Solar Household Energy, Inc.

Solar Cooking for Human Development and Environmental Relief

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Infrared imaging to identify sources of heat loss in the Haines solar cooker

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Infrared imaging to identify sources of heat loss in the Haines solar cooker

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Previously, (in TR-28), an experiment was conducted using an infrared imaging camera to determine the sources of heat loss in the cooking vessels of the HotPot and the Haines Solar Cooker (the "Dutch oven"). This experiment was done indoors, with the pot filled with water near the boiling point. One of the findings was that the silicone seal on the Dutch oven was quite effective at reducing heat loss, making the Haines Solar Cooker relatively powerful compared to other panel-type solar cookers.

The following report describes additional infrared imaging data that was gathered relating to the Haines cooker's reflector and conical polycarbonate cover.

Readers are reminded that in the general case, a hot object can lose heat in three possible ways:
1. Radiation: at the boiling point of water, radiation is emitted in the infrared with a maximum at a wavelength of about 8 microns (8×10^{-6} m). This radiation can be detected with the hand-held infrared camera described in TR-28.
2. Conduction: heat can be transferred through solid objects (in this case the pot and the polycarbonate parts).
3. Convection: the flow of air over a hot object draws heat away. A flow is set up even if there is no wind, because heated air has lower density and rises.

The relative amounts of these different mechanisms of heat loss vary with temperature, materials and the geometry of the object. An infrared camera can help to localize the sources and amount of heat loss.

Experimental data

The Haines Solar Cooker was set up on a clear day with 1 liter of water in the pot. The pots were heated by the sun until they reached a temperature near boiling. The following images were taken with the infrared camera. The emissivity was set at 0.95 for all images. The background temperature level was set at 22 deg. C. The temperature readings in the images are the values at the position of the square icon near the center of the image.

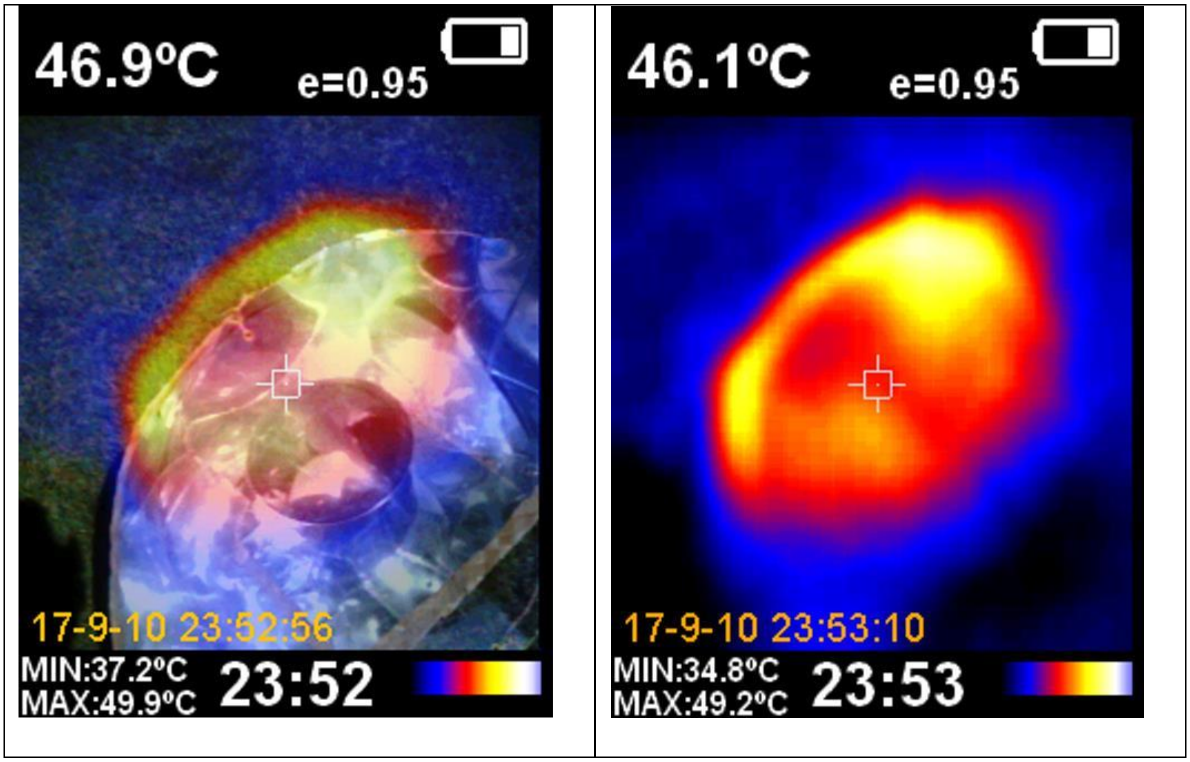

Figure 1. The left image of the top view of the Haines solar cooker at approximately a 45 degree angle to show the position of the reflector and the pot. It is a mix of visible and infared light. The right image is the infrared-only image for the same camera position. From this figure we can see that temperatures are highest near the top of the conical cover.

