Testing And Production Of An Advanced Solar Cooking Appliance

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Abstract

Innumerable designs to instigate solar cooking have been advanced worldwide. Strengths and weaknesses have become apparent when promoted in widespread field applications. This paper describes the 'Blazing Tube', a novel solar cooking appliance, which successfully addresses the shortcomings of many other solar cookers. Notably, this novel solar cooking appliance excels in efficiency, durability, reliability, as well as safety and convenience for users.

Introduction

Among the many human applications for solar energy, cooking with sunlight has long been promoted internationally. Hundreds of solar cooker designs have been crafted and implemented in suitable cultural and environmental contexts. By far, the developing nations have most often sought to bring solar cooking to the masses of people currently reliant upon solid fuels such as wood, dung, and coal.

Various tasks have been assigned to solar cookers, including food preparation, water boiling and even autoclaving. Many current designs have demonstrated the ability to fulfill such functions, yet the uptake globally has been very limited. Many factors account for this limited success at implementation of solar cooking including efficiency, reliability, durability and costs related to the technologies. Yet advanced materials and new designs, combined with resolve, continue to advance the state of the art.

One such innovation is the Blazing Tube solar appliance. Its improved characteristics are highlighted through comparative testing with a limited number of commercially available solar cookers. The testing was undertaken in Honolulu, Hawaii during the month of December. Although the test site had a favorable annual insolation rate of 500 cal/cm, the wet winter weather challenged the performance of all of the test units.

Blazing Tube Solar Appliance

This solar apparatus received its name from the incorporation of a large diameter, all-glass solar vacuum tube. It is deemed to be a true solar appliance due of its ability to boil water, fry food, bake bread and autoclave items. The design is detailed in the illustration below. The essential components include the vacuum tube (triple cavity), high efficiency reflector, and heat retention cook box. A galvanized metal frame bent into a compound parabolic curve, surrounds the vacuum tube, which attaches to the insulated cook box by means of a silicone hose. The 120mm x 1700mm selectively coated, triple cavity vacuum tube holds only 5.5

liters of high heat vegetable oil as its heat transfer fluid. The cook box houses a rectangular steel component, which is band clamped to one end of the silicone hose. The opposite end of the hose is clamped off to the open end of the vacuum tube, allowing free flow of the hot vegetable oil within the combined volume. An additional rectangular stainless steel pan is situated within the steel component and acts as the cook pan for all heating functions.

System Operation

The Blazing Tube system is designed to be user friendly, safe to operate and reliable. Because energy conservation is its main attribute, the solar energy collected by the system produces constant cooking temperatures, even into the early evening. Because the reflector is a trough shaped CPC, and the exterior of the vacuum tube remains cool, there is no burn risk to the user. Since the food is prepared in the cook box, above the vacuum tube and 75mm off ground level, eye protection is unnecessary. (Precaution must be taken when handling hot pots however.) Early in the day, the system can be oriented to the east (front wheels allow easy adjustment) and before cooking commences the transfer fluid can be preheated several hundred degrees. This allows the system to respond quickly when food or water is to be prepared in the cook pan, providing short cook times. Many tropical regions of the world experience intermittent sunny and cloudy periods daily. The Blazing Tube system addresses this solar inconsistency successfully due to the thermal storage, which the 5.5 liters of internal oil provide. If multiple meals are to be prepared, one or two daily repositioning of the unit are required. Since the CPC performs like a solar funnel, the unit does not require more elaborate tracking by the user.

The unit offers good stability in windy conditions and can be equipped with a cook box lock if food theft is a concern. A small roof could be built above the cook box to provide shade or rain protection for the user, without interfering with the solar input to the vacuum tube area. Blazing Tube can be successfully operated at high altitude freezing temperatures due to the vacuum tube, insulated cook box and oil transfer fluid.

