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Solar Cooking for Human Development and Environmental Relief

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Preliminary Study of Black Paints for Solar Thermal Applications

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Preliminary Study of Black Paints for Solar Thermal Applications

This note records some information about black paints that may be used in the construction of solar cookers. Black surfaces absorb solar radiation better than lighter colored surfaces on cooking pots or the interior of box cookers, so black paints can improve solar cooker performance in these applications. However, paints also have other considerations, namely durability and toxicity. This note also addresses these issues briefly.

Optical characteristics of black paints

Ideally, solar cookers should be constructed of parts that have one of these three optical properties:

- High specular reflectivity of reflector surfaces;
- High absorbance of pot surfaces to be heated;
- High transmission across the visible spectrum for heat shields.

This experiment examines the performance of two types of black spray paints intended for possible use on cooking pots. Here "performance" only means the ability to absorb sunlight across the total solar spectrum. There are other requirements for paints, such as vapor emissions, that must be studied in other experiments.

Experimental setup

An infrared camera, KMoon model HT-02 was used for capturing images. This infrared camera is sensitive to radiation in the range 8 – 14 microns, corresponding to temperatures from below 0 to 100 deg. C. Its false-color image was set on the "rainbow" color scale (as shown in the lower right corner of each image). The emissivity of the camera was set to 0.95 for all readings. 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 test items were three aluminum disks, each 12 in. (30 cm) diameter, 0.06 in. (0.15 cm) thick. These were set flat on a concrete sidewalk in clear sun and allowed to heat to equilibrium (over 15 minutes). The disk on the left is painted on the left half with Krylon Ultra-Black 1602 spray paint (see Appendix for sources). The other half is painted with Rust-Oleum High Heat stove paint. The middle disk is painted entirely with the High Heat stove paint. The right disk is bare unpolished aluminum.

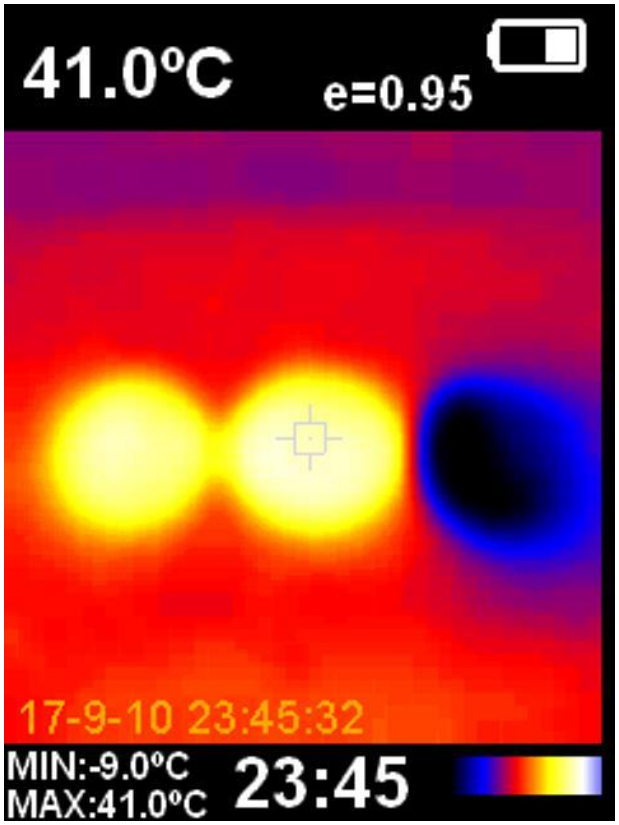

Figure 2 – This is an image of the disks in infrared light. Note that the aluminum disk, shows dark blue, which is cooler than the sidewalk. This is an invalid reading, of course, because the emissivity of aluminum is much lower than the concrete or painted surfaces.

Figure 3 - This is a closeup of the first disk which is half Krylon Ultra-Black (left half) and half Rust-Oleum stove paint. This is the image in visible light. The Ultra-Black paint has an emissivity of 0.96 (or reflectivity of 0.04) from 2 to 5 microns and 0.95 from 8.5 to 14 microns, according to the NASA reference data.

