at 08:33 GMT, with a maximum eclipse of 12% at 09:18 GMT, before concluding at 10:05 GMT. At Edinburgh the partial eclipse was 23.5% of the sun, whilst it was 36% in Lerwick in the Shetland Isles.

Date, time, path, altitude and azimuth of the eclipses are calculated accurately using spherical astronomy methods[5] There are also many computer programs which calculate these data more accurately and faster. The path and the times of this eclipse are shown in Fig. (4), while the percentage values according to the area of seeing the eclipse are shown in Fig. (5).

In Parkent and entire Uzbekistan, the eclipse was seen partially. Its magnitude in Parkent was 0.722 and the maximum obscuration was 65.90%. It began in 10:00 U.T. (15:00 LMT) with an altitude of 50° and azimuth of 245.8°. The maximum eclipse was in 11:06 U.T. (16:06 LMT) with an altitude of 38.2° and azimuth of 260.2°. It ended in 12:06 U.T. (17:06 LMT) with an altitude of 26.8° and azimuth of 270.8°.

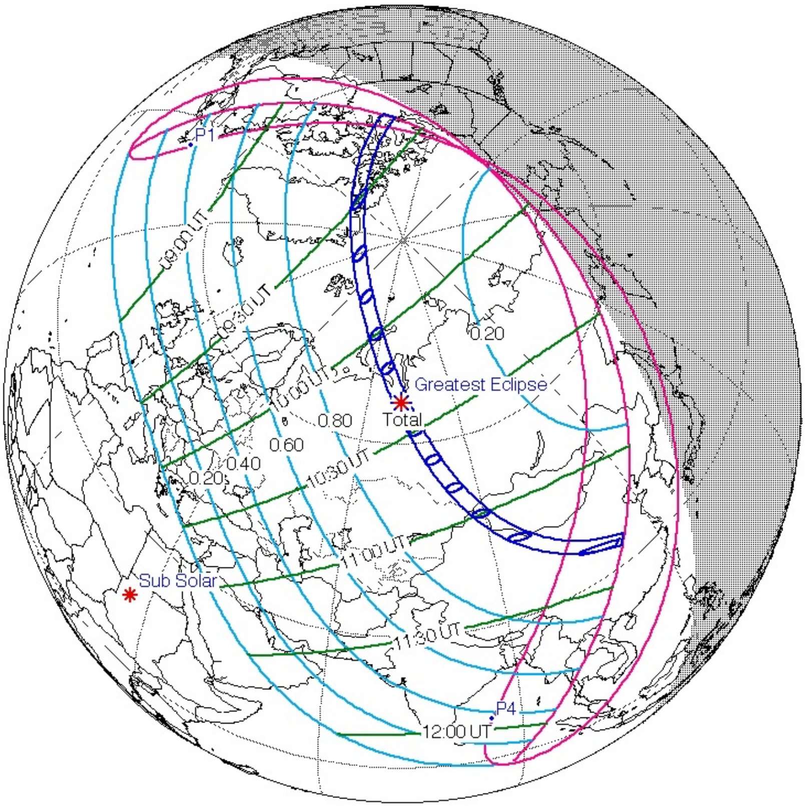


Figure. 4 The path of the solar eclipse of August 1, 2008.

