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A COMPARISON OF COPENHAGEN SOLAR COOKERS WITH OTHER SIMILAR SIZED SOLAR COOKERS

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Abstract: *The Copenhagen Solar Cooker is very efficient for its size. Claims were made that it is more efficient per square centimeter of reflected area when compared with other panel cookers. This paper describes field testing of two popular panel solar cookers using the same square centimeters of reflective material to make the Copenhagen Solar Cooker and a Fun-Panel Solar Cooker (made with Teong Tan's 2008 free pattern on freewebs.com) Two testing methods are used. The first is the WBT Water Boiling Test designed by Bernhard Muller. The second test is done with the new SCI PEP testing station designed by Alan Bigelow and built by Glenn Clausson. The same size pan and contents are used in each cooker. Testing is side by side at the same time of day. Results listed in comparison chart. A thermal image of each cooker will be shown for reference.*

Keywords: Copenhagen, Panel Solar Cookers, Cook-It, Fun-Panel

1. **INTRODUCTION**

The Copenhagen Solar Cooker was invented in 2009 by the author, Sharon Clausson [1]. The Fun-Panel Solar Cooker directions were published in 2008 by Teong Tan [2]. The Copenhagen Solar Cooker was made with self-stick reflective Vinyl on a polypropylene substrate. The Fun Panel was built out of cardboard and foil. The Fun-Panel and the Copenhagen were built with approximately .75 square meters of material. The tests are to determine how much cooking power each design produces. Two different cooking evaluations were used. The first test was the WBT designed by Bernhard Muller [3]. The second was the PEP testing protocol designed by Dr. Alan Bigelow Ph.D. Science Director for SCI and built by Glenn Clausson [4]. The pans used were both 4.25l and each held 2000ml.of water. The pictures from a thermal camera Pure Thermal 1 Camera by GroupGets.com [5] were used to show heat distribution pattern of each cooker.

2. PEP TEST EQUIPMENT

Two types of panel solar cookers were used in the evaluation:

a. Copenhagen Solar Cooker by the author Sharon Clausson (adjusted to .75 square meters) [1]
b. Fun Panel by Teong Tan (adjusted to .75 square meters) [2]

For the quantitative portion of my evaluation I used:

a. The Water Boiling Test by Bernhard Muller [3]
b. PEP testing station designed by Alan Bigelow for SCI and built by Glenn Clausson [4]
c. Pure Thermal 1 Camera by GroupGets.com [5]

PEP station test equipment:

Electronics platform	Arduino Mega open source electronics, liquid crystal display and removable SD card
Temperature	Type K thermocouples to measure water and ambient temperatures
Wind speed	Anemometer (Adafruit)
Solar irradiance	SP-215 amplified pyranometer (Apogee) mounted to a horizontal bubble-leveled plane
Additional	Global positioning system

3. PEP TESTING STEPS

* Align testing station with the pyranometer wire connector at a North /South compass direction.
* Use bubble level on mount fixture to level the pyranometer.
* Put thermocouple plugs into sockets with ambient probe out of direct sunlight.
* Push thermocouple probes through pot lids and secure with threaded nuts.
* Align solar cookers for maximum sun and put empty pots on racks in the solar cookers.
* Connect 12 VDC battery to testing station.
* Premeasure equal amounts of water and add to pots then cover with lids.
* Compare ambient temperature to water in pots, if they are within 2C then press reset button to start new test. If water temperature is below ambient then wait for equalization and restart by pressing reset. If water temperatures are more than 2C above ambient then change water and add new ambient

temperature water.
*Adjust cooker every 20 minutes to track the sun. format.

**The results on the first 2 tests are the beta testing of the equipment. A wiring error occured which reversed the polarity. After that was corrected the readings were in the normal range.

