THE SOLAR KETTLE-THERMOS FLASK: A COST EFFECTIVE, SUSTAINABLE & RENEWABLE WATER PASTEURIZATION SYSTEM FOR THE DEVELOPING WORLD

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ABSTRACT

Based on the perfect solar thermal energy harvesting paradigm of maximum solar radiation absorption and minimum loss of stored converted solar thermal energy, ***S**olar **V**acuum **G**lass **T**ubes* (*SVGT)* indefinitely deliver solar pasteurized safe drinking water, powered solely by free solar energy. The *SVGT* is the heart of the SK-TF. Being vacuum insulated, the SK-TF doubles up as a vacuum flask, delivering stored solar heated water in the morning before the sun is up. With a high stagnation temperature of more than 220°C, the SK-TF can also be used for other heating purposes e.g. an oven or autoclave. Powered solely by free solar energy, the SK-TF could very well be the answer in providing safe solar pasteurized drinking water to the global poor and needy a sustainable and renewable way.

Keywords: solar kettle, vacuum tube, renewable energy, solar, water, pasteurization, developing world

1. INTRODUCTION

(Much of this paragraph is extracted from: Recent Advances In Devices For The Heat Pasteurization Of Drinking Water In The Developing World by Dale Andreatta, Derek T. Yegian, Lloyd Connelly, and Robert H. Metcalf, from the proceedings of the 29th Intersociety Energy Conversion Engineering Conference, American Institute of Aeronautics and Astronautics, Inc., 1994.)

The United Nations Children's Fund (UNICEF) estimated that 60% of rural families and 23% of urban families in developing countries are without safe water. In some areas all water supplies may be microbes contaminated. [i]

If a water source is suspected of being unsafe, the most common recommendation is to **boil** the water.[ii]

This recommendation is seldom followed for several understandable reasons, the most important being the time and the amount of scarce fuel it would require.

According to UNICEF diarrhea is the most common childhood disease in developing countries.

The main cause of diarrhea in developing countries is contaminated water and a lack of sanitation.

Diarrhea related dehydration is the leading cause of death in children under the age of five and annually, an estimated five million children die from it.

Besides death, diarrhea is also the most common cause of child malnutrition, permanently impairing mental and physical development.

The Solution: Boiling & Pasteurization

An alternative to chlorination and UV disinfection, heating water to 65º C (149º F) for 6 minutes, or to a higher temperature for a shorter time, will kill all harmful germs, viruses, and parasites:

Worms, Giardia, Entamoeba	55° C (131° F)
Escherichia coli, Shigella, Cholera, Rotaviruses, Polioviruses	60° C (140° F)
Hepatitis A Virus	65° C (149° F)

2. SOLAR VACUUM GLASS TUBES: THE ECON-ECO FRIENDLY SYSTEM

Hitherto, boiling water takes time and effort and uses up scarce fuel resources that are often beyond the reach and means of the abject poor in many developing countries living in remote areas of the world.

However, with the advent of the *Solar Vacuum Glass Tubes* (SVGT) Fig. 1, free solar energy generated pasteurized water within two hours and without costing an arm or a leg, the solution to end unnecessary suffering and death from drinking microbes-contaminated water in a sustainable and renewable way, is perhaps now upon us!

The perfect solar thermal generation paradigm is **maximum** solar radiation absorption-conversion of free solar energy into useable thermal energy and the **minimum** loss of stored generated solar thermal energy.

The SVGT, as a solar heating device, fits the above solar generation paradigm, perfectly.

Made from strong borosilicate ("Pyrex") glass, this new generation solar vacuum glass tube collector is more than 70% efficient in converting solar energy into thermal energy (Fig.1)

Solar infrared energy penetrates the transparent outer glass tube, through the vacuum and gets absorbed by the black selective coating on the outer side of the inner tube.

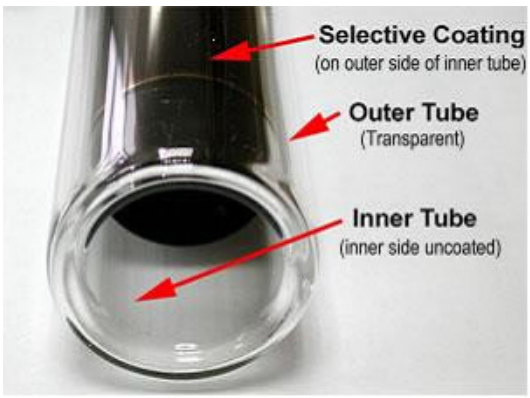

Figure 1: Solar Vacuum Glass Tube Collector[iii]

Solar thermal energy generated from sunlight by the SVGT sterilizes and kills most if not all water borne pathogens making it safe for drinking (Fig.2).

