

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

Sharon L. Clausson

Oursuncooks.com, San Diego, California, 92109



The Copenhagen Solar Cooker

- Is very efficient for its size.
- More efficient per square centimeter of reflected area when compared with some other panel cookers.
- Is made with self-stick reflective Vinyl on a polypropylene substrate.
- Invented in 2009 by the author, Sharon Clausson.



The Fun-Panel Solar Cooker

- Is built out of cardboard and foil.
- Directions were published in 2008 by Teong Tan



The three testing methods used.

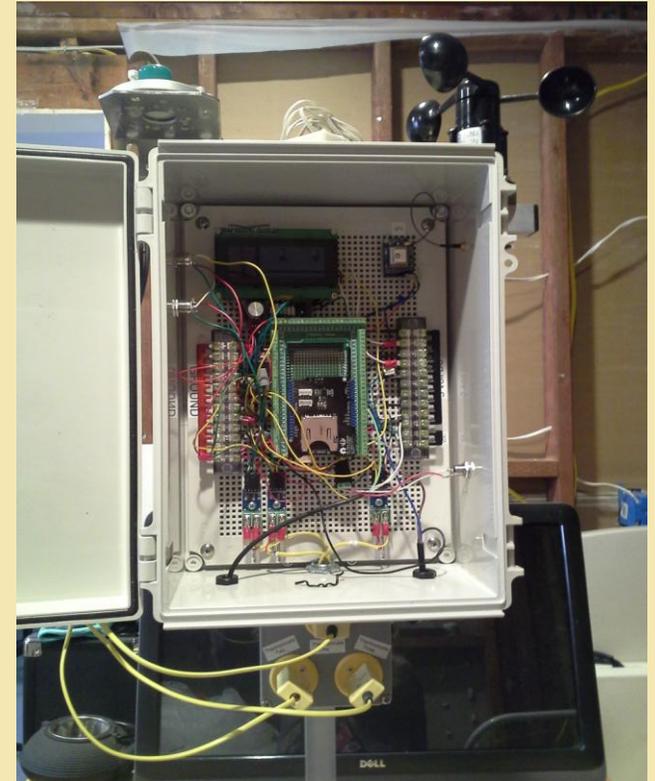
- PEP Testing station designed by Alan Bigelow for SCI.
- WBT SC test by Bernhard Muller and Faustine Odaba
- Pure Thermal 1 Camera by GroupGets.com