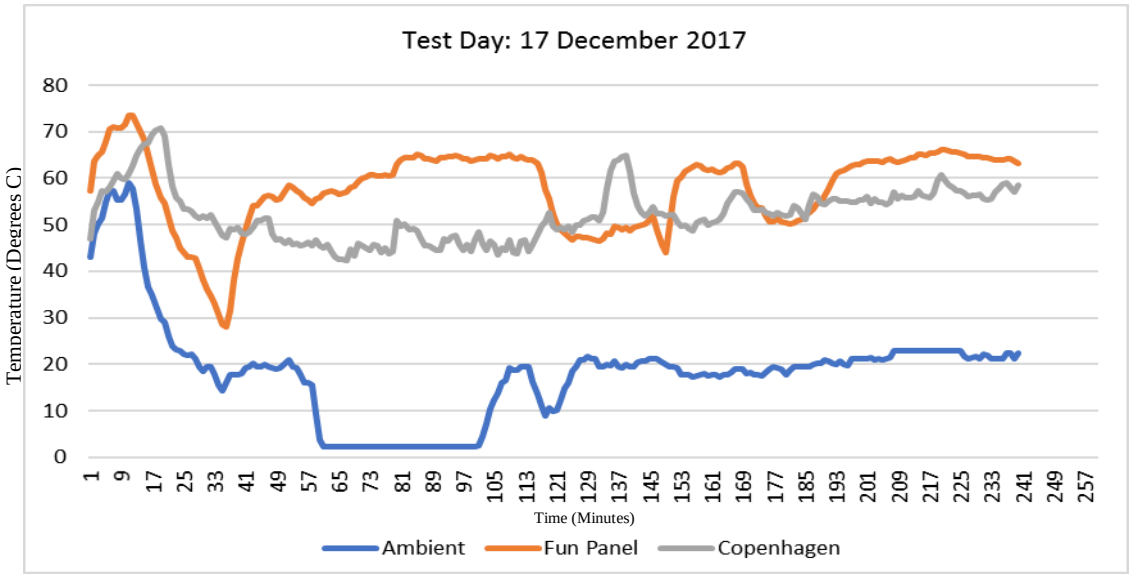


Figure 1 . Graph of Test Day 17 Results

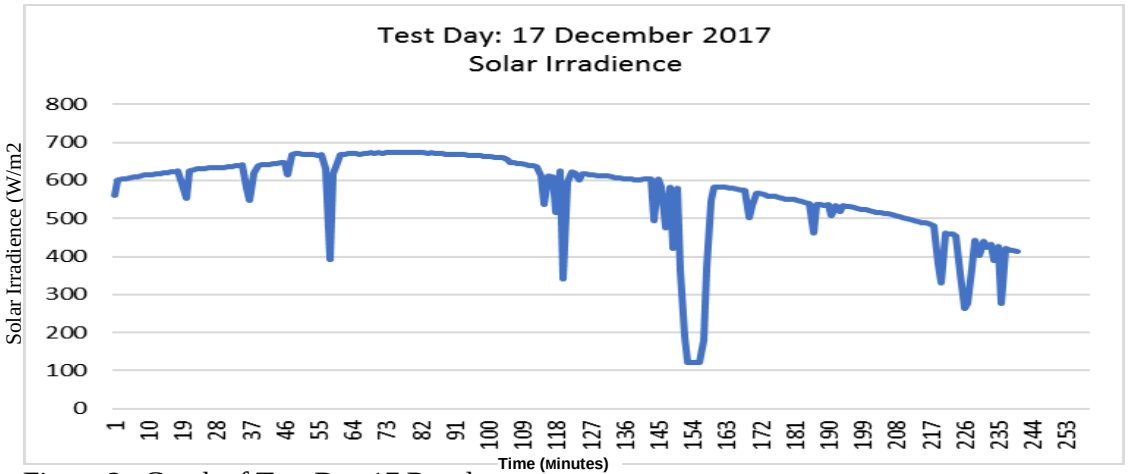


Figure 2 . Graph of Test Day 17 Results

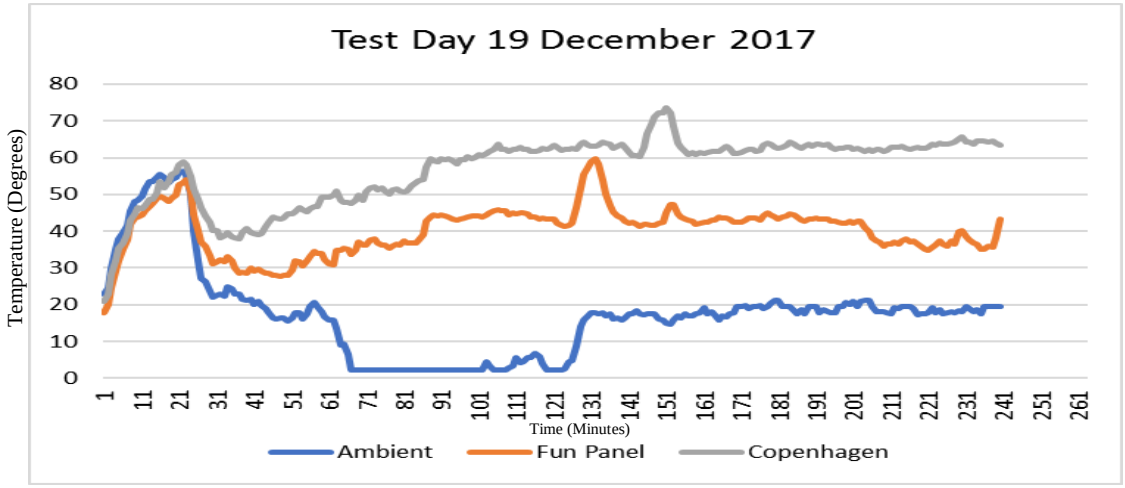


Figure 3 . Graph of Test Day 19 Results

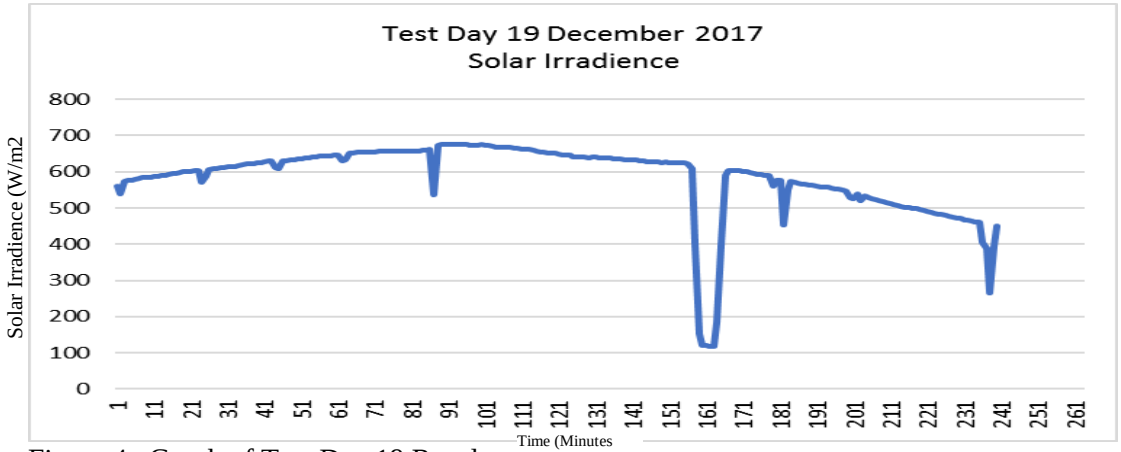


Figure 4 . Graph of Test Day 19 Results

4. WBT WATER BOILING TEST

The Water Boiling test for Solar Cookers WBT SC allows comparison with other cook stoves and open fires. The test is for cooking ability only. It is easy to understand and record test results. It can be set up in the field with a minimum of equipment.

Equipment

Accessories needed to run the test:

a. A solar cooker on a horizontal surface.
b. A blackened pot with a lid.
c. A thermocouple or thermometer.

d. An appropriate amount of water.
e. A precision scale to weigh water.
f. A measuring devise to calculate aperture area.

Fixed and variable parameters.

The WBT SC has a fixed parameter: the amount of water. In smaller or weaker solar cookers use 1 liter, and for larger ones use 2.5 liters.