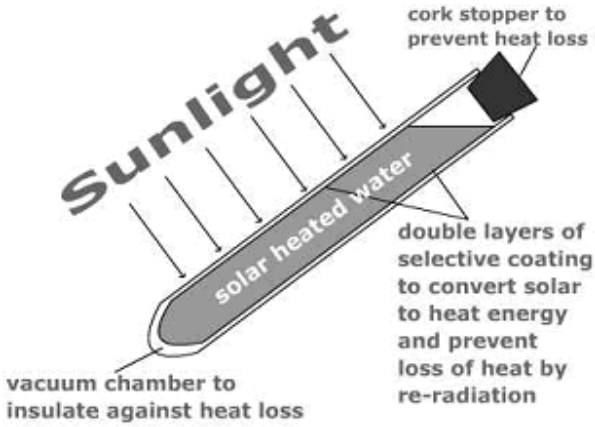

Figure 2: How the SVGT Solar Kettle-Thermos Flask Works

Since vacuum is a good thermal insulator, the heated water remains hot as the vacuum chamber prevents thermal energy from escaping by conduction, convection and radiation from the inner tube to the outer tube and beyond.

For added thermal insulation performance, the outer side of the inner tube is coated not once, but twice: two separate selective coatings, one on top of the other: Electrostatically spluttered black coating (Aluminum Nitride, Al-N) on reflective silver coating (Aluminum, Al).

To preserve the longevity of the selective coatings, a barium ring is placed within the vacuum to absorb any nitrogen or oxygen that may be out-gassed post-vacuum sealing.

The vacuum insulation is so efficient that, when corked over night, the thermal loss is less than 5°C, enabling the SGVT to double up as a vacuum flask in providing hot water in the morning even before the sun is up: keeping previously heated water warm for later use even when the sun is not up yet.

Made from glass and with the sensitive coatings protected in a vacuum chamber reinforced by a barium ring, the SVGT will last indefinitely provided it is not broken by intent or accident.

The SVGT is the heart of the Solar Kettle-Thermos Flask (SK-TF).

If purchased in bulk (at least 1,000 units per order), the SVGT and SK-TF is very affordable: FOB, USD2.00 and USD5.00, respectively.

3. SOLAR KETTLE-THERMOS FLASK (SK-TF)

The SK-TF comes in many lengths but with one standard diameter: outer/inner of 58mm/43mm respectively. The 1.2m long solar flask weighs about 1kg and can contain up-to 1.6 litre of water, good for 6 (x250ml) cups of hot water whereas the shorter 0.75m long SK-TF, is 0.6kg and can contain about 1 liter of water (Fig.3).

Figure 3: Solar Kettle-Thermos Flask

Depending on the latitude, season and weather conditions that affect solar isolation, it takes an average of 1 to 2 hours to heat the whole tube of water from room temperature to boiling point.

Operation is quite simple: Set up the solar kettle, fill it up with water, cork it and place the SK-TF in the sun, unattended.

When the water in the SK-TF starts to give off “steam”(a sign of profuse evaporation), the heated water is ready to be used. Pour the heated water into a clean container, refill the solar flask and repeat.

Alternatively, some form of a simple pasteurized water temperature indicator can be deployed to ensure that the water is sufficiently pasteurized and rendered safe for human consumption.

One possible device is the *WAPI* (Water Pasteurization Indicator) available from Solar Cookers International any cheap but reliable alcohol filled glass thermometer or even the “pop up” cooking thermometer (a.k.a the “turkey” thermometer).

A major setback of any Solar Thermal Water Heating System is that it sometimes fails you when you need hot water most: for e.g. in the morning to make hot beverages for breakfast when the sun is not up yet.

The SK-TK is not just a Solar Kettle; it is also a "Dewar" or "Thermos" Flask that keeps hot water hot overnight like a good vacuum flask, even in low ambient temperature conditions.

If hot water is needed the next morning even before the sun is up, the final batch of solar heated water of the day can be kept hot by simply plugging the opening of the SK-TK with the included cork plug. The water should remain hot overnight albeit with a heat loss of a mere few degrees Celsius.

Given that the SK-TF is made of glass, the solar pasteurized water thus produced from it is totally safe to drink as it is free from possible hot water leached copper poisoning as the case might be with copper based solar heating devices.[iv]

The SK-TK is fully portable and can be assembled and disassembled within minutes. It comes complete with a carrying bag with sling, toggle string, protective padding, cork stopper with a string, frame and vacuum tube nipple protector (Fig.4-6)

Figure 4: The SK-TF complete with Carry Case

Figure 5: The ST-SF with Cork Stopper and Anti-Misplace String

Figure 6: SK-TF Carry Case Details

Besides using the manufactured stand, cap and vacuum tube nipple protector, if for any reason local contribution is desirable, the peripherals of the solar vacuum tube can be made from any material: wood, bamboo, recycled metal, aluminum can, PET bottles, banana leaves etc (Fig.7).

