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Infrared Imagery of the HotPot and Haines Dutch Oven

Paul Arveson

Director of Research, Solar Household Energy, Inc.

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The HotPot, which was developed by Solar Household Energy, Inc., is a popular solar cooker that is in widespread use around the world. The design and performance of the HotPot has been described in previous technical notes (TN-01.1, TN-02, TN-03, TN-04). The HotPot used here is the 3-liter version, with an inner black enameled steel pot (weight 581 g).

The Haines Solar Cooker [1] was developed by Roger Haines and distributed via retail outlets including his web site. The cooking vessel used in the original Haines Solar Cooker is a Dutch oven, capacity slightly over 3 liters; diameter 26 cm; height 9.5 cm; made of steel with a thin, black, non-stick coating. It has a round lip and accommodates a glass lid that has a rubber handle, a steam vent and a well-made silicone gasket. The mass of the pot is about 368 g and the lid about 578 g. (A heavier-gauge steel pot is available; it weighs about 505 g).

These cooking vessels are intended for use with a reflector, constituting a "panel-type" solar cooker. Such devices cook food slowly at low power when placed in direct sunlight. In such a low-power device, heat transfer occurs slowly, so heat loss must be kept low in order to cook with reasonable speed and efficiency. A critical design question to ask about any panel solar cooker is, "where is the main source of heat loss?"

Studies reported in TN-04 indicated that hot air and vapor leaking out of the lid gap is the major cause of heat loss in the HotPot. The HotPot does not have a gasket, as does the Dutch oven.

To investigate the sources of heat loss, an infrared camera was procured and used to make several photographs of the two cooking vessels. Following are a series of images and their interpretation.

Infrared camera

The infrared camera used in these studies is a HT-02 thermal imaging camera, with the following specifications:

Display screen	2.4 in.
Resolution (infrared)	60 x 60 pixels
Thermal sensitivity	0.15 deg. C
Measurement range	-20 C to 300 C
Temperature accuracy	+/- 2 % or 2 deg. C
Wavelength range	8 – 14 microns
Image capture frequency	6 Hz
Emissivity	Adjustable 0.1 - 1
Memory card	Mini SD card
File format	BMP
File capacity	25,000 images

Figure 1. Infrared camera HT-02.

The temperature range of this instrument nicely covers the range required for imaging radiation from objects in the range of 30 – 100 deg. C. The display includes several false-color scales that can be selected to enhance the original gray scale image; this is common practice in scientific studies for visualizing infrared light, such as from weather satellites [2]. For the images shown here, the “rainbow” color scale was used; going from cold to hot it ranges from black to blue, red, yellow and white. Also, a spot temperature symbol is indicated along with the temperature at that spot. All measurements were made with emissivity set at 0.95, which is a typical value for most materials at normal incidence.

One of the common uses of a thermal imaging camera is to identify surface temperatures on an object, and to determine where the heat is being emitted. The following sections will illustrate this application for the two cooking vessels described above.

Thermal imaging of the HotPot

For these measurements, it was not necessary for the HotPot to be heated by sunlight; any source of heat will do when we are only investigating heat loss (not gain). So the HotPot steel vessel was loaded with 1 liter of water and heated on an electric stove. When the water reached a full boil, the pot was removed from the stove and placed on a cool heating pad for imaging. Typical images are as shown below.

Figure 2. HotPot with 1 liter of boiling water, seen in mix of visible and infrared light.

The steel pot was just placed in the glass outer liner, which was cool. Glass does not transmit infrared light beyond 2 or 3 microns, so the outer liner shows no infrared radiation. The glass lid, however, shows this radiation because it is hot. For subsequent measurements, the outer liner was removed to reveal the strong radiation from the metal pot.

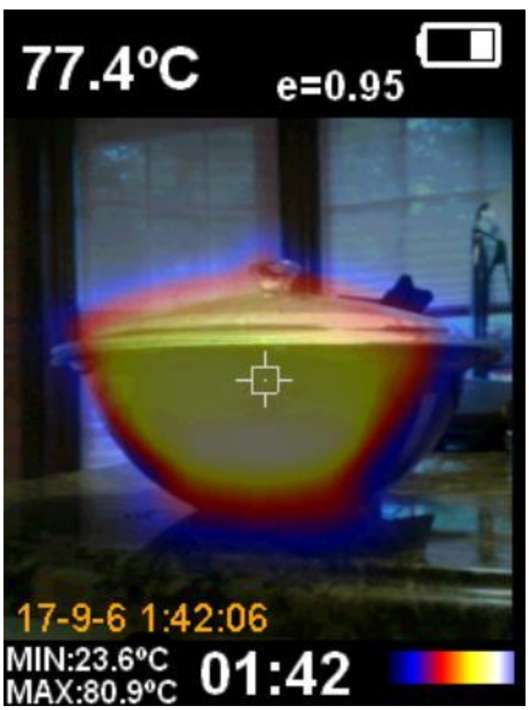

Figure 3. HotPot inner steel pot with glass lid in mix of visible and infrared light.