PEP Testing Station

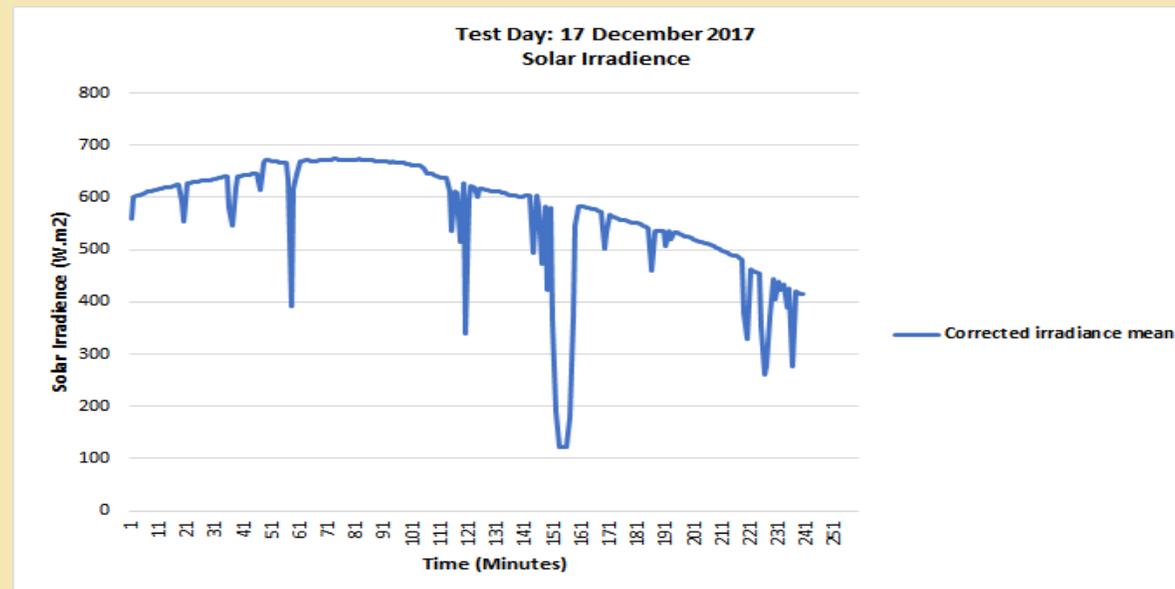
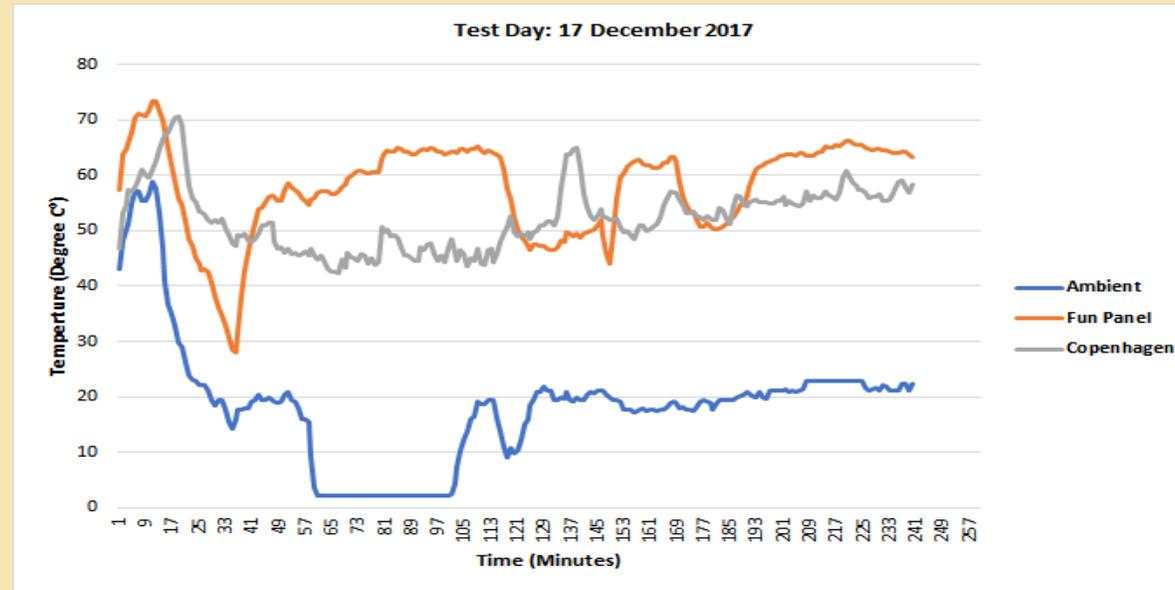
PEP Testing Steps

- * 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.

