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Reflective Array Solar Water Heater for Milk Pasteurization

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The solar water heater is a method of utilizing solar thermal energy by storing heat energy in water which can be used directly. Solar thermal energy has a high utility potential. It has a power of 1 kW/m² on average on the surface of the earth with energy up to 7 kWh/m²/day on average per year. One of the uses of the solar water heater is that it can be implemented in the milk pasteurization system. The research equipment consists of an accumulator vessel with an area of 2x2 m² and a water pipe collector. The water that had been heated in an accumulator (thermos) was used directly as the heating source in the milk pasteurization process. Meanwhile, the most common heating method used in the pasteurization process is electricity and gas energy. The result showed that using 82°C of accumulator water, it took 12 minutes (14.48–15.00) to reach the milk temperature needed in the pasteurization process which is 70°C for 6.75 litres of milk. The efficiency of solar heat energy absorption by an accumulator is 47%. This value can be increased by increasing the volume of water.

Keywords: solar water heater, reflective array method, milk pasteurization

Introduction

The world's fossil energy reserves (oil, gas, and coal) have declined since 2008 (World Oil Reserve, 2009). One of the renewable alternatives is solar energy that is free and everlasting. Solar energy has a power of 1 kW/m² on average on the surface of the earth with energy up to 7 kWh/m²/day on average per year (Budhy and Andrew, 2014). Solar energy is generally converted to electricity, but it also can be stored as heat energy using liquid material and dry material (EBTKE). One of the implementations of solar energy is as a solar water heater.

The implementation is very relevant and effective to use. It is related to Indonesia's geographical position in the tropical coordinate region, which has high solar energy, 1600 kWh/m²/per year (Dang, 2017). In addition, this implementation has a high efficiency of collecting and storing heat energy up to 70% (Brian, 2013).

One of the uses of a solar water heater in the industrial is milk pasteurization system. Milk pasteurization is done to prevent damage to pathogenic bacteria in milk. The milk pasteurization process is mostly done with

thermal method. The thermal method is conventional food processing using heating temperature between 60–100°C (Yinghao, 2011). In general, the heater used to perform the pasteurization process utilizes electrical or gas energy. On the other hand, many developing countries do not yet have an abundant electricity supply and this should be a concern (Tuszyński, 1983). The research is expected to be able to reduce the use of electrical and gas energy needed in the milk pasteurization process and for the welfare of an area that still lacks an electricity supply (Atia, 2010).

The equipment used in the research is a heat accumulator that has a 3.8 m² width vessel and a 3.8 m² flat plate collector inside, and also a 3.8 m² reflective array. The heat energy of the accumulator will be absorbed by water inside the flat plate collector. The heated water will be used directly as a milk heating medium in the pasteurization process.

Modelling of the System

Solar water heater method

Research on the conversion of solar energy shows that changes to heat energy have the highest efficiency of 80% (EBTKE; Quijera, 2011). In the study of the implementation of solar thermal energy, the method introduced heat storage in liquid material temperature using salt, oil reaching 300°C, and water reaching 60°C (EBTKE). Heat storage using dry material reaches a temperature of 120°C (Brian, 2013).

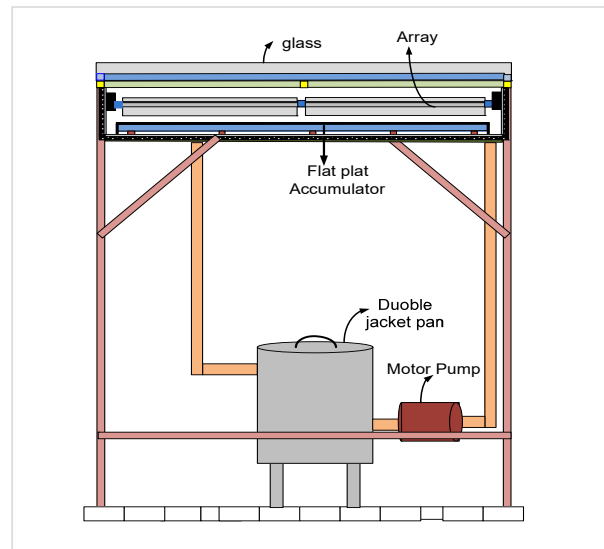
Air heat accumulator utilizes the greenhouse effect method (EBTKE). In the greenhouse method, water and ground are used as heat-absorbing materials. Meanwhile in this study, the solar heater used water media as an absorber and storage of heat energy trapped in the greenhouse (Brian, Charles, Ferenz George, and Kilkis, 2013).

