Dharmaningsih

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Dear Sir or Madam

We introduce ourselves as Dharmaningsih which roughly means the "obligations of good people" in the Indonesian language. We have been showing Indonesians how to use solar energy in their every day activities, such cooking food and water pasteurization. This works as far as it goes, but we have decided to manufacturer and sell a water pasteurization device that actually boils water at first and then devices that can be used for cooking food and other activities in the future.

Indonesian people want to see their water boil before drinking it and no amount of guarantees from us that 70 ^{0}C is sufficient will change their minds to the contrary. This is true for university professors as well as for poor village people. (As an aside, a friend of ours with a doctorate in chemistry looked at the many bottled water manufacturers that have sprung up and found that only 20% of then produced water free of living pathogens.)

Solar Boiling of Water

Our boiling water device is made out of evacuated glass tubes that are produced in China and are available very cheaply, costing on the order of US$ 1 each for sizes of about 58 mm diameter and up to 2 miters long. The following pictures may give you an idea of what we have in mind.

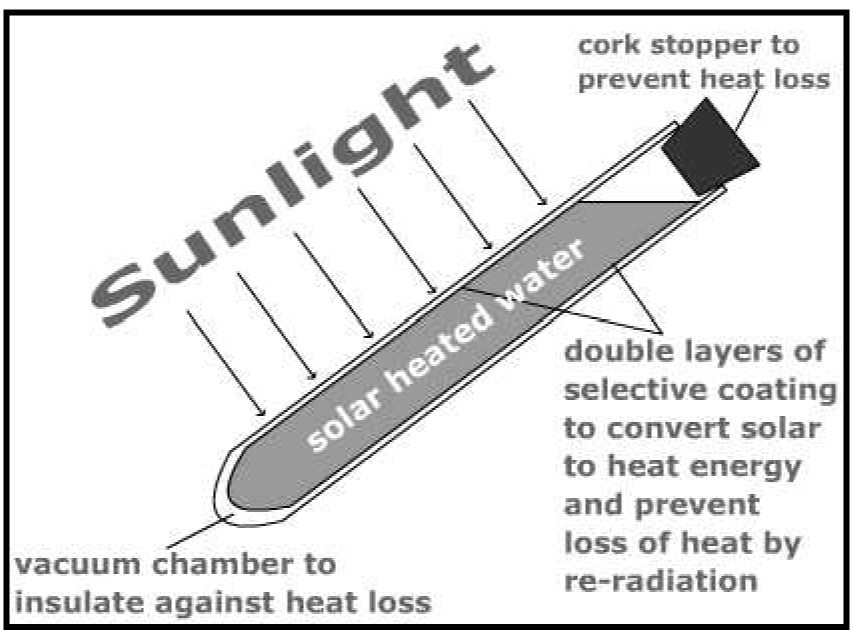

Figure 1. A drawing showing the concepts of the solar water boiler.

Figure 2. Two sizes of flasks that Alex Kee in Malaysia uses.

The way these tubes are constructed is shown in the following photos:

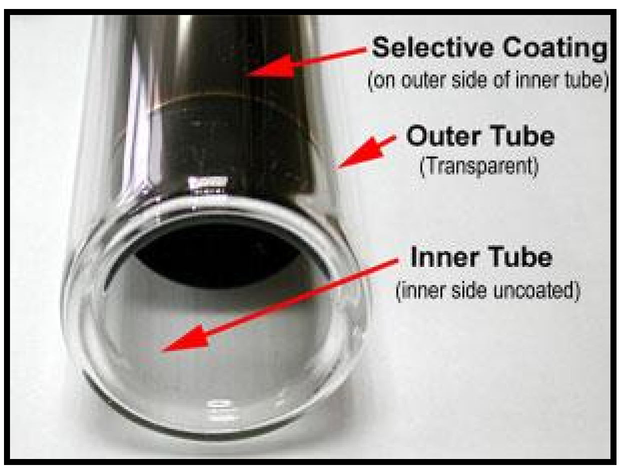

Figure 3. Construction of a Al/N/Al coated evacuated tube.

Figure 4. Construction of a different type of copper coated tube.

These tubes are used in solar water heaters and they have stagnation temperatures for a solar insulation of 1,000 W/m^2 of 220 ^{0}C for the Al/N/Al coated tube and 350 ^{0}C for the copper coated tube. There is also a barium getter that absorbs any oxygen or nitrogen that outgases in the evacuated region.

Figure 5. The appearance of the barium getter layer in a tube with a good vacuum at the left and the appearance of it in a tube with no vacuum at the right.

These tubes are typically used in solar water heaters as is shown below.

Figure 6. Solar tubes used in a typical thermosiphon water heater configuration.

We hope these pictures are sufficient to show you what we have in mind, i.e. we make solar water boilers out of very inexpensive evacuated and coated glass tubes available from China.