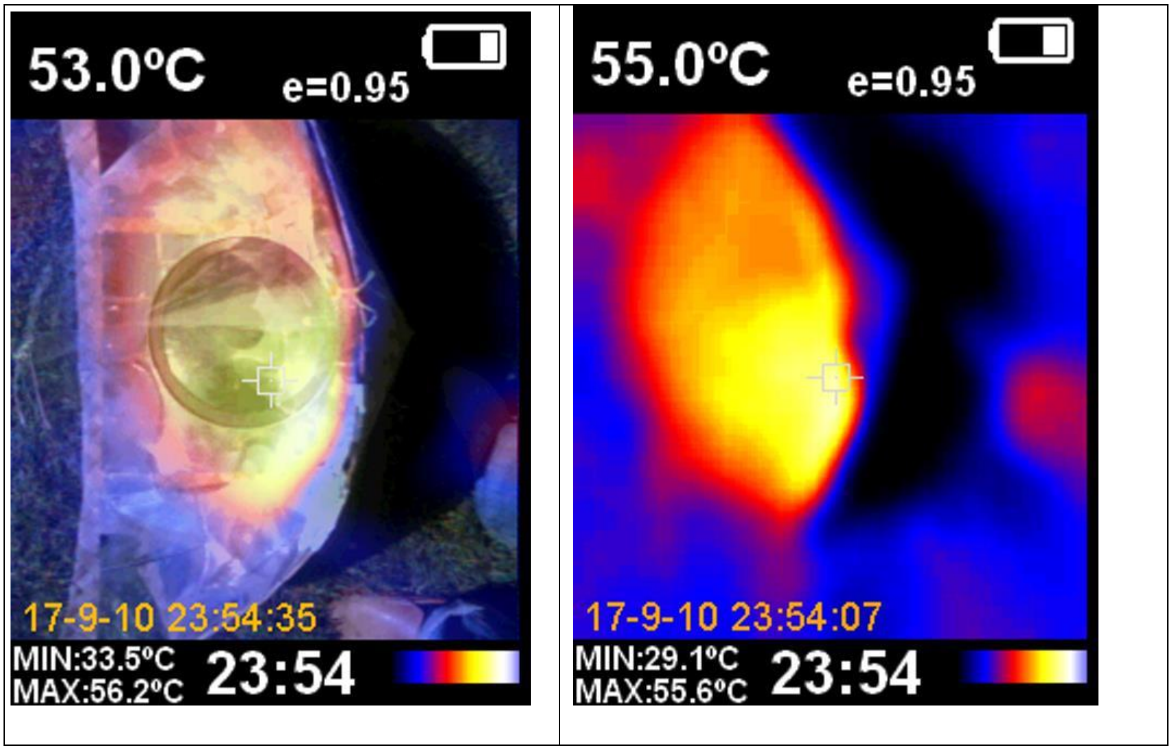

Figure 2. The left image shows the Haines solar cooker as viewed from above. It is a mix of visible and infrared light. The right image is the infrared-only image for the same camera position. This top view in infrared light shows high temperatures near the top of the conical reflector, as well as on the reflector itself.