Below are a few of the possible creative use of local material to make the stands and caps:

Figure 7: Improvised with Local Material Possibilities: Lashed Jungle Wood Tripod Stand, Re-used discarded baby pram metal, camera tripod stand, plastic cups etc

Besides being deployed singularly, the SK-TF can be set up in an array, delivering a larger batch of solar pasteurized water each and every time as required (Fig.8).

Figure 8: SK-TFs: Array Set-up

Other Uses of the SK-TF

Given the high stagnation temperature of the SK-TF of more than 200ºC, the SK-TF can double up as an autoclave oven to sterilize equipment and silica gel desiccant regeneration (Fig. 10).

Surgical instruments needing heat sterilization can simply be wrapped in suitable material and placed carefully inside the SK-TF and left unattended in the Sun for a few hours or the whole day to be sterilized and ready for use later.

The SK-TF can also double up as a cooking oven for food that can fit into the cavity of the SK-TF (Fig. 9).

Figure 9: SK-TF as an Oven

Silica gel desiccant is very useful as a moisture controller in hot and humid countries where in the absence of refrigeration, precious life saving drugs and herbs can spoil easily by the condensation of atmospheric moisture due to high relative humidity.

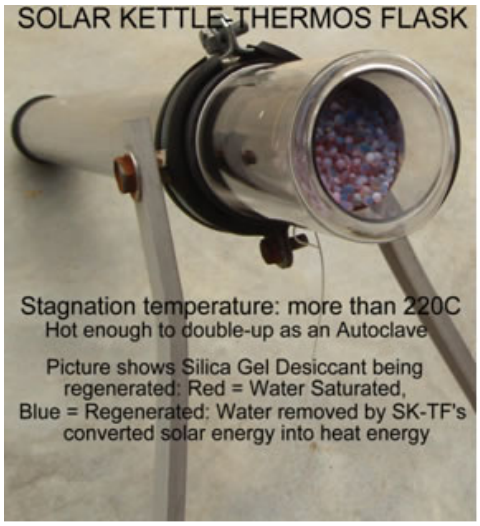

Figure 10: SK-TF, also a Silica Gel Regenerator

Silica gel desiccant has also been found useful in the desiccant drying of organic matter where active ingredients, sensitive to heat, makes heat driven drying methods unsuitable.

Whilst silica gel can be regenerated through the exposure to dry heat of 100ºC to 120ºC, and reused almost indefinitely and therefore suitable for deployment to the remote areas of the world, ovens are hard to come by there.

However, since the SK-TF, solely powered by solar energy is now available, the viability of using silica gel in remote areas of the world can be realized (Fig. 10).

The SK-TF can also be made to function as a solar water distiller with a simple homemade water condenser attachment (Fig. 11).

The SVGT efficiently converts water into steam and when steam condenses on the surface of the aluminum soda can, pure water, suitable and safe for drinking can be produced from arsenic contaminated to brackish and even salt water.

Figure 11: The SK-TF as a Solar Water Distiller

If so desired, residual table salt can also be recovered from salt water after the solar water distillation process, killing two birds with one stone.

Given that the Solar Vacuum Glass Tube is made from glass, maintenance is very minimal and, if necessary would incur just an occasional scrub of soap and water or just water on the outside and inside of the tube.

If available, vinegar (acetate acid) can substitute soap as the cleaning agent.

The inside of the tube can easily be scrubbed with a standard bottle brush or some other improvised cloth or coconut husk bristles on a stick.

4. FIELD TESTS

The SK-TF has been tested extensively in equatorial Malaysia since early 2003 and despite the heavy cloudy equatorial skies, never fails to deliver pasteurized water within 2 hours.

The SK-TF has also been tested in places conventionally considered “least favorable” solar heating wise (see Fig. 12) and pushed the solar limits further away from the Equator.