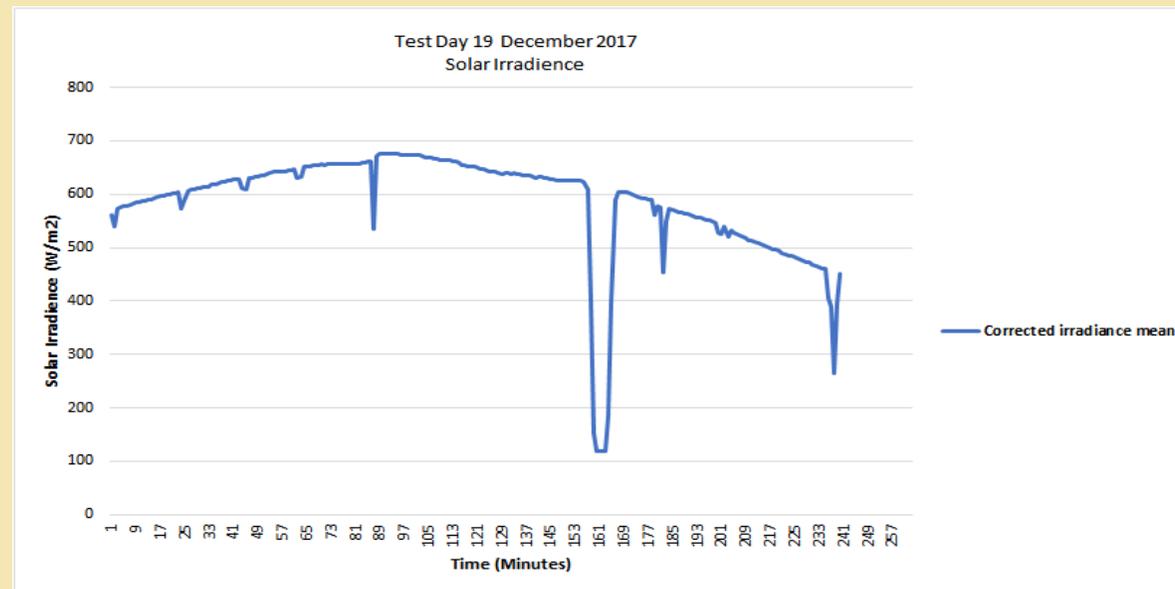
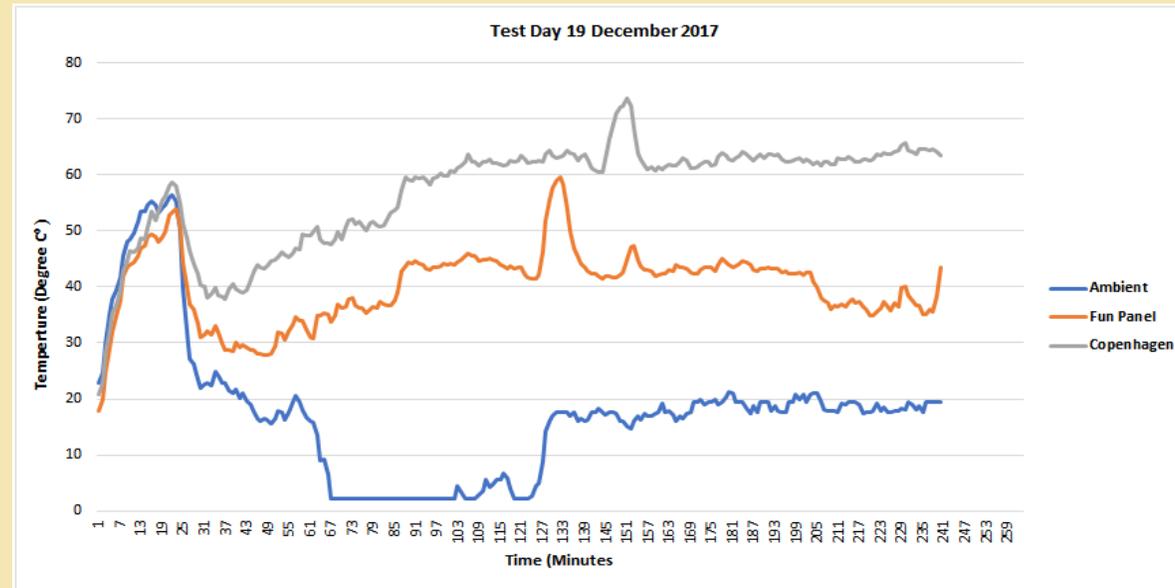
**The results on the first 2 tests are the beta testing of the equipment. A wiring error occurred which reversed the polarity. After that was corrected the readings were in the normal range.