The variable parameters are

a. location, mainly latitude
b. position of the sun
c. type of cooker
d. aperature area
e. reflector material
f. insulation, if any
g. heat trapping material
h. date and time
i. initial water temperature
j. local boiling point

To avoid confusion, the test should not be conducted if sun is less than 30 degrees above horizon (zenith angle more than 60 degrees), and if the ambient and/or water temperature is less than 0C (32F)

5. THERMAL IMAGING COMPARISONS

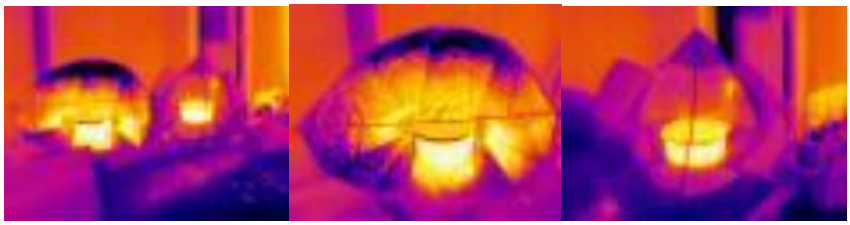
Thermal imaging equipment:

a. Pure Thermal 1 camera by GroupGets.com - data sheet
https://groupgets.com/manufacturers/flir/products/lepton-2-0 on a
https://hackaday.io/project/8796-pure-thermal-1-development-board

b. USB cable
c. Laptop computer with Windows XP using Windows Pictures and Fax Viewer

6. THERMAL IMAGING TEST STEPS

a. Set up solar cookers in the sun
b. Put correct measure of water in pans and put in solar cookers.
c. When pots are hot attach camera to USB cord and cord to laptop
d. use keyboard to take pictures



Both Solar Cookers Fun Panel Copenhagen

Figure 1. Thermal image of Fun Panel on left and Copenhagen Solar Cooker on right.

The Yellow is the hottest and the deep purple the coolest. Note the very different distributions of solar Energy in each cooker. Future tests will be done on each solar cooker the author has made.

7. ACKNOWLEDGMENTS

I want to acknowledge the inputs of the following:

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8. CONCLUSIONS

The comparison of these two solar cookers combined with three evaluation methods highlighted their differences and similarities. It showed the weaknesses and strengths of the different testing methods.

- To do the PEP test the author's husband built the PEP Station from directions offered on the Solar Cookers International website and designed by Dr Alan Bigelow Ph.D. The build went well. Testing some components took more time than expected. Not having familiarity with graphing software author had difficulty interpreting the raw data. A suggestion on this beta project would be to include a more comprehensive explanation for parsing the raw data.
- Bernhard Mullers' WBT SC test was much simpler and less expensive. The readings from the PEP were used to populate most of the WBT SC form. This method is much easier for field testing and just as accurate. The equipment is also minimal.
- The purpose of using the Pure Thermal1 Camera was to show yet another way to look at solar cooker performance. More tests with this camera are needed to learn how to utilize the information it provides. A clear difference can be seen by looking at the thermal images of the Fun Panel and the Copenhagen side by side.
- The shape of both cookers is very similar when in use. Observations in the early day and later day, not included in the tests, showed the water in the Copenhagen solar cooker getting hotter than the water in the Fun Panel. However during test hours they were quite similar. After the test ended the water in both cookers had almost the same temperature.
- The Copenhagen was enlarged to match the .75 square meter size of the Fun Panel. Further research needs be done with a Fun Panel made of the same material as the Copenhagen.
- The Copenhagen could benefit from the addition of booster panels between the points. Both

cookers reached higher Temperatures with a supporting dowel to hold “wings” open.

- Teong Tan invented the Fun Panel from an aeronautical engineering point of view. The author invented the Copenhagen from an intuitive artistic maker point of view. The similarities in the performance of both is notable.
- An hour after sunset the water in the Fun panel was 30.1 C and the water in the Copenhagen was 42.4 C and the ambient was 19.01. It must be noted that because of its adjustable design the Copenhagen panels can be clipped into a cone shape which holds the heat a little longer.
- More research is needed to see if adding an insulated wrap to the pans left in the cookers would hold the heat longer.
- This paper reflects the evaluations of a previous paper by Dane Dormino and Steven Jone [6].
- Both the Fun Panel and the Copenhagen Solar Cooker perform well enough to cook and food chosen and in very similar amounts of time.

REFERENCES

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