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Lid gaps are the major cause of heat loss and variability in the HotPot

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Lid gaps are the major cause of heat loss and variability in the HotPot

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This method was used in some heating experiments with the "HotPot" solar cooker. This cooker has a black enameled steel pot surrounded by a glass liner and a glass lid. It comes in 5-liter and 3-liter sizes. The pot has an outer glass liner, which serves to contain hot air around the pot (the "greenhouse"). The pot is surrounded by a series of polished anodized aluminum panels, called the "Morningstar" reflector. The pot components fit together as shown in Figure 1.

Figure 1. Three components of the HotPot solar cooker vessel

Numerous heating experiments with the HotPot have been conducted over the past three years. These experiments have been documented in previous Technical Reports TR-01.1, TR-02, and TR-03. Some of the key observations from these experiments are summarized here. These observations also may apply to other designs of low-power panel-type solar cookers.

Figure 2 below shows three HotPot experiments conducted in Tucson, AZ in 2012. On three summer days with clear skies, the HotPot temperature was measured over the same time of day; nearby pyranometer data from the University of Arizona lab confirmed that the sky was clear. One liter of room-temperature water was heated in the pot. The experimental setup is described in detail in TR-02.

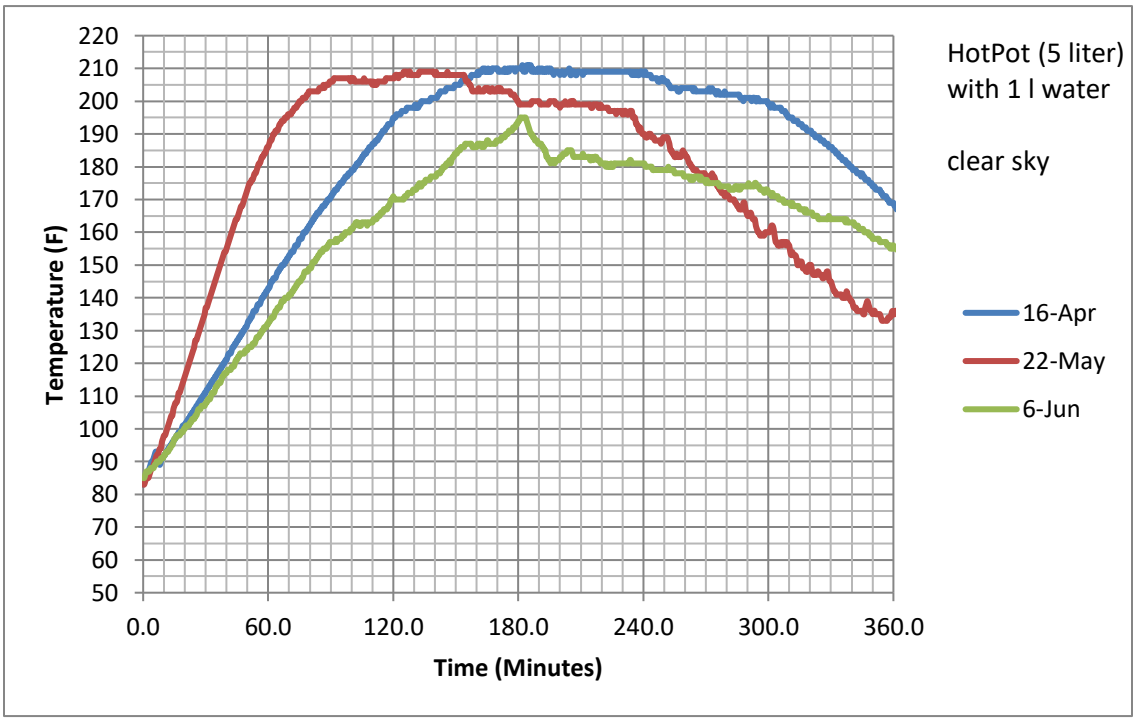

Figure 2. Measurements of HotPot on three days in Tucson.