This image illustrates the placement of the HotPot on the kitchen counter (windows are showing in the background). The image also contains the temperature of a spot on the HotPot surface, the minimum and maximum temperatures recorded, and the date and time. The temperature reading in the upper left is the temperature at the square spot in the center of the image. (Note: the apparent drop in temperatures near the edges of these images is an artifact due to the drop in emissivity of materials at steep angles from normal.)

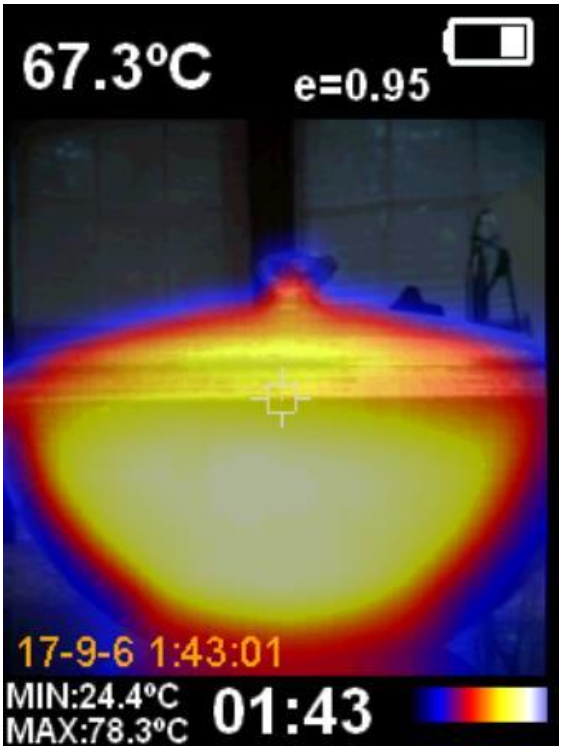

Figure 4. HotPot inner steel pot with glass lid in visible and infrared light.
Figure 4 is the same as Figure 3 except that the visible light image has been reduced in order to bring out the infrared image. The temperature is being measured at a spot on the lid gap, which is reading a value 10 degrees C lower than the temperature of the pot as shown in Figure 3.

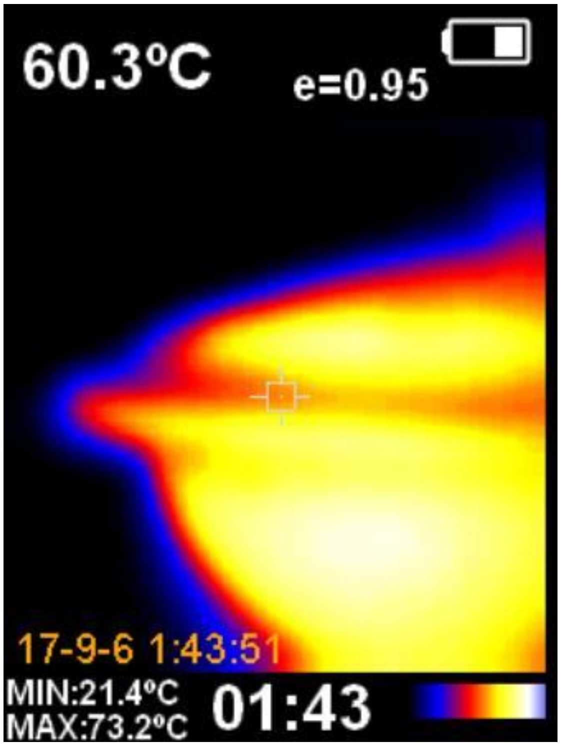

Figure 5. Close-up side view of the HotPot steel pot and lid in infrared light.

This figure shows a closer view of the edge of the HotPot. We can clearly see that the region around the lid gap (the red strip) is cooler than either the pot or the upper part of the lid. This indicates that more heat has escaped from the lid region, causing its temperature to decrease.

Thermal imagery of the Haines Dutch oven

A similar experiment was conducted for the Haines Dutch oven. A liter of boiling water was placed in the pot, and the lid placed on the pot.