In Fig. 1, to maintain absorbed energy, the accumulator is utilized by a reflective array controller (reflective array method). The way method works as follows: if the heat power in the accumulator is smaller than solar power, the array will open, and the array will close if the solar power is smaller than heat power in the accumulator.

The materials of the array are stainless steel with a 78% reflectivity efficiency, and the controller array is driven by a low energy DC motor, 12 watts. Arrays and motors were placed below the vacuum glass. The vacuum glass is made of tempered glass (capable of up to 300°C).

The system of utilizing heat energy can be carried out directly by storing it in water media. Water was stored in a spiral pipe placed in the vessel with an area of 3.8 m². With this ability, water was flowed and used to heat milk in the pasteurization process. Heating milk in this process required the water to be 82°C. Water that had been heated in the accumulator was poured into a double jacket pan by an electric motor pump.

Fig. 1. Array reflective solar water heater method



Data collection method of solar water heater energy capacity

The purpose of the data collecting is to find the energy capacity and parameters involved. This research is very important in the optimization and calculation of solar energy storage.

Equations (1) – (5) are expressed in the application programme that is connected directly to the sensor via DAQ DT-9813 interface to obtain data and graphs for analysis. This research is also to obtain the absorption efficiency of the accumulator. The empirical measurement method is applied as seen in Fig. 2.

The absorption efficiency of the accumulator can be calculated by Equation (1):

$$\eta_p = \frac{E_{acc}}{E_s} \times 100\% \quad (1)$$

Where,

$$E_{acc} = m_w C_w \Delta T_w \quad (2)$$

$$\Delta T_w = T_{w_1} - T_{w_0} \quad (3)$$

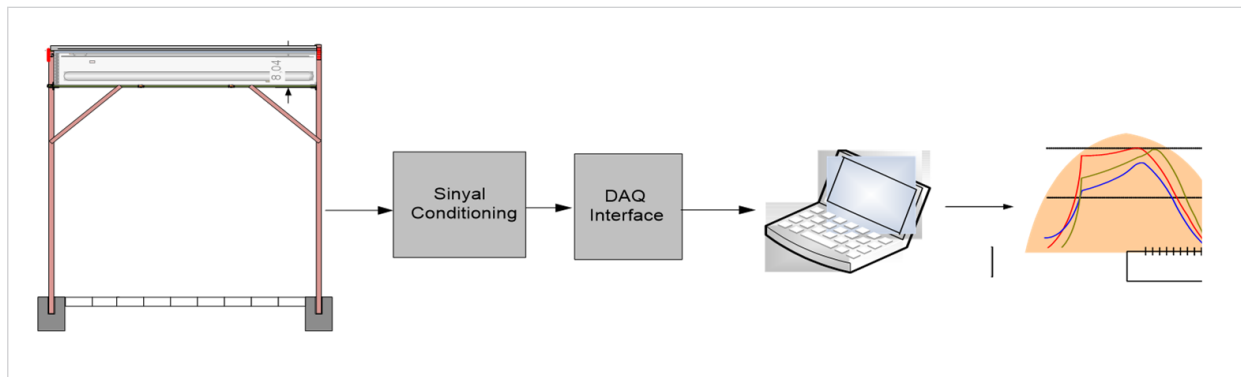
And

$$E_s = \int_{t_0}^{t_1} P_s dt \quad (4)$$

$$P_s = I_s / 121 \text{ lux} \quad (5)$$

Where: η_p = stored energy efficiency [%]; E_{acc} = accumulator energy [kWh]; m_w = water mass [L]; C_w = specific heat capacity of water [kJ/°K]; T_w = water temperature [°C]; E_s = solar energy [kWh]; P_s = solar power [W]; I_s = solar intensity [Lux].

