Three Prototypes of Solar Bottle Bulb

Different Interior Bottle Exposure Levels

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ABSTRACT

Different size and arrangement of solar bottle bulbs might greatly affect the lighting effect, and there is not a general agreement on the best ratio of interior bottle exposure levels, which has greatly restricted the universalness of application. This study was to examine the lighting performances for three prototypes of solar bottle bulbs and to compare the performances related to three different interior bottle exposure levels, say, 1/3, 1/2, and 2/3. Experiments have been conducted for three alternative prototypes and three interior bottle exposure levels. Prototype 3 provided as much illuminance as Prototype 1 did but transmitted much more heat into the interior space. In terms of interior bottle exposure, the 1/2 model performed the best. Some unexplainable phenomena were also observed with recommendations for further study.

Introduction

The first solar bottle bulb was born in Brazil invented by Alfredo Moser in 2002 (Alex, 2013), who was a mechanic worker looking for a substitute to electrical lighting when Brazil was suffering in energy crisis and blackout. It was believed that the solar bottle bulb could produce luminance equivalent to about 50 watt incandescent bulb to brighten the living space and because of total internal reflection and Snell's Law, sunlight passing though the water bottle provided a much better lighting effect than that simply opening a hole in the roof to allow direct sunlight (Alrubaih et al., 2013; Kim & Todorovic, 2013). Although this kind of ecofriendly bulb could supply daylight into living space only during daytime, it has greatly changed the impoverished people's lives because the materials are cheap, easy to install, and environmental friendly.

Introduction

- This kind of bulb reduces the risk of fatal fire related incidents such as improper use of dangerous electrical connections which might cause destruction and explosion (Wang et al., 2010). However, no experiment has been done to quantify the actual luminance produced by various types of solar bottle bulbs. In general, human eyes perceive that the light produced by solar bottle is equivalent to the range from 40 to 60 watt incandescent bulb depending on the weather condition (Fonseca et al., 2013). With additional support by galvanized iron to secure the sides of the bottle using rubber sealant, solar bottle bulb becomes more durable and it prevents leakage while raining. Solar bottle bulb is also known as inspired by the Appropriate Technologies Collaborative (ATC) in helping poor communities in developing country such as Brazil and Philippines through simple and appropriate innovation (Priti, 2013).

Introduction

- Solar bottle bulb has been widely used over the world especially in those poor and developing countries. However, there was not yet serious measurement or precise evaluation conducted on how these kind of popular lighting devices perform. Further, different size and arrangement of solar bottles might greatly affect the lighting performance, and there is not yet a general agreement on what is the best ratio of interior bottle exposure levels, which has greatly restricted the universalness of application (Buzz Skyline, 2013). In light of that, this study was to examine the lighting performances for three prototypes of solar bottle bulbs and to compare the lighting performances related to three different interior bottle exposure levels, say, 1/3, 1/2, and 2/3, for a chosen prototype. As a definition for example, the 1/3 interior bottle exposure level means that 1/3 of the bottle height is under the roof plane.

Introduction

Solar Bottle Bulb and Light Passing Through

- The first solar bottle bulb was fabricated in Brazil in 2002 yet it was not known to the world until the MyShelter Foundation in Philippines took interests in this idea and worked together with the students from Massachusetts Institute of Technology to report it to the world in 2006. This foundation was initiated to help the poor community by having launched several projects with materials that could be easily found in ground to improve poor community shelter and to provide free lighting for the poor dwelling.