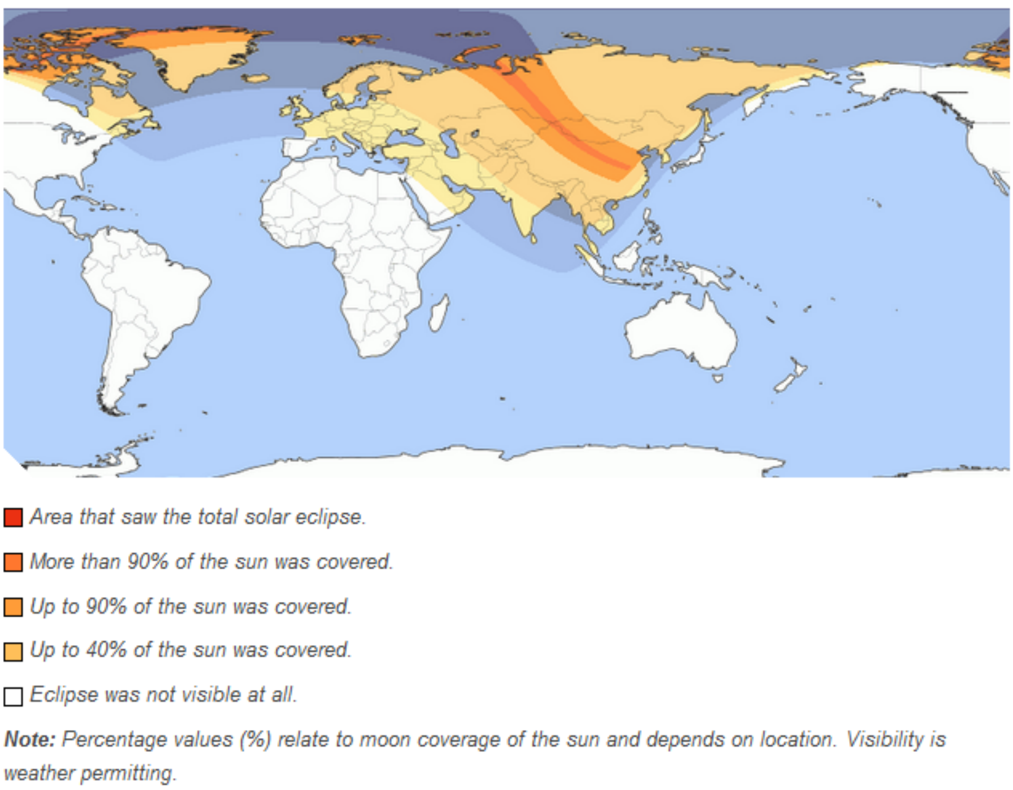
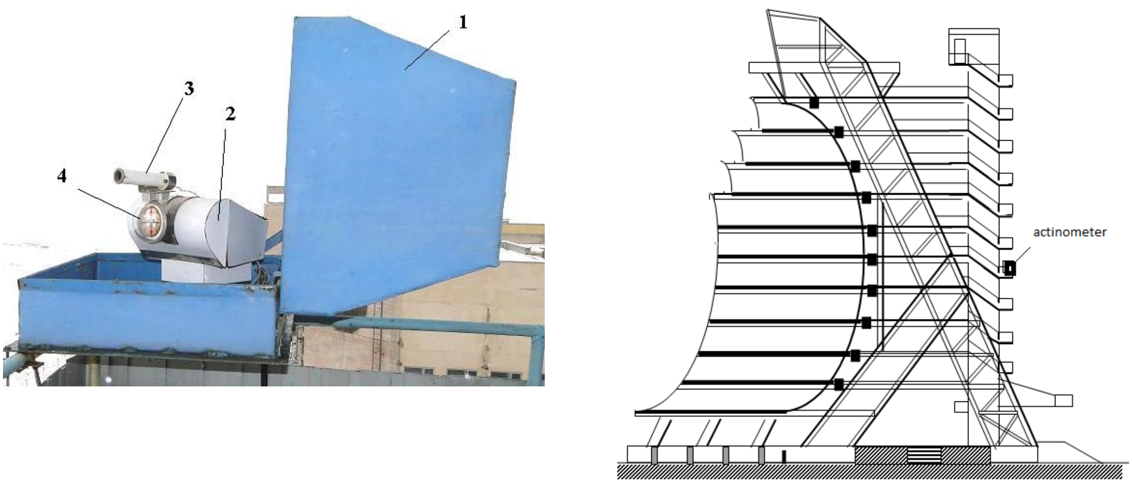


Figure. 5 Percentage values according to the area of seeing the eclipse.

1.2. Data acquisition

Using Actinometer of type AT-50 (which is an instrument used to measure the heating power of radiation) located on the sixth floor of the technological tower as displayed in Fig. (6), the change of the solar radiation during the eclipse of August 1, 2008 was recorded minutely in the area of the BSF. The recorded solar radiation has dramatically decreased during the first 35 minutes until it was about to vanish, while it needed the rest two hours of the eclipse to return back gradually to its normal values as displayed in Fig. (7).