Families can perform several tasks each sunny day, such as drinking water disinfection (by pasteurization or boiling) and cooking, often two separate meals if desired. Cook times can vary according to weather conditions; with sunny days allowing the unit to rival a modern electric stove performance. Most any cooking technique can be accommodated, making cultural acceptance easier.

Testing The Blazing Tube

The test was conducted comparing it to 3 three commercially available and widely used solar cooker models:

The parabolic solar cooker "SK14" (SK14 in the following text). The LongLifePremium14 is made in Germany. It has a diameter of 1,4 m and a power rating for clear skies is 700 Watts. The cooker used has an all aluminum frame and came with three (aluminum) legs. The parabola should be adjusted every 20 minutes to optimize the cooking process. Only one pot at a time can be cooked and this model requires direct sunlight for optimal use. **Experiences in Hawaii:** The SK14 is not very stable in the wind. The parabola starts swinging and rattling, which can lead to the liquid in the coking pot to spill. To stabilize the cooker on windy days sand bags had been used on all three legs and a brick attached to one of the sides of the parabola for additional weight.

The solar box cooker from Global Sun Oven® (Sun Oven in the text): The Global Sun Oven®, manufactured and sold by Sun Ovens International, Inc, and food can be boiled, steamed, roasted or baked at cooking temperatures indicated up to 182° C (360°F). More than one small pot could be accommodated. It weighs 9.5 kg (21 pounds). The website of this cooker indicates that it does not need to be adjusted more than 2 or 3 times a day, although the FAQ section recommends 30 minutes intervals for maximum heat.
Experiences in Hawaii: The Sun Oven keeps the temperature very well. The reflectors tend to flip in the wind and are noisy. Using the retractable single foot in the back on the highest setting makes the Sun Oven unstable and the use of a piece of wood or similar to stabilize the box is recommended. Intermittent clouds or bouts of rain do simply slow down the heating process, but do not cause a sudden drop in temperature.

The panel-style solar cooker CooKit: One of the best known panel style cookers, sold by Solar Cookers International, it is made in the USA. Light weight, made of cardboard and foil it folds flat to 33x33 cm and it is 5 cm thick (13"x13"x2"). It is listed as reaching temperatures in the mid-200ºF. According to the manufacture's information the CooKit can not get wet. **Experiences in Hawaii:** Testing it on rainy, or intermittently rainy days was not possible and only limited data is available for this unit. The unit is very easy to handle, but requires a clear plastic bag to cover the pot.

Cooking pots: Cooking pot 1: Aluminum, store bought cooking pots with 24 cm (10") in diameter and 10 cm high (4") with a glass lids, painted black on the outside.
Cooking Pot 2: Aluminum, store bought, cooking pots with 23 cm (10") in diameter and 12 cm hight (4½ inches), painted black on the outside
Cooking Pot 3: A dark enamel cooking pot with a lid was used for the blazing tube cooker.

Pyronometer: The SDL-1 Solar Data Logger, by Micro Circuit Labs was used to measure the sun's irradiance at 150-second intervals during the testing.

Temprature: The SunEarth differential temperature controller (model SETR 0301 U, manufactured for SunEarth by Steca GmbH, Germany) was used to measure the temperature in both tests heating vegetable oil and boiling water. As sensors the PT1000-Probe provided with the controller were immersed into the oil or water.

Location: On the rooftop of a 4 story building in Honolulu, Hawaii (21˚17.44N 157˚49.89W, altitude 20, which receives an annual average of 500 cal/cm. The roof was covered with tar and gravel and sheltered by a 1.07 m high wall. All four units were tested, weather permitting.

Setting: All four cookers were set up facing the sun and were adjusted manually, based on the SK14 requirements, a few times an hour to optimize each of them facing the sun. Testing started in the morning and lastet until the sun was at an angle too low to reach the units (unless total cloud cover made adequate testing impossible). All test were conducted in the USA and the measurement were taken in Fahrenheit since the SunEarth differential temperature controller is manufactured for the US market.