Results for PEP for 17 Dec 2017



Results for PEP for 19 Dec 2017



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. The data from the PEP test results were used to populate WBT SC form.

Accessories needed to run the test:

- A solar cooker on a horizontal surface.
- A blackened pot with a lid.
- A thermocouple or thermometer.
- An appropriate amount of water.
- A precision scale to weigh water.
- A measuring devise to calculate aperture area.
- WBT SC Form

WBT SC - Water Boiling Test for Solar Cookers					v. 1.0.3.
Complete green fields only.		Results are displayed in red color.			
Amount of Water to be boiled (one or 2.5 liters)		Initial water temp. (°C)		Ambient temp. (°C)	
Type of cooker (box, panel, concentrator, hybrid, etc.)					
Position of the sun at the beginning of the test in degrees above horizon					
Position of the sun at the end of the test in degrees above horizon					
Test Location Name and Country	Altitude in meters	Location Latitude	Coordinates Longitude °E	Date dd/mm/yyyy	
The local boiling point for this location is:					100°C
Reflector material (aluminum foil, glass mirror, etc.) *)				Aperture (sqm)	
Insulation material (box cookers only) *)					
Heat trapping material (plastic oven bag, glass, etc.) *)					
*) if any					
Local time	elapsed time (hrs., min.)	Temp., full °C			
12:00	0:00	0			
12:10	0:10				
12:20	0:20				
12:30	0:30				
12:40	0:40				
12:50	0:50				
13:00	1:00				
13:10	1:10				
13:20	1:20				
13:30	1:30				
13:40	1:40				
13:50	1:50				
14:00	2:00				
14:10	2:10				
14:20	2:20				
14:30	2:30				
Optional					Please enter the elapsed time to 65° water temperature
					minutes
Optional					For more precise calculations, please enter the weight of pot and lid.
Optional					Check mark material of pot and lid
					Aluminum or alloy
					Iron
					Copper
					Other
					Observations

Test protocol designed by Bernhard S. Mueller and Faustine Odaba

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. aperture 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)

Results for WBT SC for 17 Dec 2017

WBT SC - Water Boiling Test for Solar Cookers					v. 1.0.3.
Complete green fields only.		Results are displayed in red color.			
Amount of Water to be boiled (one or 2.5 liters)	2.0	Initial water temp. (°C)	55	Ambient temp. (°C)	44
Type of cooker (box, panel, concentrator, hybrid, etc.)	Fun-Panel				
Position of the sun at the beginning of the test in degrees above horizon	28.6				
Position of the sun at the end of the test in degrees above horizon	28.6				
Test Location Name and Country	Altitude in meters	Location, coordinates Latitude Longitude °E		Date dd/mm/yyyy	
San Diego, CA. USA	176	32.48	117.14	17/12/2017	
The local boiling point for this location is: 99°C					
Reflector material (aluminum foil, glass mirror, etc.) *	Aluminum Foil		Aperture (sqm)		
Insulation material (box cookers only) *					
Heat trapping material (plastic oven bag, glass, etc.) *	Glass Lid				
*) if any					
Local time	elapsed time (hrs., min.)	Temp., full °C		Please enter the elapsed time to 65° water temperature	
12:00	0:00	55		110	minutes
12:10	0:10	73			
12:20	0:20	45			
12:30	0:30	28			
12:40	0:40	56			
12:50	0:50	56			
13:00	1:00	60			
13:10	1:10	64			
13:20	1:20	65			
13:30	1:30	65			
13:40	1:40	52			
13:50	1:50	56			
14:00	2:00	50			
14:10	2:10	62			
14:20	2:20	63			
14:30	2:30	50			
Optional					
For more precise calculations, please enter the weight of pot and lid.					
Optional					
Check mark material of pot and lid					
x	Aluminum or alloy				
	Iron				
	Copper				
x	Other				
Observations					
Clouds and Shadows					