(a) (b)

Figure. 6 (a) General view of the actinometer with the sun tracking system . 1 is the protecting cover, 2 is the tracking system of the sun trajectory, 3 is the actinometrical tube AT-50, 4 is the sensor for orientation to the center of the sun. (b) The location of the actinometer in building of the BSF.

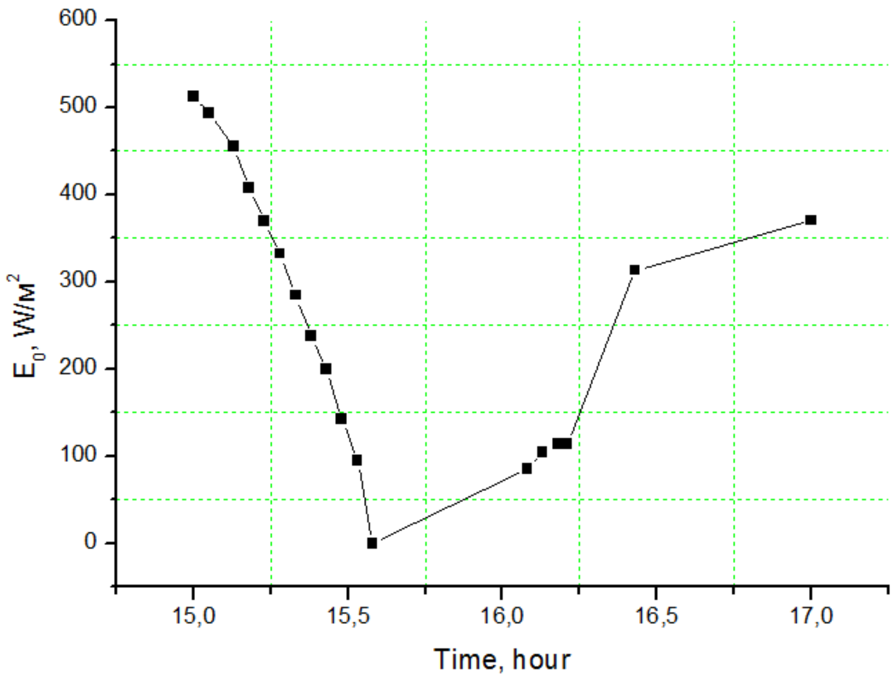
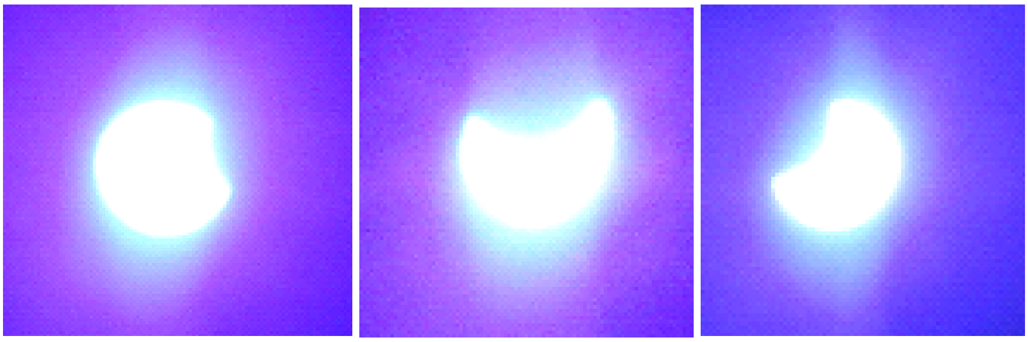


Figure. 7 The change of solar radiation during a solar eclipse.

For the control of a focal spot, a System of Technical Sight (STS) was used. This system consists of a diffusely reflecting screen being in focal zone of BSF, a digital camera in a laboratory room in front of a focal zone at distance of 20 m and a software for data processing. The diffusely reflecting screen has the sizes 100 × 100 × 7 mm is cooled by cold water and covered by a white heat-resistant cover of type KT-117 as shown in Fig. (8).