Testing periods: December 18 to 28, 2008 with vegetable oil and water. December 18,19 and 20: 1 liter of vegetable oil (soy bean oil) was heated in each unit with constant monitoring of the temperature in 15 minutes intervals. December 22, 23, 24, 27 and 28: 3,78 liters or 1 US gallon of water were brought to a boiling point of 100˚C (212˚F). After reaching the boiling point, the water was replaced with ambient temperature water, to determine how many cycles of boiling water could be achieved in one day.

Summary And Conclusions:

Graphic results show more consistent cooking temperatures maintained by the Blazing Tube. The unit was less prone to solar variations and achieved 100˚C even under cloundy conditions with occasional rain showers.

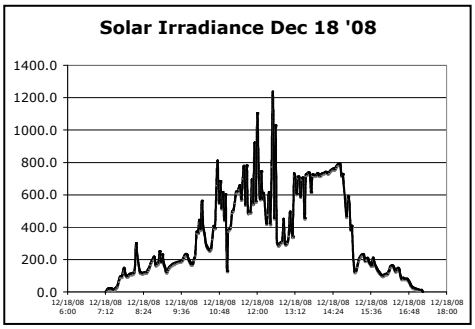
Testing the fixed angle unit of the Blazing Tube in December was limiting, and better results would be achieved in other seasons.

Multiple tasks such as cooking, water pasteurizing and autocalving during one day are more readily achieved by the Blazing Tube.

Heat retention in the cooking box of the Blazing Tube allows food to be kept hot in the evening for hours long after sunset.

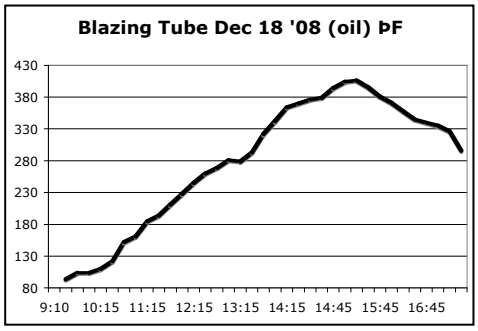
The Blazing Tube proved to be more user friendly, since the cooking area is separate from the heating unit and there is no need for the use of sun glasses or possible burns from the reflectors. The cooking box could be equipped with an umberella or placed under a tree or thatched roof to protect the person cooking form the direct radition of the sun, without impacting its optimal preformance.

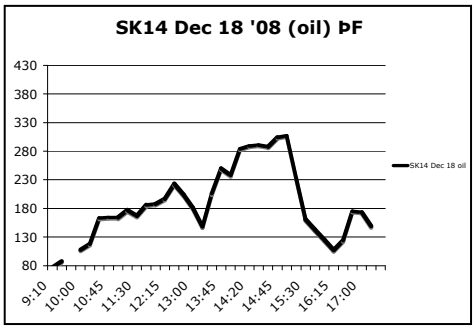
The Blazing Tubes cooking box is high above the ground, far away from e.g. chicken or roaming pigs and the additional enclousure around the cooking pots or baked goods keeps them away from dust and children.

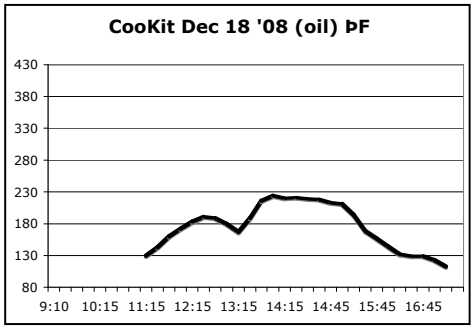


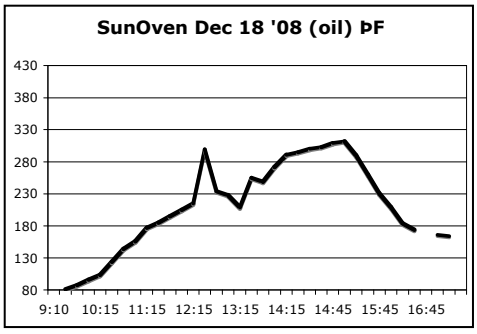
December 18 2008: Heating 1 liter of vegetable oil all day to test hight temperature achievement

Although solar conditions were not ideal, the Blazing tube unit surpassed the other three and exhibited a consistent temperature rise throughout most of the day.