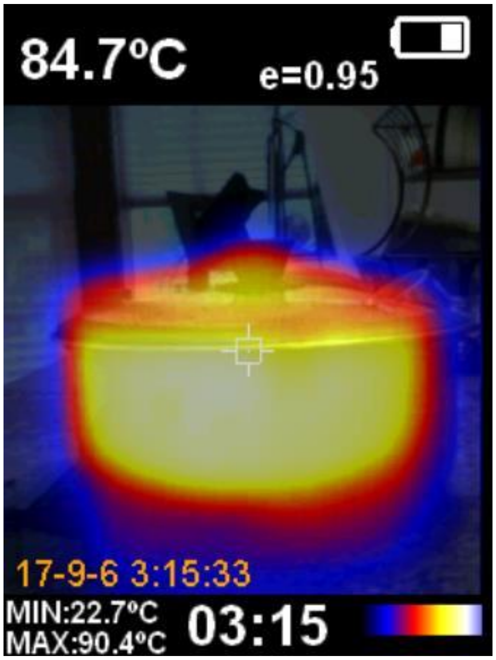

Figure 5. Side view of Dutch oven seen in mix of visible and infrared light. The shiny edge of the metal pot is seen in visible light.

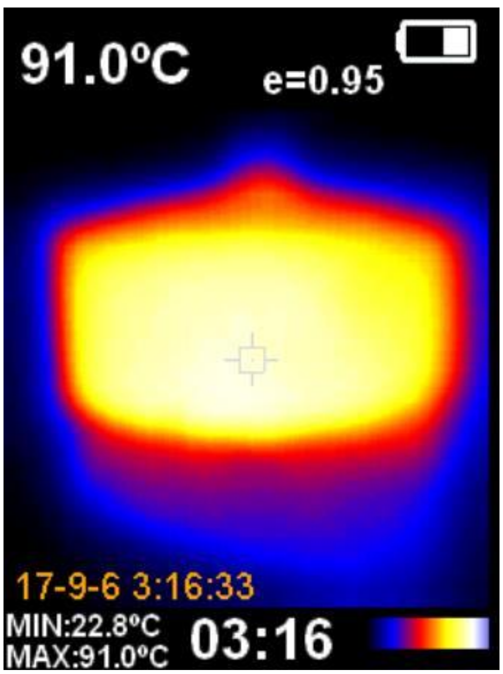

Figure 6. Side view of Dutch oven seen in infrared light.

Figures 5 and 6 show no cooler region along the edge of the lid. The silicone rubber seal on this pot is effective at containing the heat loss from convection.

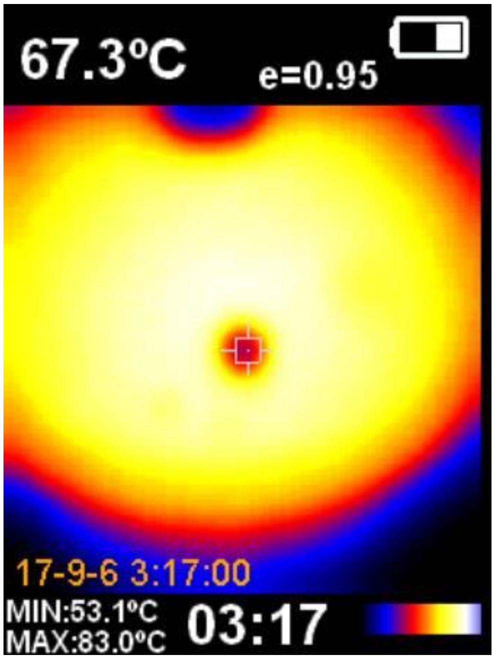

Figure 7. Top view of the Dutch oven in infrared light showing the temperature at the steam vent in the glass lid.

In order to prevent dangerous pressure buildup, a steam vent is provided in the glass lid of the Dutch oven. This is a point of heat loss that is necessary in any covered cooking vessel. The temperature at the steam vent is about 16 degrees cooler than the rest of the lid.

Conclusions

The infrared images clearly show regions where heat loss is occurring. These are locations where the surface temperature is lowest. These regions are shown by means of a color scale on the infrared camera. In the case of the HotPot, the major source of heat loss is around the rim of the lid. There are gaps in the lid here, which allow steam and hot air to escape, because the HotPot does not have a gasket.

The heat loss in the Dutch oven is much lower, because it has a well-made silicone gasket. This lower heat loss raises the cooking power and efficiency of the Haines Solar Cooker, and helps to explain its relatively high performance in side-by-side comparisons with other panel-type solar cookers. [3].

Finally, this report illustrates the utility of a relatively low-cost (under $250) low-resolution infrared imaging camera to diagnose heat loss in cooking vessels and other equipment associated with solar cookers. Future experiments with this camera are planned and will be reported in technical notes.

References

1 - Haines solar cookers web site, http://www.hainessolarcookers.com .

2 - NOAA satellite imagery color enhancements, http://www.goes.noaa.gov/enhanced.html

3 – Haines, R., Haines Solar Cooker Comparison Boiling Test, Aug. 2015 (Unpublished document). [The Haines solar cooker with its Dutch oven was included in a test of eight different solar cookers.]