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Performance Study on the Use of Used-Engine Oil as Thermal Storage Median in Solar Still

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***Abstract**: A performance study of a non-phase change, Used-engine oil as thermal energy storage material have been carried out to investigate its heat storage capability for use in improving the yield of a solar still. The methodology used involved charging the solar still basin with water and the storage chamber with energy storage material (used-engine oil). The water was heated by solar radiation being transmitted through the glass cover. A steam will be generated which on impinging at the bottom of the glass cover exchange heat with outside cover of the glass cover and condensed into distilled water. The excess heat in the water basin passes through the heat exchanger to the storage chamber to warm the oil. The stored heat is utilized in the night time for the continuous distillation. The experimental result shows that the still with used-engine oil in the storage chamber has a daily distillate yield of 3.41 liters/m^2. It has the least cost of producing a litre/m^2 of distillate because of its low input cost. The cost of producing a litre/m^2 of distillate is N51.82 kobo. While the control still had a daily distillate yield of 2.37 litres/m^2, the cost of producing a litre/m^2 distillate is N69.94 kobo. The used-engine oil proved to be a good thermal storage liquid both in terms of cost effectiveness and stability. Thus its usage as thermal storage material in solar distillate production is highly recommended.. The extra capital cost that resulted was offset by the higher yield which resulted in lower production cost per litre of distillate.*
***Key Words:** used-engine oil, Insolation, thermal energy storage material, sensible heat storage medium.*

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I. Introduction.

Solar energy, being an abundant, non-depletable, available on site and pollution free, has long been regarded as a potential heat source. Since solar still distillation process requires at most medium grade heat, solar stills are therefore, being used worldwide, to produce portable drinking water. However, the cost of solar energy collection and utilization becomes expensive due to its diffuse, low intensity and intermittent nature. It therefore, requires some kind of energy storage. Since heat dominates energy consumption in solar stills, thermal storage is particularly important.

According to Bugaje and Ramshaw (1995), efficient and economic heat storage is the key to effective and wide spread utilization of solar energy for thermal applications. Thus, it can be said that energy storage holds the key to the provision of energy when the intermittent source of energy is not available.

The sensible heat storage capacity of the used-engine oil depends on the heat capacity and the temperature of the medium during charging or discharging at the storage.

The need for thermal energy storage is further encouraged by the fact that the nighttime production of the distillate from solar still in the tropics may be equal or even surpass the daytime production. This is because the daytime temperatures in the tropics are often high. The study area (Birnin Kebbi, latitude 1 *2.5°N*, longitude 4.3°E) for instance, has the daytime temperature usually above 30°C. The temperature of the transparent cover of the still will be very high during the daytime, leading to near zero temperature difference between the inner and the outer surfaces of the cover. This situation is even more pronounced if the wind speed is low. This then lowers the rate of heat removal from the cover of the solar still.

This situation differs during the nighttime when the insolation from the sun is no more present, leading to the lowering of the cover temperature. The ambient temperature at nighttime is generally lower than that of the daytime. The thermal storage material in the basin however, retains most of the heat it had gained during the daytime and is able to release this to the system for the production of distilled water during the night. The amount of water produced during thistime depends on the heat capacity of the storage materials and material used in the construction of the still (Maduekwe and Zaki, 1996).

II. Literature Review

Thermal energy storage has received considerable attention in recent years because of the growing interest in the utilization of a number of renewable energy resources, which have supplies that vary with time.

In the several attempts made to improve on the yield of solar stills, the selection of a suitable heat storage material is probably the most important in this respect. Many materials have been studied to determine their suitability or otherwise. Maduekwe and Zaki (1996) carried out an experimental work on the use of Glauber salt solution, a phase change material, and liquid paraffin, a non-phase change material, as possible heat storage media. Bugaje and Ramshaw (1995), carried out a similar work but using tubes and quilts containing paraffin wax as a medium for storing solar thermal energy.

Tayeb (1995) carried out research work on the use of organic-inorganic mixtures for solar energy storage. The mixtures used are composed of Glauber's salt and stearic acid in different proportions. The effect of cooling fluid flow rate and ambient temperature as well as the effect of addition of a nucleating agent was studied. The results showed that the highest amount of energy stored could be obtained from a mixture containing 40% stearic acid and 60% Glauber 's salt.

Chendo and Egariew (1991), carried out a comparative performance study on the effects of pebbles, charcoal and wick on a single sloped shallow basin solar still. The results show that distillation rates of the participating stills between sunrise and sunset increased in the following order: Charcoal, Wick, Control still and pebble. Comparison of the respective still's daily productivity showed that the pebble lined still has the greatest yield with its maximum yield occurring four hours after sunset, due to its better heat storage capability.

III. Experimentation

The used-engine oil, proposed by the author, if used as a sensible heat storage medium in a solar still can lead to increase in its daily distillate yield. A double-sloped basin type solar still with energy storage chamber below the water basin and a second still with no energy storage chamber, serving as the control still, was constructed, oriented in the east-west direction and charged periodically. The experimental work involved charging water in the basins and the energy storage material, used-engine oil, in the storage chambers. The water in the basin was heated by the solar radiation being transmitted through the glass cover. This results in water vapour evaporating and impinging on the glass cover, which was inclined at 12° to the horizontal.

As the atmospheric air blows over the upper part of the glass cover, the water vapour condensed underneath the cover. The distilled water runs down where it was collected in a measuring cylinder.