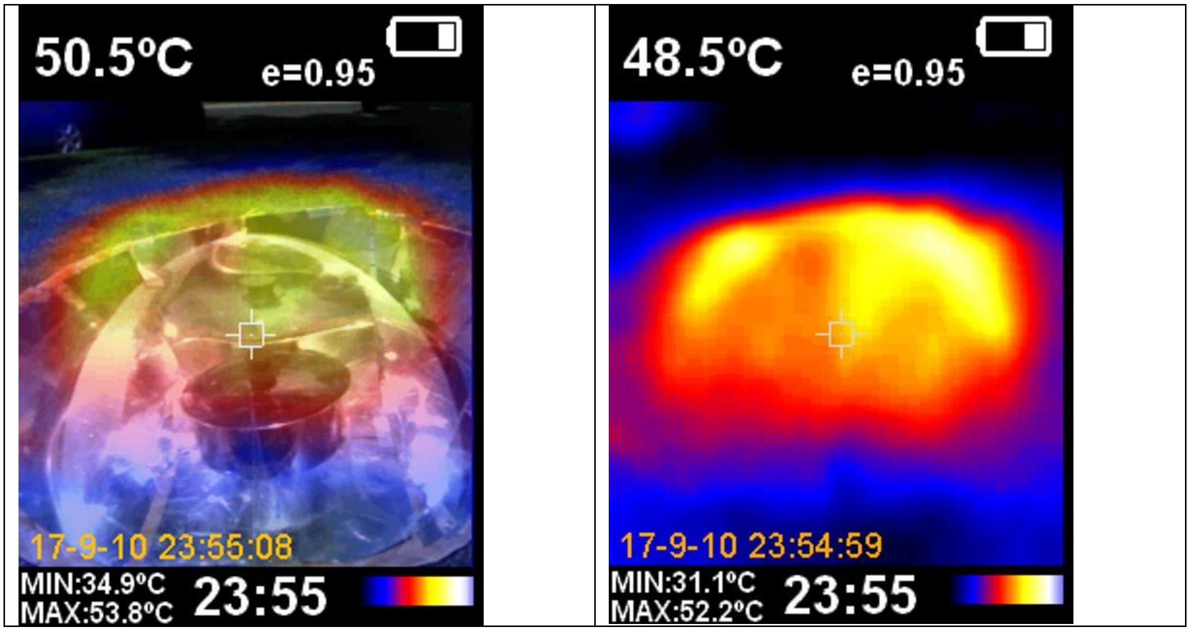

Figure 3. The left image shows the Haines solar cooker as viewed from the front. It is a mix of visible and infrared light. The right image is the infrared-only image for the same camera position. It shows high temperatures in the top half of the conical cover.

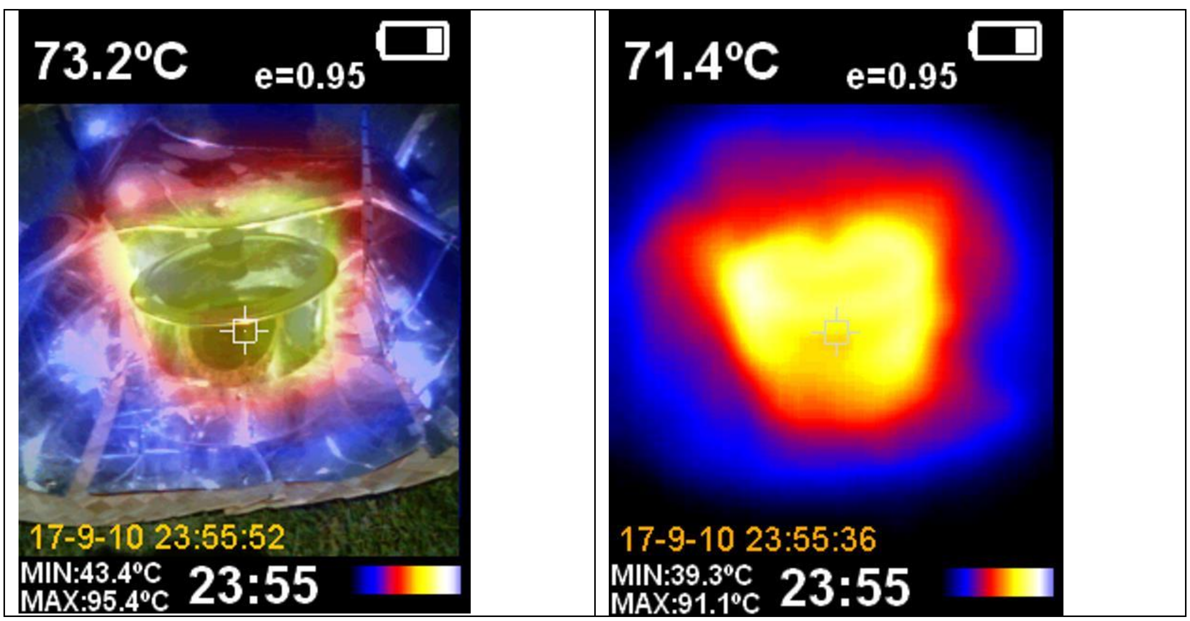

Figure 4. The left image shows the Haines solar cooker as viewed from the front, without the cover. It is a mix of visible and infrared light. The right image is the infrared-only image for the same camera position, but immediately after the cover was removed. It shows that hot air and steam are present above the hot Dutch oven, and they radiate infrared light.