Solar Bottle Bulb and Light Passing Through

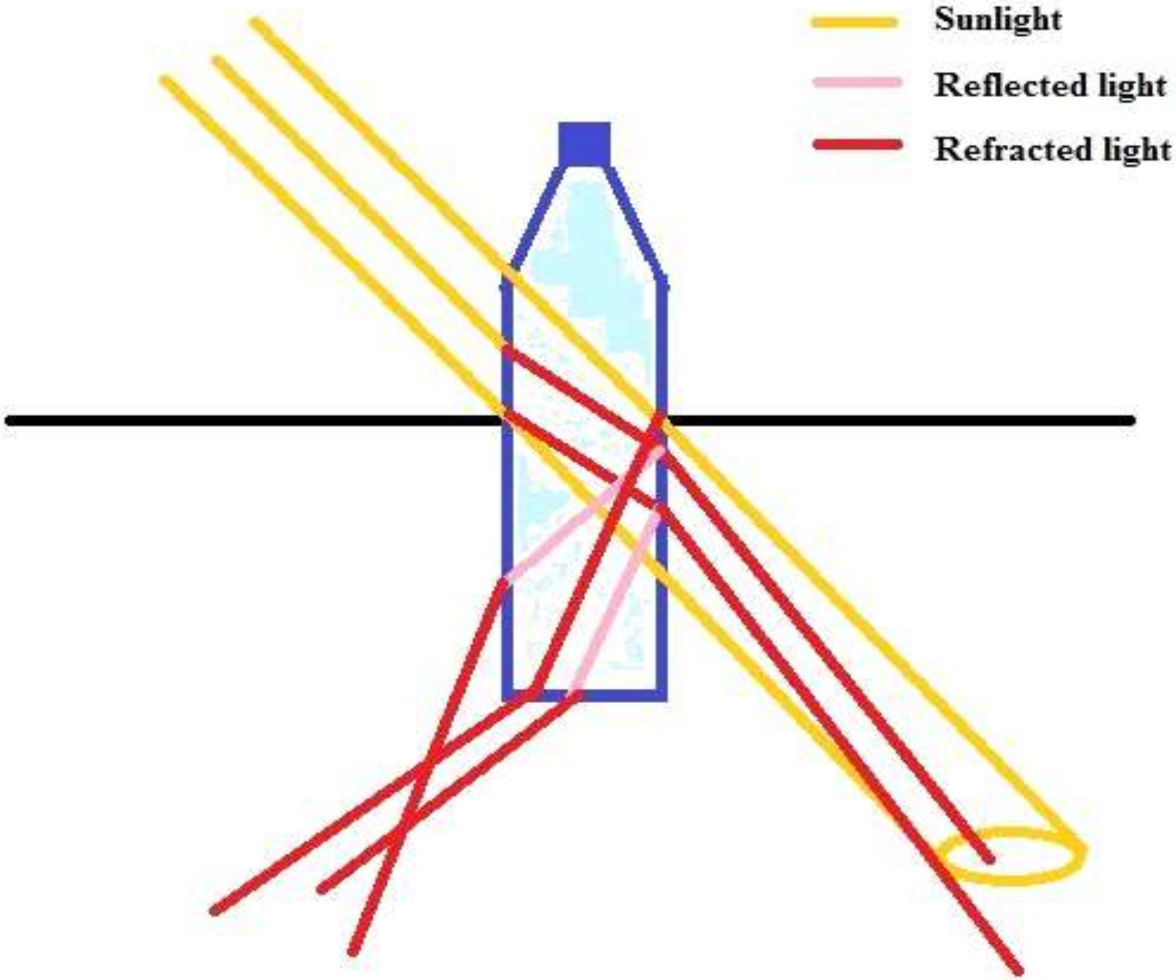
- Not only the poor but also many other parties who install solar bottle bulbs simply because they love this idea for instance, one Japanese restaurant named "Mufune Japanese Restaurant" in Dumaguete, Philippines attracted many customers by installing solar bottle bulbs (Priti, 2013). As it was well introduced over the world, some interested parties even tried to evolve on it and shared their idea throughout internet for example as shown in Figure 2, a small solar panel was mounted beside the bottle to charge the battery for night usage. However, for poor families, this kind of evolution is interesting but not practical (Shameri et al., 2013; Sachs et al., 2001). The solar bottle bulbs are now slowly expanding their colony into more and more countries in the developing world.

Solar Bottle Bulb and Light Passing Through

Solar Bottle Bulb and Light Passing Through

- Possible light reflection and refraction in a solar bottle bulb is shown in Figure 3. The light passing through the bottle faces with refracting bending and internal reflecting, which shares the similar physical principles as the light refraction and reflection through diamond, optical fibres, or light wells (Webb, 2006; Daimon & Masumura, 2007). Without a solar bottle bulb, a simple hole on the roof could not evenly distribute the sunlight to every corner of a inner space because the light passing though a simple hole is unidirectional (Fernandes et al., 2013; Egan, 1983). On the contrary, according to Snell’s law and fine tuned by internal reflection, a room could be better lighten up by a solar bottle bulb.