The excess heat that passed through the heat exchanger to the storage chamber in the daytime wormed up the energy storage material, used-engine oil. This energy storage material gives up the excess heat stored in it at nighttime, and the distillate production continued. The approaches used in carrying out this work are:

i. Review of past work on solar stills was carried out to obtain significant data for the design and construction of the stills.
ii. The design data and working drawings are then produced with its bill of quantities.
iii. Materials were sourced and the stills were constructed with locally available materials.
iv. Performance evaluation of the constructed stills were carried out and the results and conclusions presented.

IV. Results And Discussion

TABLE 4.1 Hourly distillate of the two stills On 12th May 2004.

Reading no.	Local Time	Storage Still (liter/m2/day)	Control Still (Iiter/m2/day)
1	7.0 a.m	0.02	0.00
2	8.0 am	0.02	0.01
3	9.0 am	0.10	0.10
4	10.0 am	0.14	0.19
5	11.0 am	0.18	0.28
6	12.0 noon	0.22	0.30
7	1.0 pm	0.24	0.32
8	2.0 pm	0.26	0.30
9	3.0 pm	0.28	0.28
10	4.0 pm	0.29	0.28
11	5.0 pm	0.27	0.18
12	6.0 pm	0.26	0.10
13	7.0 pm	0.26	0.02
14	8.0 pm	0.25	0.00
15	9.0 pm	0.20	0.00
16	10.0 pm	0.11	0.00
17	11.0 pm	0.04	0.00
18	12.0 pm	0.00	0.00
Total		**3.141**	**2.38**

TABLE 4.3: Daily distillate yield from 6pm to 12am for l2days

Day no.	Date	Storage still yield (liter/m2/day)	Control still yield (liter/m2/day)
1	12-5-04	2.28	2.36
2	13-5-04	2.40	2.36
3	14-5-04	2.22	2.22
4	15-5-04	2.22	2.26
5	16-5-04	2.20	2.30
6	17-5-04	2.30	2.45
7	18-5-04	1.70	1.99
8	19-5-04	2.16	2.29
9	20-5-04	2.20	2.22
10	21-5-04	0.83	0.96
11	22-5-04	1.95	1.99
12	23-5-04	1.10	0.97

TABLE 4.1 Shows that the distillate of the control still was highest between 8am to 2 pm when there is highest insolation. From 2 pm upward, the yield of this still fall below that Of the other. The reason for this higher distillate of the control still before 2 pm was due to the fact that the still with storage was utilizing part of the energy received in trying to reach thermal equilibrium with the content of the storage chamber. From 2pm the yield for the control still started falling below that with storage chamber because, the direct insolation became weaker and the storage materials used in the other still started releasing the heat stored in it to the basin due to high heat content.

TABLE 4.3 Daily distillate yield from 6pm to 12 am for 12days

Day no.	Date	Storage still yield (liter/m2/day)	Control still yield (liter/m2/day)
1	12-5-04	0.86	0.02
2	13-5-04	0.01	0.01
3	14-5-04	1.00	0.02
4	15-5-04	1.09	0.02
5	16-5-04	1.06	0.02
6	17-5-04	1.04	0.01
7	18-5-04	0.98	0.01
8	19-5-04	0.98	0.01
9.	20-5-04	0.98	0.02
10.	21-5-04	0.26	0.01

TABLE 4.2 shows daily production of distillate against the day of occurrence. Except for day 10 and 12 that were cloudy, the two stills had considerable output throughout the day. It is clear, however, from Table 4.1 that during the daytime the control still was producing more distillate than the other still with storage material.

TABLE 4.4: Daily distillate yield for l2days

Day no.	Date	Storage still yield Control still yield (liter/m2/day) (liter/m2/day)	
1	12-5-04	3.14	2.38
2	13-5-04	3.41	2.37
3	14-5-04	3.22	2.24
4	15-5-04	3.31	2.28
5	16-5-04	3.26	2.32
6	17-5-04	3.34	2.46
7	18-5-04	2.68	2.00
8	19-5-04	3.14	2.30
9	20-5-04	3.18	2.24
10	21-5-04	1.09	0.97
11.	22-5-04	2.93	2.00
12.	23-5-04	1.40	0.98

TABLE 4.3 is the result of the daily distillate production in the nighttime for l2days period while there was little or no output from the control still, there was considerable output from the still storage material in the night.

The total cost of constructing the still with used-engine oil in the storage chamber was N 5,073.11. The total cost of constructing the control still was then N4,159.10. The cost of producing a liter of distilled water is obtained by dividing the total cost of the still by the number of liters that can be produce in the life span of the still.

V. Conclusion

The higher daytime yield of the still with used-engine oil in storage system may be attributed to the fact that the oil is reasonably “black” to solar radiation, hence the enhanced absorption of it. The control still has a higher yield in the daytime than the still with storage system. This is due to the fact that during most period of the daytime, the still with energy storage material was utilizing part of the energy received in trying to reach thermal equilibrium with the content of the storage chamber.

The cost of the solar still with or without thermal storage material is guided by the current price of the materials. While the control still production cost of about N4,159.00

A solar still do not deteriorate early and the lifespan can be upwards of 10years if properly kept and maintained. A lifetime of 10years was assumed with a zero salvage value. It was found that for a still using used engine-oil as energy storage material and having an average distillate yield of 3.41litres/m2/day, the cost per liter is 40.76kobo. The rate of production of distillate for the control still was 2.37litre/m2/day and this amounted to a cost per liter of 48.08kobo.

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