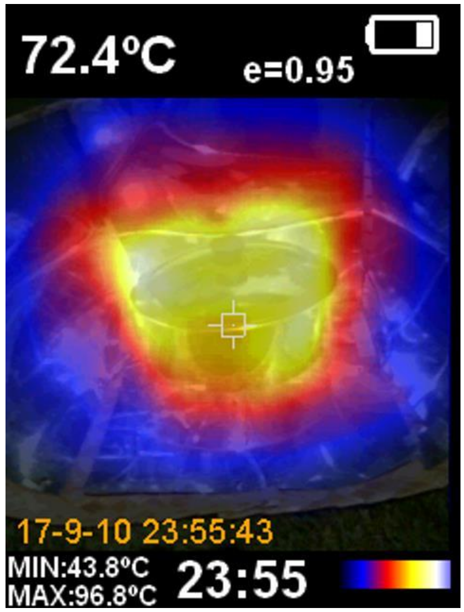

Figure 5. This image, with a mix of infrared and visible light, shows that high-temperature gas is present above the pot lid.

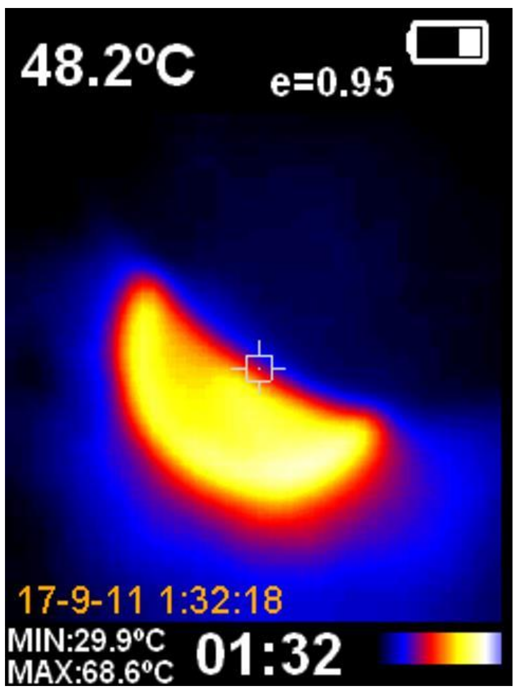

Figure 6. In this infrared image, the cover was removed and allowed to cool for a few seconds. Then it was partially placed above the hot cooking pot. This demonstrates that the polycarbonate cover is opaque to infrared light at around 8 microns, the temperature of the pot. However, the cover is thin so that it heats or cools quickly, and heat can be readily conducted to its outer surface, where can radiate infrared light.

Conclusions

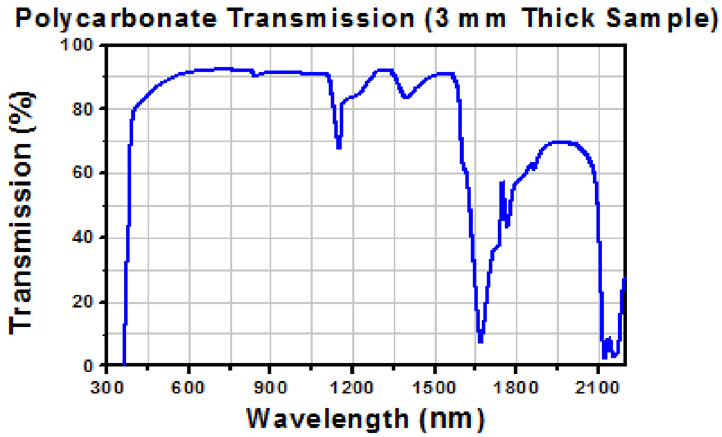

Figure 7. – Transmittance of polycarbonate from the visible to 2100 nanometers wavelength (2.1 microns) [2]. Other data in the literature show that transmittance remains low up to at least 25 microns [3].

Thermal radiation at the boiling point of water has a peak of about 7.8 microns. The image indicates that polycarbonate absorbs radiation at around these wavelengths, causing the material to heat up. The measurements indicate that the temperature of the polycarbonate cover was around 50 deg. C when the pot was at 100 deg. C.

In the Haines solar cooker, the polycarbonate cover therefore reduces heat loss by both convection and radiation. It acts like a greenhouse, by blocking infrared radiation coming from the pot. It also serves to reduce convection by blocking air flow. However, the cover is thin, and readily conducts heat through the heated cover, which then radiates this energy into space. This means that the heated cover itself, as well as the air gap in the cover, are sources of heat loss. Also, since it has high surface area, the hot cover sheds some heat by convection into the air. This implies that the heat loss can be expected to be strongly dependent on wind speed.

References:

Arveson, P. "Infrared imagery of the HotPot and Haines Dutch oven", Technical Report TR-28, Solar Household Energy, Inc., 2017

Anon., "Transmittance of polycarbonate in the infrared", http://www.mdpi.com/energies/energies-08-12404/article_deploy/html/images/energies-08-12404-g002.png

Abdel-Ghany, A. M., et al., “Radiometric Characterization, Solar and Thermal Radiation in a Greenhouse”, Energies 2015, 8(12), 13928-13937, http://www.mdpi.com/1996-1073/8/12/12404/htm