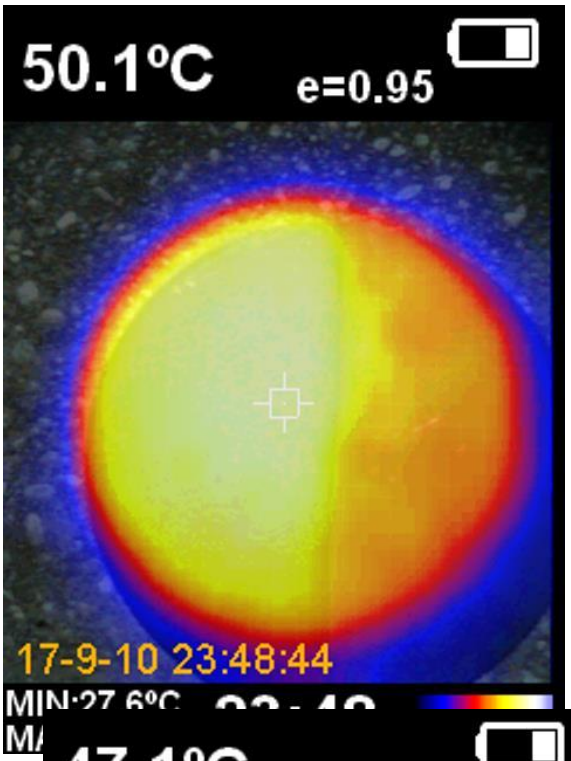

Figure 4 – This is an image of the two-tone disk in the infrared. The temperature on the darker side of the disk is reading 50.1°C.

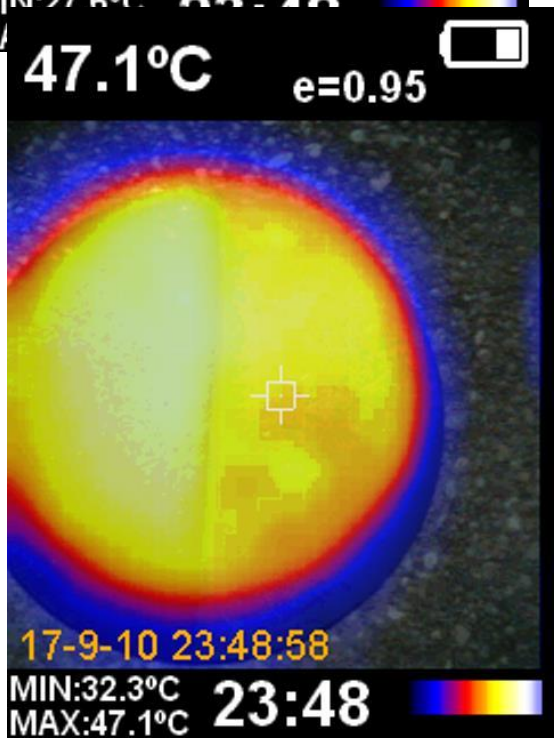

Figure 5. The sensor is pointing to the area with stove paint. Its temperature reads 47.1 deg. C.

The Ultra-Black paint is 3 degrees hotter. If it were placed on a separate disk, it would probably be higher. This experiment should be repeated accordingly, and other paints should also be tried.

Although 3 deg. C is not a major improvement, this experiment does illustrate that not all black paints are alike. The Krylon Ultra-Black spray paint is reputed by some to be the best black paint that is readily available in the US. There were some others slightly

better that sold under brand names Nextel Suede, Alexit Velvet etc. but they do not appear to be readily available. The Appendix lists several sources of affordable black paints that may also be candidates for solar cooking application.

Application to cooking pots

To make a more relevant application to cooking, an experiment was conducted to compare the temperature of two identical pots. One of the pots was spray painted with Ultra-Black paint and allowed to dry. The other pot was an original black painted pot as supplied with Haines solar cookers. The experiment used the previously-described instrument package which has four thermocouples available for comparisons (see TR-09.1). Two thermocouples were taped 4 cm. above the bottom of each pot. The pots were then inverted and left in the Sun on a flat surface to heat to equilibrium temperature, as shown in Figure 6.