Solar Bottle Bulb and Light Passing Through



Experiment Design

- To quantify the performance of the most frequently used size and arrangement of solar bottle bulbs found in the media, three experimental prototypes were designed and fabricated. A dark room replicate was designed and fabricated using a cardboard box to fit with the solar bottle bulb and measuring devices including Lux sensors, pyranometers, data logger, and spectrometers. The solar bottle bulbs were fabricated using: a) 1.5 litre and 500 ml PET plastic bottles; b) Bleach; c) Filtered water; d) Cardboard; and e) Rubber sealant. The steps of fabrication was i) prepare a cardboard of size over 200mm width and 400mm long to cover the opening of the box; ii) paste black sugar paper at the bottom of the cardboard; iii) outline a circle of diameter of the bottle and a smaller circle and cut the inner smaller circle; iv) cut from the inner circle 1 cm radially making strips and bending it upwards; v) attach the cardboard to the PET bottle. Suggested to scratch the surface of the bottle to allow sealant and bottle sticking well together; vi) seal the bottle in place; vii) fill in filtered water and 2 capfuls of bleach; and viii) cover the bottle with bottle cap.

3.1 Dark Room Replica

- To prevent the interior illuminance measured from being disturbed by interior household items that might cause reflection towards measuring devices, a replica of a dark room was fabricated using a cardboard box with internal surface pasted with black paper as shown in Figure 4. Three 504mm by 513mm by 300mm cardboard box were covered by black sugar papers inside. An opening on top of the box was made to fit in those prototypes. It was used as a constant and stationary darkroom to obtain accurate data.

3.2 Three Prototypes under Examination

- Prototype 1 (as shown in Figure 5) is the conventional 1.5-litre bottle.

- Prototype 2 (as shown in Figure 6) has three 0.5-litre bottles which made up a total volume of 1.5 litre that is same to the volume of one big 1.5-litre bottle, arranged closely to one another in a triangle shape.

- Prototype 3 (as shown in Figure 7) was fabricated mainly to test its difference to Prototype 2. Prototype 3 has the similar triangle arrangement as Prototype 2 but its 3 small bottles were arranged 1 inch apart from each other.