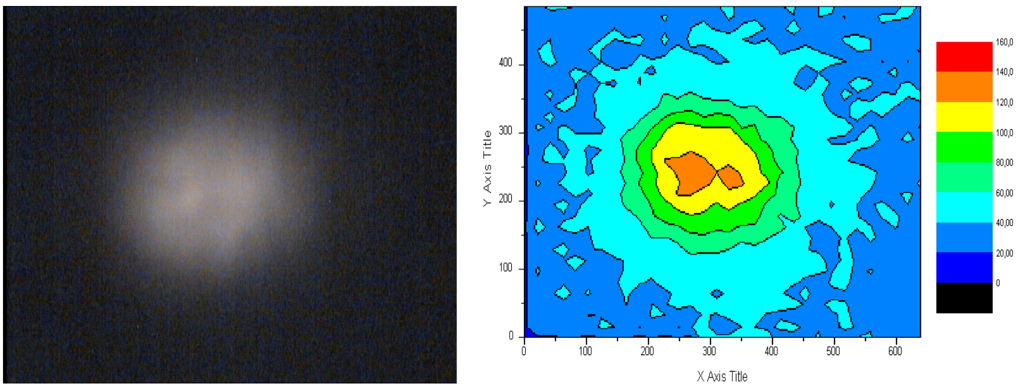
Figure. 8 Diffusely reflecting screen of the BSF, covered with a white heat-resistant cover.

The eclipse was seen partially in Parkent. The maximum covered area from the solar disc was approximately 66%. Some photos have been recorded for the intervals of the eclipse from the location of the BSF as displayed in Fig. (9). Also, the focal stains and isolines of the thermal solar radiation inside the focus of the BSF which is reflected onto the dish from 36 heliostats have been plotted in arbitrary unit using a technical vision system as displayed in the Figs (10), (11), (12) and (13).



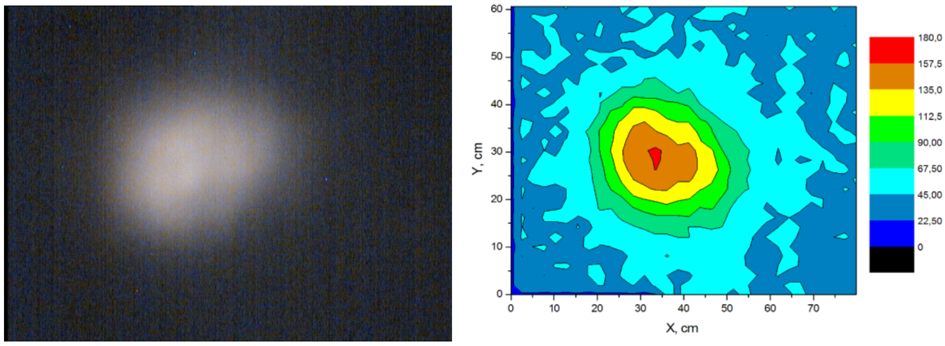
(a) (b) (c)

Figure. 9 Recorded photos of the solar eclipse of August 1, 2008 at three cardinal times: (a) In its beginning at 15:14 L.T., (b) In its intermediate (maximum) point at 16:17 L.T. and (c) In the end time at 16:37.



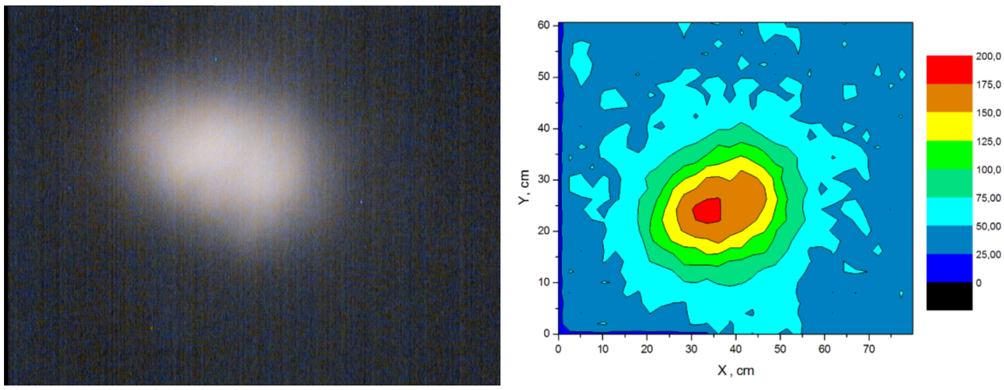
(b) (b)

Figure. 10 (a) The image and (b) Isolines of a focal stain from 33-heliostats at 14:58.