We plan to mount these on white reflective boards and then place them in the Sun. There are a number of configurations which we can use that depend on the amount of money customers can afford. The minimum configuration will have a glass tube mounted on a white board and will also have a whistler of the tea kettle variety to let people know when the water is boiling. More expensive models will be more convenient to use, but based on the same principle. Wholesale prices will be on the order of US$ 10 and up.

Solar Heat Sources

These will be used when temperatures greater than 100 ^{0}C are needed and justify the higher system costs. For these systems we will use copper coated tubes with a stagnation temp of 350 ^{0}C assuming a solar insolation of 1,000 W/m^2 and we will provide a insolation higher than 1,000 W/m^2 by using a combination of concentrators. Our intension is to use a group of Fresnel lenses arranged around the central glass tube.

To make these we will need two molds, one for the outer divergent lenses and one for the inner convergent lenses. This will be similar to the glass tubes but without the vacuum and will be made out of a plastic. The reason we go with two rather than just one is because of etendue which says that the concentration ration goes as;

Equation 1 $C = (n'/(n \sin(\phi)))^2$

Where ***C*** is the concentration ratio, ***n'*** is the refractive index of plastic we use, ***n*** is the refractive index of air in our case, and ϕ is the angle of maximum incident radiation that we find useful.

For ϕ equal to 90^{0} which would be for our 180^{0} wide angle lens this works out to $(n'/n)^2$ and is equal to ~ 2.5, not very much of a concentration factor. By going with two lenses we can achieve as much concentration as we want with constraints not related to etendue. I.e. And by using lenses we can achieve a higher concentration than what is available for reflectors alone.

With this arrangement we should be able to obtain temperatures greater than 500 ^{0}C that can be used for food frying or an oven as well as for industrial processes. We could use something like iron pellets contained inside the glass tube that would be heated and then emptied into an insolated container once the appropriate temperature is reached. The insulated container can then be transported to where and when it is needed.

The Reasons for Doing This

Global warming aside, this will used to save money and money is the only reason that makes sense in poor third world countries. The people of Indonesia have to purchase their water (see the introduction) or boil it using either LPG, kerosene, of wood or a wood type substance to combust. All of these are expensive for these people either in terms of money or in terms of time spent. A typical family of four will spend about Rp. 3,000 per day or about US$0.30 on kerosene fuel which works out to about US$ 10 per month or US$ 120 per year. Not very much by your standards, but a significant amount by local standards. We can save a large fraction of this amount by selling water boilers. Of course it rains with forest fires and what not, but by in large a significant saving. And almost everyone in Indonesia, 220 million people, is a potential costumer. We can expand elsewhere to the 4 or 5 billion people who have to boil their water.

In the third world there is semi working, non working, or non existent government or private water system that mandates that the water be boiled for human consumption. We are proposing a way that people can boil water using the free Sun.

Thank you for your attention and best regards,

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PS Following is a very simplified theory that may give you an idea of what goes on.

Theory

Let's start by showing both the radiation of the Earth and that of the Sun just outside the Earth's atmosphere. This is a graph expressed in energy units, electron Volts, rather than in reciprocal energy as is the case as when expressed in wavelength. The reason wavelength is so common is because it is the way spectrometers behaved historically.