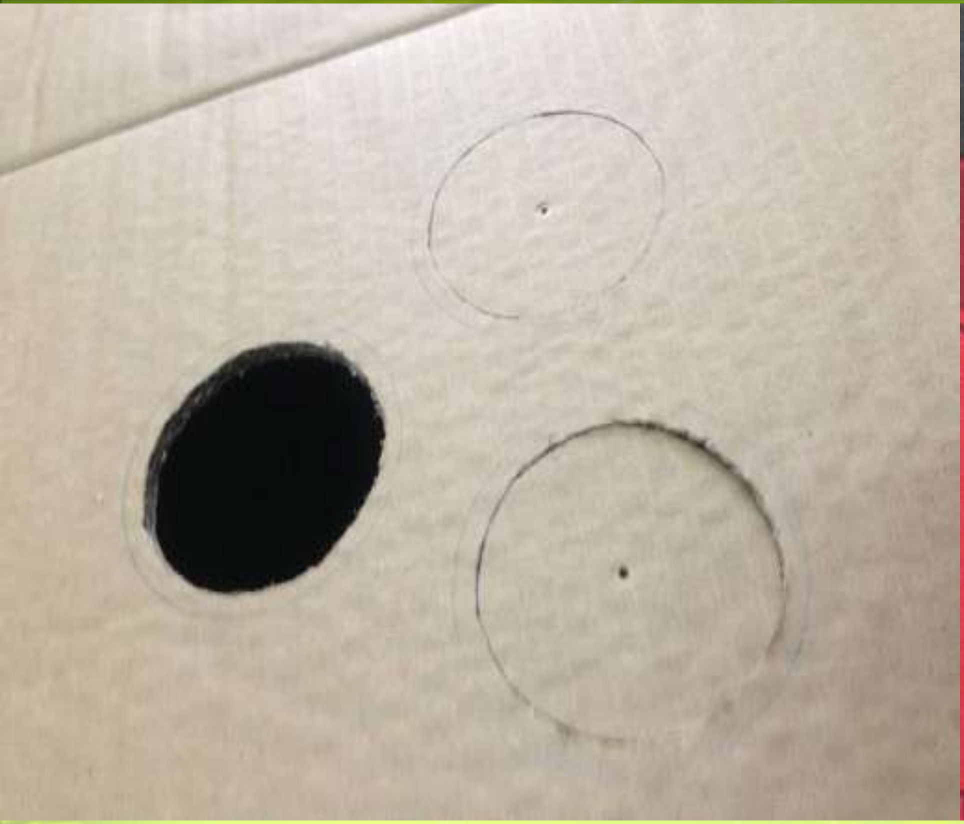
3.2 Three Prototypes under Examination

Prototype 1

3.2 Three Prototypes under Examination

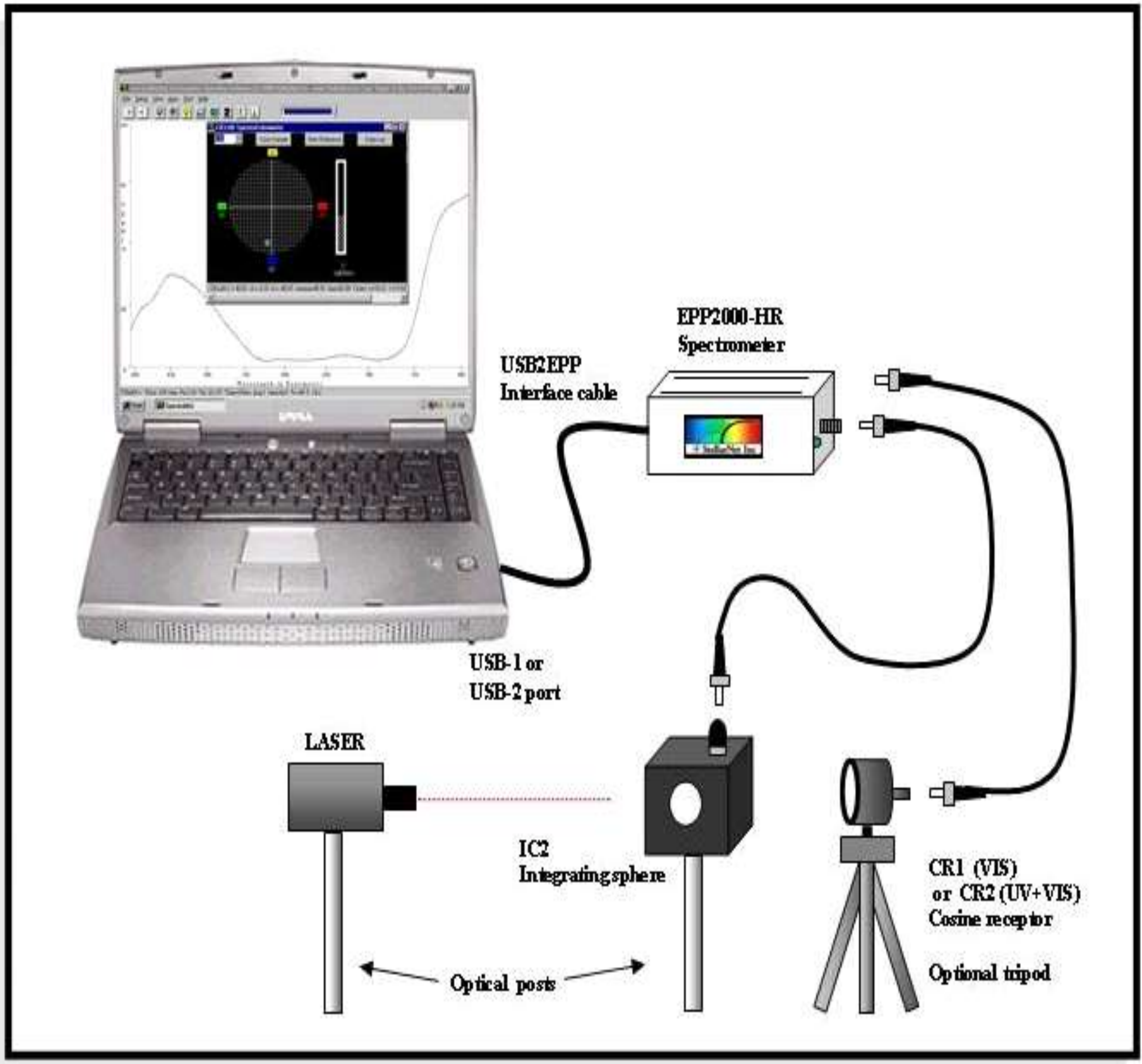
Prototype 2

3.2 Three Prototypes under Examination



Prototype 3

3.2 Three Prototypes under Examination



Five Experiments and Hypotheses

Hypothesis 1: The lighting performances of three prototypes are significantly different although each has the same total volume of water;