Test protocol designed by Bernhard S. Mueller and Faustine Odaba

WBT SC - Water Boiling Test for Solar Cookers					v. 1.0.3.
Complete green fields only.		Results are displayed in red color.			
Amount of Water to be boiled (one or 2.5 liters)	2.0	Initial water temp. (°C)	47	Ambient temp. (°C)	44
Type of cooker (box, panel, concentrator, hybrid, etc.)	Copenhagen Panel				
Position of the sun at the beginning of the test in degrees above horizon	28.6				
Position of the sun at the end of the test in degrees above horizon	28.6				
Test Location Name and Country	Altitude in meters	Location, coordinates Latitude Longitude °E		Date dd/mm/yyyy	
San Diego, CA. USA	176	32.48	117.14	17/12/2017	
The local boiling point for this location is: 99°C					
Reflector material (aluminum foil, glass mirror, etc.) *	Reflective Mylar		Aperture (sqm)		
Insulation material (box cookers only) *					
Heat trapping material (plastic oven bag, glass, etc.) *	Glass Lid		0.55		
*) if any					
Local time	elapsed time (hrs., min.)	Temp., full °C		Please enter the elapsed time to 65° water temperature	
12:00	0:00	47		110	minutes
12:10	0:10	63			
12:20	0:20	55			
12:30	0:30	47			
12:40	0:40	48			
12:50	0:50	46			
13:00	1:00	45			
13:10	1:10	49			
13:20	1:20	46			
13:30	1:30	44			
13:40	1:40	50			
13:50	1:50	51			
14:00	2:00	52			
14:10	2:10	49			
14:20	2:20	57			
14:30	2:30	52			
Optional					
For more precise calculations, please enter the weight of pot and lid.					
Optional					
Check mark material of pot and lid					
x	Aluminum or alloy				
	Iron				
	Copper				
x	Other				
Observations					
Cloudy and Shadows					

Test protocol designed by Bernhard S. Mueller and Faustine Odaba

Results for WBT SC for 19 Dec 2017

WBT SC - Water Boiling Test for Solar Cookers v. 1.0.3.					
Complete green fields only.		Results are displayed in red color.			
Amount of Water to be boiled (one or 2.5 liters)	2.0	Initial water temp. (°C)	17	Ambient temp. (°C)	15
Type of cooker (box, panel, concentrator, hybrid, etc.)		Fun Panel			
Position of the sun at the beginning of the test in degrees above horizon		28.4			
Position of the sun at the end of the test in degrees above horizon		28.6			
Test Location Name and Country	Altitude in meters	Location, coordinates Latitude Longitude °E		Date dd/mm/yyyy	
San Diego, CA. USA	176	32.48	117.14	19/12/2017	
The local boiling point for this location is: 99°C					
Reflector material (aluminum foil, glass mirror, etc.) *		Aluminum Foil		Aperture (sqm)	
Insulation material (box cookers only) *				0.55	
Heat trapping material (plastic oven bag, glass, etc.) *		Glass Lid			
*) if any					
Local time	elapsed time (hrs., min.)	Temp., full °C		Please enter the elapsed time to 65° water temperature	
12:00	0:00	17		150 minutes	
12:10	0:10	46		Optional For more precise calculations, please enter the weight of pot and lid.	
12:20	0:20	51			
12:30	0:30	30		Optional Check mark material of pot and lid	
12:40	0:40	28			
12:50	0:50	32		x Aluminum or alloy	
13:00	1:00	38			
13:10	1:10	37		Iron	
13:20	1:20	43			
13:30	1:30	45		Copper	
13:40	1:40	43			
13:50	1:50	60		x Other	
14:00	2:00	41			
14:10	2:10	43		Observations	
14:20	2:20	43			
14:30	2:30	44		Clouds and Shadows	