Figure 6. Experimental setup to compare performance of two types of paint; the Ultra-Black painted pot is on the left.

The temperatures in each pot were recorded every minute over the course of 200 minutes. For the first 100 minutes, the experiment proceeded as shown in Figure 6. For the second 100 minutes, the four thermocouples were brought together in one pot so that any calibration differences between them could be determined. When the calibration differences were subtracted, it was found that the temperature difference due to paint was 0.62 deg. C. So the Ultra-Black painted pot was slightly hotter than the original pot, but we judge this to be an insignificant improvement. A more general conclusion is that any black painted pot will probably provide adequate performance.

Durability of paints

The selection of an appropriate paint or surface treatment for solar cookers involves other requirements in addition to its optical effectiveness. First of all, the coating must be durable, especially when it is to be applied to cooking pots, which are subject to continual handling and washing.

Experiments show that the Krylon Ultra-Flat Black paint bonds better than the Rust-Oleum High Heat paint. However, applying any spray paint directly on clean metal surfaces results in a coating that is not very durable and will readily flake off during normal use. Durability of any paint may be improved by light sanding and using a primer before painting, and oven curing at 450°F after painting. These extra steps will add to manufacturing labor time and cost. Ideally, pots with a flat black enamel coating are preferred, if available -- they would not need to be painted at all. But experiments on optical performance of any such materials should be done, using the technique described above.

Toxicity of black paints

All paints contain volatile organic compounds (VOCs) that serve to bind the pigment to the painted surface. VOCs are defined as organic compounds that have a boiling point less than 250'C. Many VOCs are toxic to some degree. The EPA has classified these compounds in its online database at https://comptox.epa.gov/dashboard). A typical black paint includes VOCs such as acetone, xylene, n-butyl acetate, and ethyl 3-ethoxypropionate as solvents, propane and butane as propellants, and carbon black as a pigment. Spray paints also include organic propellants, which are gases like propane and butane. The detailed data on composition is provided in Safety Data Sheets, which are available for most commercial products at http://www.paintdocs.com/

The VOCs evaporate when initially applied, but some remain. This will require a "burn-in" period during which the pots are heated to a high temperature in open air. This is a standard practice that the EPA recommends for any type of cookstove.

As with durability, ideally a pot with a flat black enamel or ceramic surface would be preferable to any painted cooking pot. Hence clay or ceramic pots should also be investigated for possible application for low-powered solar cookers.

Appendix: Some Sources of Black Paints

Krylon Ultra-Black spray paint is available at $6.50 for 12 oz. from
http://www.filmtools.com/krylon-ultra-flat-black-spray-paint.html

Rust-Oleum High Heat black paint is available from hardware stores and Amazon. A one-quart can is priced at $14.61.
https://www.amazon.com/dp/B000BZWZR0/ref=asc_df_B000BZWZR05165110/

Zynolyte high-temperature paint (1200 deg. F). Its original purpose was to paint stoves, but now is used for manufacturers of black-bodies, for NASA, Sandia Labs, etc. An 11 oz. spray can for $4.87 is available from http://www.toolup.com/Aervoe-Z635-Black-Zynolyte-Hi-Temp-Paint-11-oz-Can

Zynolyte primer to improve adhesion: http://aervoe.com/paints_coatings/Zynolyte-Multipurpose-Primer.html

DEI 010301 Black High-Temperature Silicone Coating by Design Engineering (rated up to 1500 deg. F.)
http://www.amazon.com/010301-Black-High-Temperature-Silicone-Coating/dp/B000MY3ML8

High-temperature black paint
http://atfinet.com/index.php/products/high-temperature-paint

http://www.kbs-coatings.com/Xtreme-Temperature-Coating-Directions.html
brush-on 1500 F coating. This paint requires primer and heat treatment.

Sources of black paint emissivity data:
https://masterweb.jpl.nasa.gov/reference/paints.htm