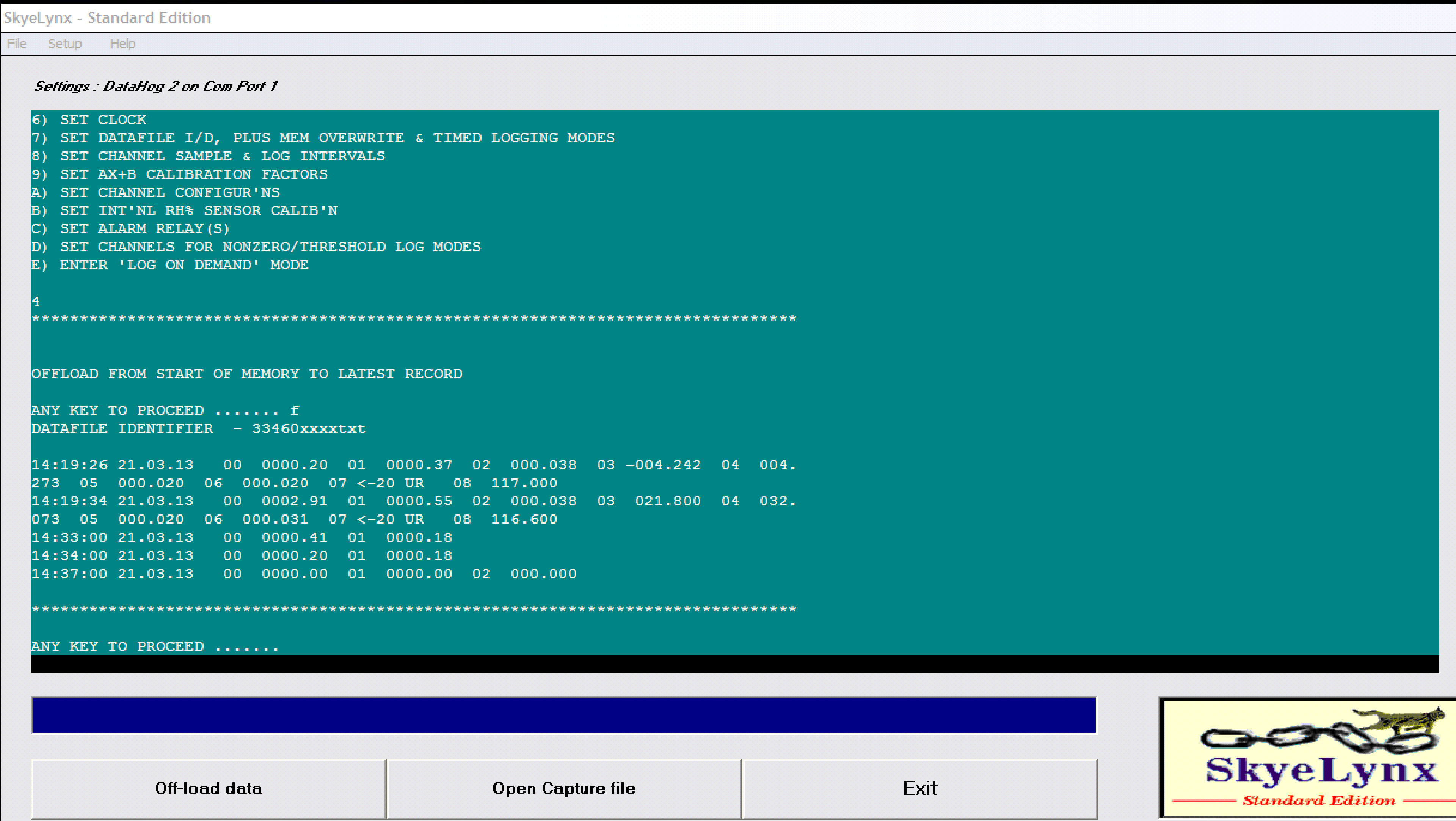
Hypothesis 2: The color of light provided by solar bottle bulb is significantly close to natural light;

Hypothesis 3: The illuminance provided by a solar bottle bulb for indoor lighting purpose varies greatly dependent on various weather conditions within a same day

Hypothesis 4: More interior bottle exposure provides more illuminance at the bottle bottom than less interior bottle exposure does (The 1/3, 1/2, and 2/3 interior bottle exposures were tested simultaneously).