Test protocol designed by Bernhard S. Mueller and Faustine Odaba

WBT SC - Water Boiling Test for Solar Cookers v. 1.0.3.					
Complete green fields only.		Results are displayed in red color.			
Amount of Water to be boiled (one or 2.5 liters)	2.0	Initial water temp. (°C)	21	Ambient temp. (°C)	15
Type of cooker (box, panel, concentrator, hybrid, etc.)		Copenhagen Panel			
Position of the sun at the beginning of the test in degrees above horizon		28.4			
Position of the sun at the end of the test in degrees above horizon		28.6			
Test Location Name and Country	Altitude in meters	Location, coordinates Latitude Longitude °E		Date dd/mm/yyyy	
San Diego, CA. USA	176	32.48	117.14	19/12/2017	
The local boiling point for this location is: 99°C					
Reflector material (aluminum foil, glass mirror, etc.) *		Reflective Mylar		Aperture (sqm)	
Insulation material (box cookers only) *				0.55	
Heat trapping material (plastic oven bag, glass, etc.) *		Glass Lid			
*) if any					
Local time	elapsed time (hrs., min.)	Temp., full °C		Please enter the elapsed time to 65° water temperature	
12:00	0:00	21		110 minutes	
12:10	0:10	47		Optional For more precise calculations, please enter the weight of pot and lid.	
12:20	0:20	55			
12:30	0:30	38		Optional Check mark material of pot and lid	
12:40	0:40	43			
12:50	0:50	49		x Aluminum or alloy	
13:00	1:00	52			
13:10	1:10	53		Iron	
13:20	1:20	59			
13:30	1:30	62		Copper	
13:40	1:40	63			
13:50	1:50	63		x Other	
14:00	2:00	60			
14:10	2:10	62		Observations	
14:20	2:20	63			
14:30	2:30	63		Clouds and Shadows	

Test protocol designed by Bernhard S. Mueller and Faustine Odaba

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



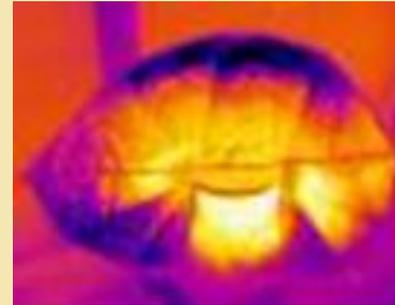
THERMAL IMAGING TEST STEPS

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

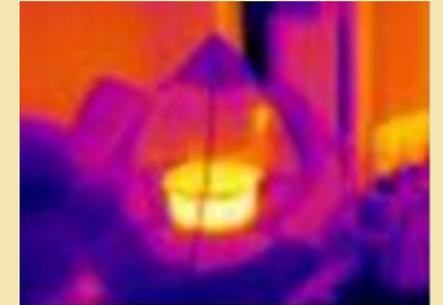
The Yellow is the hottest and the deep purple the coolest.
Note the very different distributions of solar energy in each cooker. Future tests will be done on each solar cooker the author makes.



Both Solar Cookers



Fun Panel



Copenhagen

CONCLUSIONS:

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

- To do the PEP test the author's husband built the PEP Station.
- The build went well.
- Testing some components took more time than expected.
- Bernhard Mullers' WBT SC test was much simpler and less expensive. This method is much easier for field testing and just as accurate. The equipment is also minimal. The readings from the PEP were used to populate most of the WBT SC form.
- The Pure Thermal 1 Camera was used 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.
- The Copenhagen was enlarged to match the .75 square meter size of the Fun Panel.
- Both cookers reached higher Temperatures with a supporting dowel to hold "wings" open.
- This paper reflects the evaluations of a previous paper by Dane Dormino and Steven Jones.
- Both performed well enough to cook most foods and in very similar amounts of time.
- More research is needed to compare the testing methods.