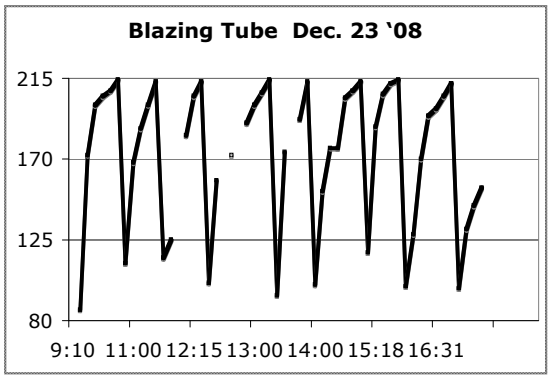


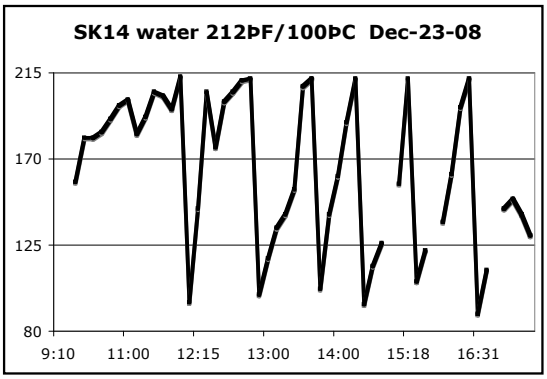
December 23: Most boiling cycles achieved with High Insolation Test on December 23, 2008: Boiling 1 gallon (3.78 liters of water) batches as many times as possible in all four solar cookers. Though not a cloudless day Decemebr 28 provided the best solar conditions.

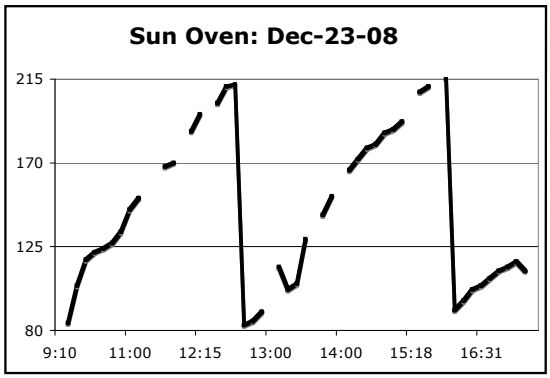
Goal: to establish how many heating cycles, reaching 100˚C can be achieved in one day by each unit.

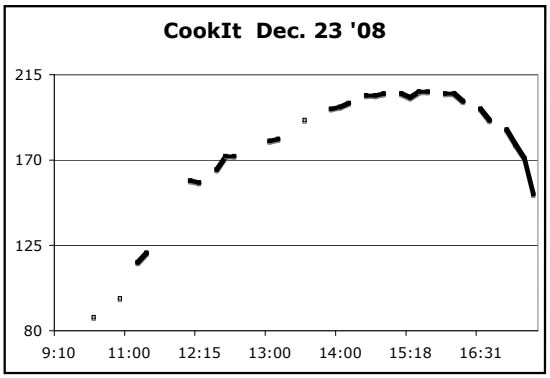
Set-up: Cookit and Sun Oven aluminum pot with glass lid. SK14 closed black pot with solid lid. Blazing Tube: enamel pot with lid. This data represents the best day with direct sunshine during the testing period. After reaching the boiling point the water was immediately replaced with new water at ambient temperature.