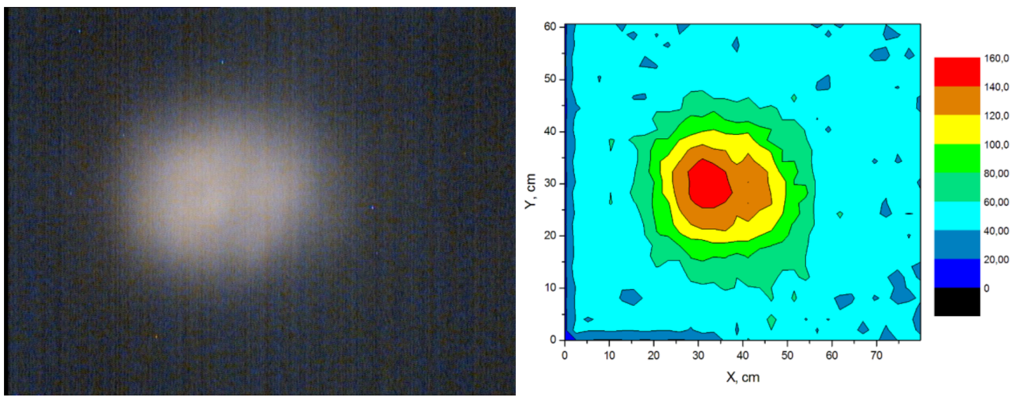
(c) (a) (b)

Figure. 11 (a) The image and (b) Isolines of a focal stain from 33-heliostats at the beginning of the solar eclipse at 15:24.



(a) (b)

Figure. 12 (a) The image and (b) Isolines of a focal stain from 33-heliostats at the moment of the maximum phase of a solar eclipse in 16:16.



(a) (b)

Figure. 13 (a) The image and (b) Isolines of a focal stain from 33-heliostats at the end of the solar eclipse at 17:08.

2. Discussion

From Fig. (7), it can be noticed that the solar radiation measured directly in the area around BSF decreased dramatically in the first half an hour from 500 W/m^2 at 15:00 to a few Watts per squared meters at 15:35. Then, it began to increase gradually until reaching about 370 W/m^2 at 17:06.

The dramatically decrease of the solar radiation during the first half an hour can be interpreted in terms of the solar altitudes and azimuth. Since the eclipse was in August 1, the declination of the sun was 17° 39′ and the sun itself has crossed the meridian by about three hours. Accordingly, its radiation received on the earth's surface starts already to decay. In addition, the solar eclipse increases this decay to be so dramatically.

From the Figs. (10), (11), (12) and (13), we can notice that there is no significant divergence in the focus pattern of the BSF during the solar eclipse, when it is set in the mode of tracking the sun apparent trajectory. The profile of the heat energy inside the focus gets increased in its peak (red colored) gradually to reach 90% of the scale of the arbitrary unit. By the time, the peak gets wider until reaching about 10% of the total area of the focus. The radiation intensity profile inside the focus varies according to the design and the dimensions of the concentration elements (the heliostats and the concentrator). Accordingly, the slight divergence could happen is still within the experimental error and has no effect on the operation of the BSF.

3. Conclusion

The results of this research showed the following:

1. The peak of the focus profile of the BSF started from 70% of the scale arbitrary unit and got increased during the solar eclipse until reaching 90% of this scale.

2. The peak profile got wider by the time during the solar eclipse until reaching 10% of the area of the entire focus of the BSF.

3. There is no significant divergence of the focus of the BSF when it is set in the mode of tracking the sun apparent trajectory during the solar eclipse. Therefore, we can report that the BSF and those types of solar furnaces can operate efficiently during such a kind of the partially seen solar eclipse especially around the time of noon and afternoon.

4. References

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