Hypothesis 5: Solar bottle bulb full of water has greater indoor lighting performance than half-water bottle bulb and simple plastic covered hole do.

Monitoring



SkyeLynx - Standard Edition
File
Setup
Help
Settings : DataHog 2 on Com Port 1
6) SET CLOCK
7) SET DATAFILE I/D, PLUS MEM OVERWRITE & TIMED LOGGING MODES
8) SET CHANNEL SAMPLE & LOG INTERVALS
9) SET AX+B CALIBRATION FACTORS
A) SET CHANNEL CONFIGUR'NS
B) SET INT'NL RH% SENSOR CALIB'N
C) SET ALARM RELAY(S)
D) SET CHANNELS FOR NONZERO/THRESHOLD LOG MODES
E) ENTER 'LOG ON DEMAND' MODE
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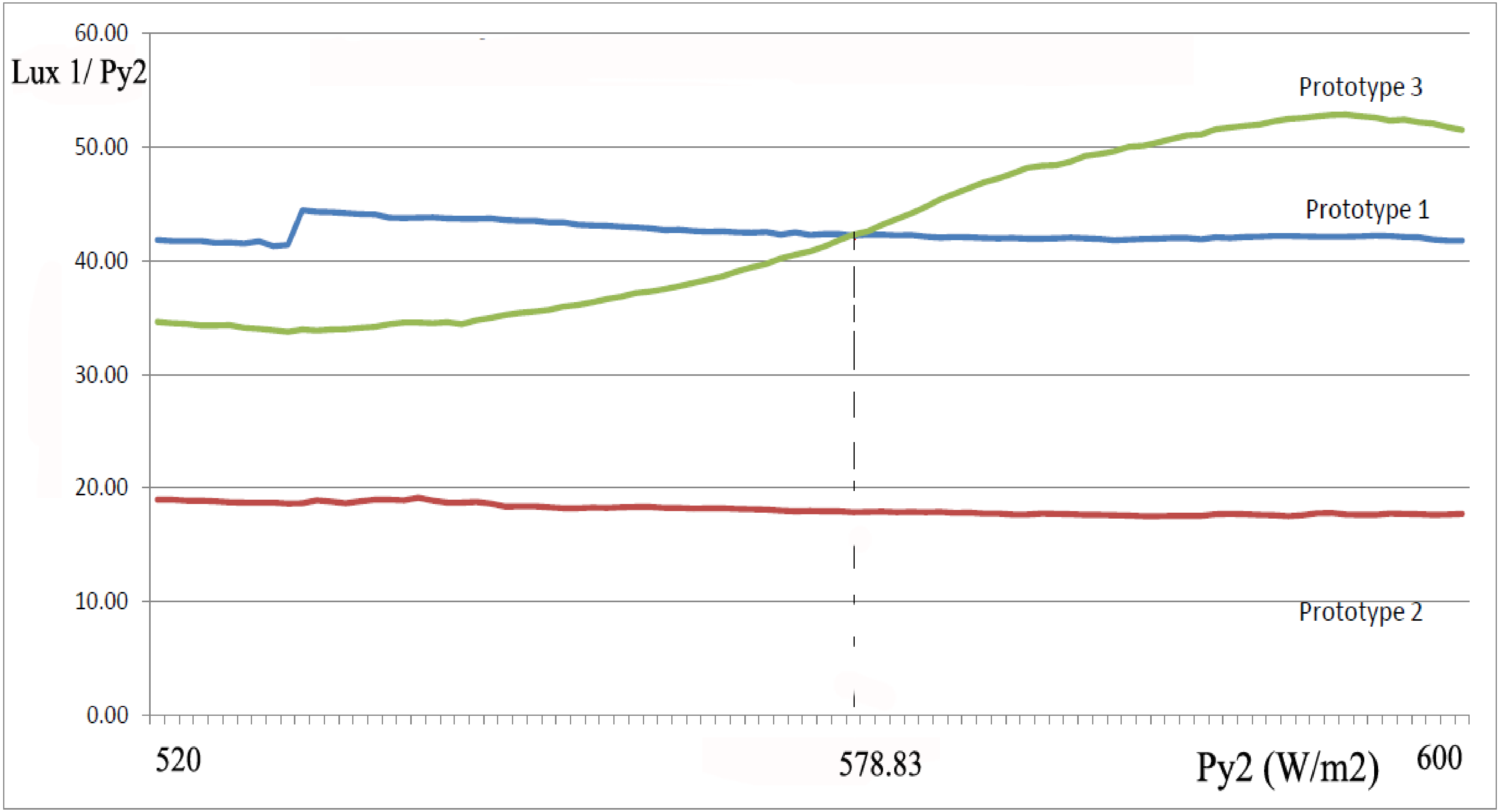
Mean Value of Experiment 1for 3 Prototypes