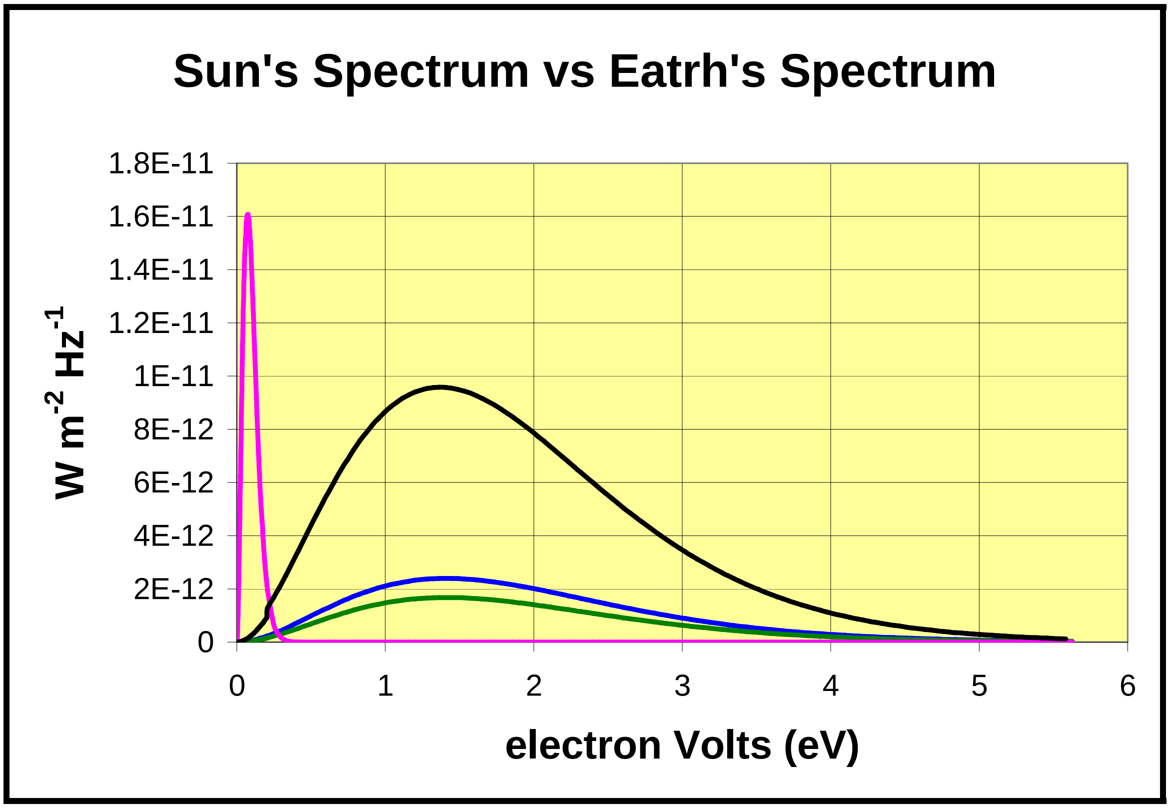

Figure 7. Earth's spectrum in red at the left and the three broad lines representing the Sun

In Figure 7 the top line is the Sun impinging on the Earth at high noon, the line in between is the average of the Sun over one day at a location on Earth, and the bottom line is after subtracting the albedo (reflected light), more or less. The lower line is the about the same as the Earth's radiation not by coincidence, but because it is mandatory with some caveats.

The Earth's spectrum is different than the Sun's except for a small region where they intercept. This fact is used to control the ratio of sunlight let in and amount of heat light let out. We want materials where much sunlight is let in and at the same time the heat light produced is kept in. Maybe an explanation is in order: The sunlight is converted into heat when it is absorbed by lets say Al/ N. This heat penetrates the water heating it up, but now it is a new source of radiation above ambient that is reflected by the Al layer.

The equation governing this behavior is Planck's formula that solved the "ultraviolet catastrophe" problem and is given by;

Equation 2. $M = 8\pi h\nu^3 d\nu/c^3(e^{h\nu/kT} - 1)$

Where ***M*** is called exitance and is expressed in Watts/square meter (W/m^2), ***h*** is Planck's constant and is equal to 6.626×10^{-34} Joules/second (J/s), ***v*** is the frequency in Hertz, ***c*** is the speed of light in vacuum and is equal to 2.998×10^8 meter/second (m/s), ***e*** is the naparian, ***k*** is Boltzmann's constant and is equal to 1.381×10^{-23} Joules/Kelvin (J/K), and ***T*** is the absolute temperature in Kelvin (K).

Long before this was known, Stefan and his student Boltzmann came up with the Stefan-Boltzmann law that was based strictly on thermodynamic arguments. And when Planck's formula is integrated, low an behold, out pops the Stefan-Boltzmann law which is given below.

Equation 3 $M = \varepsilon\sigma T^4$

Where ***M*** is the same as in Equation 2, ε is the emissivity, a dimensionless number between zero and unity, σ is Stefan's constant equal to 5.67×10^{-8} $W/(m^2 K^4)$, and ***T*** is the same as given above.

When talking about the Sun we use different terminology and substitute the solar insulation with a maximum of 1,000 W/m^2 along with the concentration factor.

Equation 4 $T = (IC/\sigma)^{1/4}$

This is where ***I*** is the solar insulation, ***C*** is the concentration factor, and ***T*** is the stagnation temperature. And for a concentration factor of one, this works out to $(1000/\sigma)^{1/4} = 364$ K or 91 ^{0}C as the maximum temperature that can be obtained under these conditions for a flat plate.

For the Al/N/Al tubes the absorbance is 0.95 and the emission is 0.07. The geometry is important here, where for a sphere the absorption is πr^2 while the emissivity goes as the area of the sphere, $4\pi r^2$, so the ratio is ¼ x 0.95/0.07 = 13.6/4 = 3.4 and is the same for all spheres. And for a cylinder the absorption goes as 2rh while the emission goes as $\pi rh + 2\pi r^2$. So the ratio for Al/N/Al goes as 13.6 x 2rh/($2\pi rh + 2\pi r^2$). If we ignore the end pieces, $2\pi r^2$, this reduces to 13.6 x 2/2π = 4.3.

For the sphere we obtain a stagnation temperature of $(3.4 \times 1000/\sigma)^{1/4} = 495$ K = 221 ^{0}C and for the cylinder $(4.3 \times 1000/\sigma)^{1/4} = 525$ K = 252 ^{0}C. with reported values of 220 ^{0}C and in pretty good agreement with our theory. We haven't considered the ambient temperature which tends to complicate things a bit and would be beyond the scope of this simple explanation.