On 10th July 2005 at Eastbourne, Wellington, New Zealand, Mr. Stan SWAN, a lecturer with the University of Massey, New Zealand managed to solar pasteurize water even in Winter and at 41ºS, a location considered less than tropical[v]

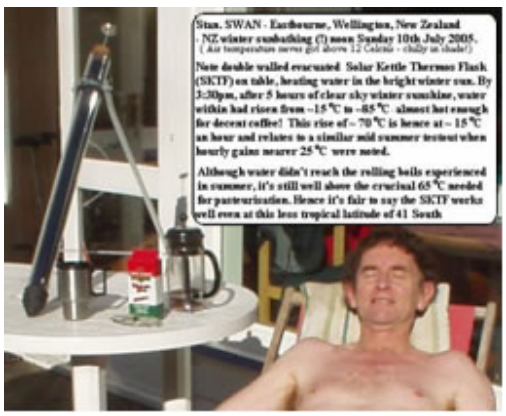

Figure 12: Mr. Stan. SWAN and the SK-TF, Sunbathing!

On 28th November 2005, he managed to produce boiling water with the SK-TF within 3 hours at Dunedin, South Island, New Zealand (49S), even when the ambient temperature was 18º C.

The average hourly thermal gain of the SK-TF was noted to be about 15ºC and 25ºC per hour for winter and summer respectively.

Therefore, assuming a starting water temperature of 25º, in a geographical area with clear skies, the targeted 65ºC pasteurization temperature could be reached within 2 hours.

In areas where the ambient temperature is high and solar insolation, strong, a shorter solar water pasteurization processing time can be expected.

5. CONCLUSION

The SK-TF, using free solar energy will kill the most heat-resistant microbes in water, which cause tuberculosis, undulant fever, streptococcal infections, and Salmonellosis.

The SK-TF is completely reliant on free solar energy, freely available to all and not controllable or regulate-able by any power institution. It is, by coincidence or providence, favourably distributed within the latitudinal zone 35°N and 35°S: the zone that most developing countries fall within (Fig.13).

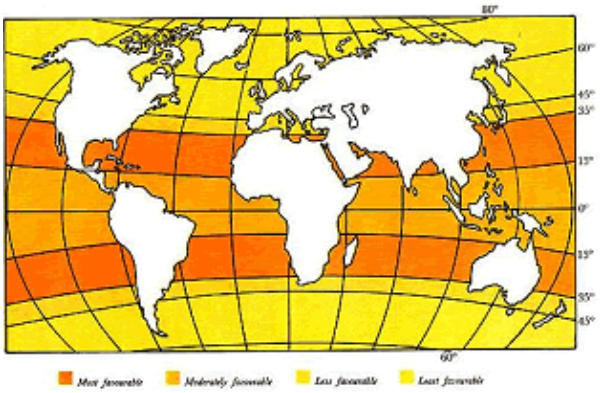

Figure 13: World Solar Insolation Distribution: Favourable Zone, between 35N and 35S

The SK-TF, unlike solar concentrators, is safe and will not accidentally burn eyes and body with concentrated sunrays.

The SK-TF, which can be procured for as little as USD5.00 per unit (if purchased in bulk) is very affordable and cost effective because, with just a small one time capital expenditure, continuous and free solar energy pasteurized drinking can be made on a daily basis by the individual, almost perpetually.

Consequently, the SK-TF could very well be the most viable option in the provision of pasteurized drinking water to the people in developing countries because it empowers the individual in providing pasteurized drinking water for himself/herself and his/her family members in a renewable and sustainable way relying entirely on solar energy, provided free of charge with compliments from the sun!

All that is needed on our part is to distribute these life saving SK-TFs to the needy individuals.

Besides producing solar pasteurized drinking water, the SK-TF, given its high stagnation temperature can double up as an oven for cooking, silica gel regenerator, autoclave oven and a solar water distillation generator.

Currently, given the factor of thermal equilibrium dynamics, the only solar thermal devices that can deliver such high stagnation temperature of 200ºC and above are devices employing some kind of solar concentration: parabolic dish, trough etc.

The SK-TF, driven by solar vacuum collector technology is unaffected by low ambient temperatures and could now even be deployed in areas hitherto considered not viable for solar thermal energy deployment e.g. areas beyond 35ºN and 35ºS.

With the SK-TF, there is a Place in the Sun, where there is room for everyone!

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[i] UNICEF, The State of the World's Children, 1989, Oxford University Press, pg. 48, 1989. In February, 2006, UN announced that more than 1billion people in the world do have no access to clean and safe drinking water.

[ii] Ibid pg 3, 1988

[iii] For details, please see above write-up on *Solar Vacuum Glass Tube*

[iv] http://www.hhs.state.ne.us/enh/pbcuwatr.htm Nebraska Health and Human Services System: Lead and Copper in Water Supplies: "C**old vs Hot water**: Hot tap water is for washing only; not consumption because hot water can dissolve lead and copper faster than cold water. Heat cold tap water tap on the stove or in the microwave."

[v] http://www.manuka.orcon.net.nz/sktfwint.jpg Mr. Stan.SWAN, sunbathing with his SK-TF in the deep of NZ's winter.