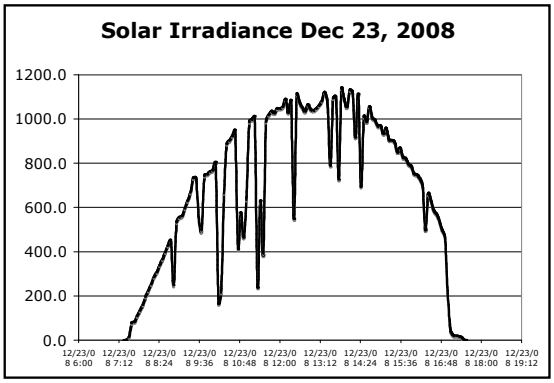
Results: The Blazing Tube completed 8 gallon boiling cycles for a harvested heat energy total of 8656 BTU. The SK14 achived six gallon boiling cycles providing 6492 BTU. The Sun Oven did two gallon boiling cycles for 2164 BTU's harvested. And the CooKit had a comparative total of 1032 BTUs.





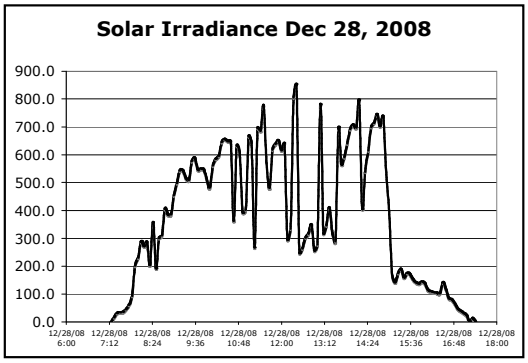


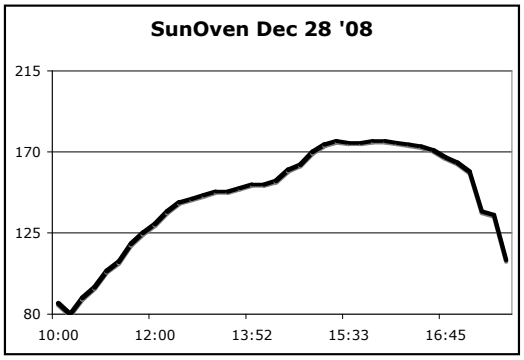


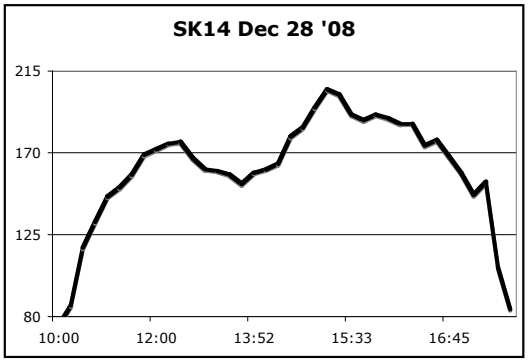


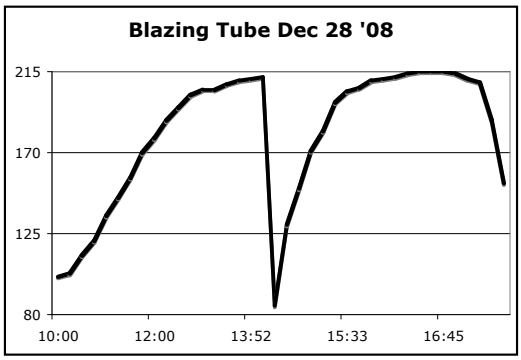
December 28 2008: Boiling water under less favorable conditions and testing heat retention of the water until late at night.

CooKit is absent due to overly wet weather during the test.









Extended test duration until 22:30. Results exhibit superior conservation characteristics of Blazing Tube.