Prototypes	**Py1** (W/m^2)	**Lux 1/Py2 ($Luxm^2/W$)** (Lux sensor 50mm below bottle bottom with direct view to the bottom of bottle)	**Lux 2/Py2 ($Luxm^2/W$)** (Lux sensor located 50mm above bottle bottom but 50mm distance to bottle side with direct view to the side of bottle)
Prototype 1	59.68	42.50	39.57
Prototype 2	58.80	18.12	27.62
Prototype 3	124.00	43.42	35.01

Line graph of luminous efficacy ratio



Mean Performances of 1/3, 1/2, and 2/3 Interior Bottle Exposure in 15 minutes

Proportion	Py1 (W/m^2)	Py2 (W/m^2)	Lux 1 (Lux)	Lux 1 /Py2	Lux 2 (Lux)	Lux 2/ Py2
2/3	85.478	713.476	16959.42	23.77	15425.91	21.62
1/2	73.689	713.476	23680.40	33.19	20548.80	28.80
1/3	51.331	713.476	15458.97	21.67	11463.65	16.07

Mean comparison of illuminance for finishing A, B, C in 10 minutes

Finishing	Py1 (W/m^2)	Py2 (W/m^2)	Lux1(Lux)	Lux1/Py2	Lux2(Lux)	Lux2/Py2
A (full water bottle)	75.826	794.631	24196.38	30.45	16772.86	21.11
B (half water bottle)	89.727	794.631	11086.26	13.95	4612.93	5.81
C (simple plastic hole)	729.834	794.631	72523.82	91.27	1863.29	2.34

Conclusion

Solar bottle bulb can provide sufficient lighting to a room without transmitting much heat into the interior. Solar bottle bulb does not perform well under overcast and raining condition as the illuminance magnificine at 3.513 reduces the interior illuminance greatly. Spectrometer verified that the light color of solar bottle bulb is close to the sunlight. Although the same volume of water was used, the 3 prototypes did not provide the same quantity and quality of light. Prototype 3 performed similarly with Prototype 1 in illuminance but it transferred much more heat into the interior space. Prototype 2 performed the worst in both illuminance and heat transfer. The 1/2 exposure model provided more illuminance than either the 1/3 exposure model or the 2/3 exposure model, while the 2/3 exposure model allowed more energy transmission than the other two did. Experiments presented two interesting phenomena that could not yet be explained in this study that firstly, when the solar radiation (Py2) was below 578.83 W/m^2, Prototype 1 performed better than Prototype 3 in both illuminance and energy transmission while Prototype 3 surpassed Prototype 1 in illuminance after the solar radiation beyond 578.83 W/m^2.

Conclusion

Secondly, in the experiment for interior bottle exposure levels, as the solar radiation Py2 increased from 700 W/m^2 to 720 W/m^2, the Lux/Py2 also increased for the 1/2 exposure model but the 1/3 and 2/3 models appeared a decreasing trend after 715 W/m^2 solar radiation. These are expected to be explained in further study. As a limitation of this study, the experiments were only conducted within the equatorial zone with a high sun angle. The results might be significantly different for areas with lower sun angle than the equatorial zone, thus more experiments are recommended in the temperate zone and the frigid zone for comparison study. Further, relative measurements could be approximated by a painting the interior of the box white to be used as a modified integrating box and taking measuring the illuminance with the sensor shielded from direct view of the bottles.

Thank You!