Clearly these measurements are not repeatable. The measurements show a heating rate that varies by more than a factor of two. Something is causing these data to be non-repeatable. What could it be? We noted that the solar irradiance was nearly the same, as recorded by precision instruments (although there was a slight drop on June 6 due to thin clouds). Wind speed was monitored and was low in all three measurements. There was a slight difference in sun angle for the three dates, but these are not significant for a panel-type cookstove like the HotPot. Positioning of the reflector was kept the same for all tests.

Many additional experiments were conducted in Rockville, MD during 2012-2015. The results of these experiments are documented in the previous Technical Notes. These data also show significant variations in HotPot heating performance.

The Lid's Air Gap Problem

It is reasonable to assume that differences in solar cooker performance should be influenced by the main cause of heat loss. Since convection is more efficient than conduction or radiation, a closer examination of the HotPot's lid gaps was conducted. It was found that repeatability could be improved by ensuring that the lid was placed on the pot at exactly the same angular position in repeated experiments. In this way, the slight variations in lid gaps would be repeatable.

In other experiments, the pot lid was sealed with tape to prevent convective heat loss. This also improved repeatability of heating data. However, completely sealing the lid is not feasible due to a buildup of pressure that could be dangerous. Or, after food has cooled, reduction of pressure could cause a tightly sealed pot to make it impossible for a person to remove the lid! Also, a tight seal is not feasible for measurements because it prevents the wire of a thermometer from entering the pot. Therefore a tradeoff must be made: the cooking pot can have a partial seal, but not a complete one.

Visualization of vapor flow through lid gaps in the HotPot

To visualize a simulation of pressure-driven vapor leakage from the HotPot lid, a small amount of dry ice and water were placed in the pot. This generated dense water vapor and pressure due to the evaporating CO_2 from the dry ice. This simulated the effect of boiling water escaping from the pot lid gaps.

Figure 3. Water vapor escaping from lid gap.

Figure 4. Water escaping from lid gap (top view).

Figure 5. Another top view of the HotPot with vapor escaping.

These photos show uneven and significant quantities of vapor leakage from the lid gap in the HotPot. Such leakage is not exclusive to the HotPot; it is likely to be similar for any kind of cooking vessel that has a loose-fitting lid.

Conclusion

Most of the heat loss occurs due to gaps in the lid. Slight variations between units will cause this loss to be non-repeatable. This heat loss limits the performance (i.e. cooking power and efficiency) of the HotPot; it makes the cooker heat up more slowly.

Would a gasket help solve the lid gap problem?

Having identified the major cause of heat loss as due to lid gaps, an attempt was made to seal the lids with gaskets – for both for the lid and for the outer "greenhouse". We used food-grade silicone caulk/sealant to place a silicone rubber seal around the lid of the HotPot. First we coated the metal bowl with Vaseline, to which silicone sealant does not adhere. Then we applied a bead of silicone to the glass lid and the greenhouse, and then placed them on the metal bowl to assemble the three components. After curing, we found that adhesion of silicone caulk to glass was very strong. Adhesion to the clean enameled metal was adequate.

Manual placement of the bead on the lids was difficult and the result was somewhat uneven. This could be improved using a motorized caulking gun and a rotator to automate the process; this will be constructed in future work. The resulting gaskets should provide well-defined and controlled steam venting and repeatable performance.

Another way to seal the lid would be to use a commercially-made silicone gasket or O-ring to make a seal. However, the gasket would have to be permanently glued to the pot, so some sealant adhesive would still be needed for this. We found that silicone rubber tubing does not adhere to silicone sealant, so this approach was not pursued further.

Further heating experiments with the HotPot and other cooking vessels should be conducted after gaskets have been added, as we continue to seek improvements in solar cookers.

References

1. Arveson, P. and Dadok, M. "Theoretical model of temperatures in a HotPot solar cooker". Solar Household Energy, Inc. Technical Report TR-01.1, June 2015.

2. Arveson, P. and Joseph, B. "Temperature measurements of the HotPot". Solar Household Energy, Inc. Technical Report TR-02, June 2015.

3. Arveson, P. "Repeatability of HotPot solar cooker heating experiments". Solar Household Energy, Inc. Technical Report TR-03, Sept. 28, 2015.