Fig. 2. Measuring data method



Results and Discussion

The analysis is carried out to determine the ability of the accumulator and heat supply in the milk pasteurization process. This capability is shown by several sensors converted by Arduino. Furthermore, the output of the sensor is fed to the data retrieval instrument DAQ (data acquisition) DT9813.

The research was conducted at Malang State Polytechnic, Malang, East Java, precisely at the coordinates of 7° 56'44.57" south latitude and 112° 36'53.20" east longitude, located at an altitude of 499 m above sea level, on 22 October 2018 with a state of sunlight shown in Fig. 3.

The light intensity at that time was relatively low with a maximum intensity of 90,000 Lux, which was reached at 11.45–12.00 local time. From 08.00–11.00 local time,

there was no significant increase. Then there was a decrease and fluctuation until 15.00 local time. And until 15.00–16.00 local time, the intensity decreased to 10,000 lux. Furthermore, the relative intensity fluctuated and decreased. Light intensity monitoring was carried out by the light intensity sensor module GY-30 BH1750.

Reflective solar water heater capability in the milk pasteurization process

It can be seen from Fig. 4 that using 82°C takes 12 minutes (14.48–15.00) to reach the milk temperature needed in the pasteurization process, which is 70°C and for 6.75 litres of milk. This shows that a reflective solar water heater can be used for the pasteurization process. The

Fig. 3. Solar intensity on 22 October 2018

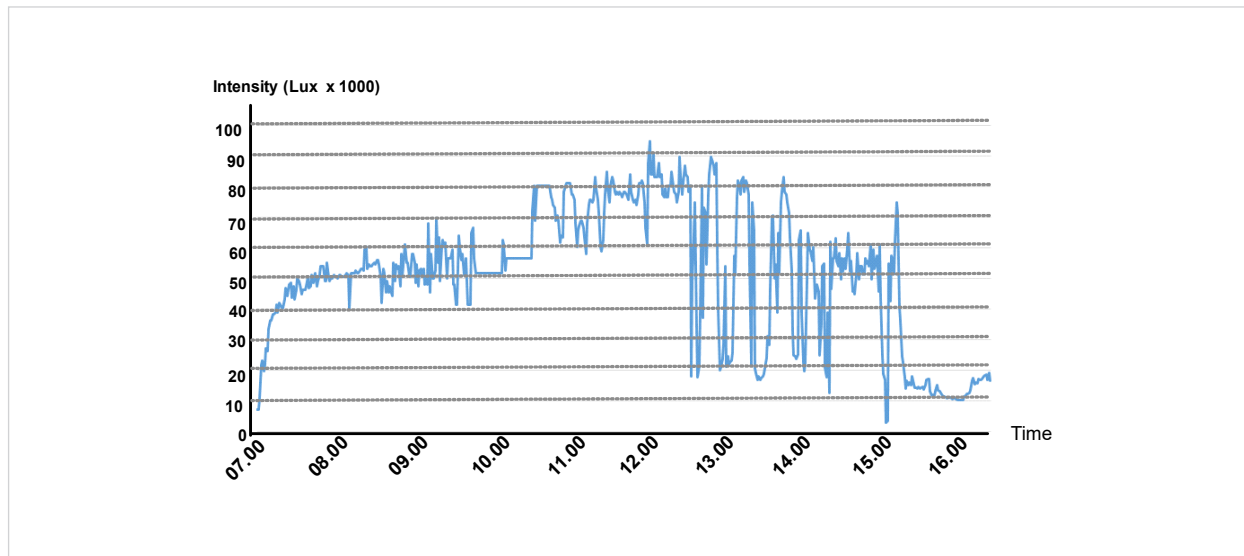
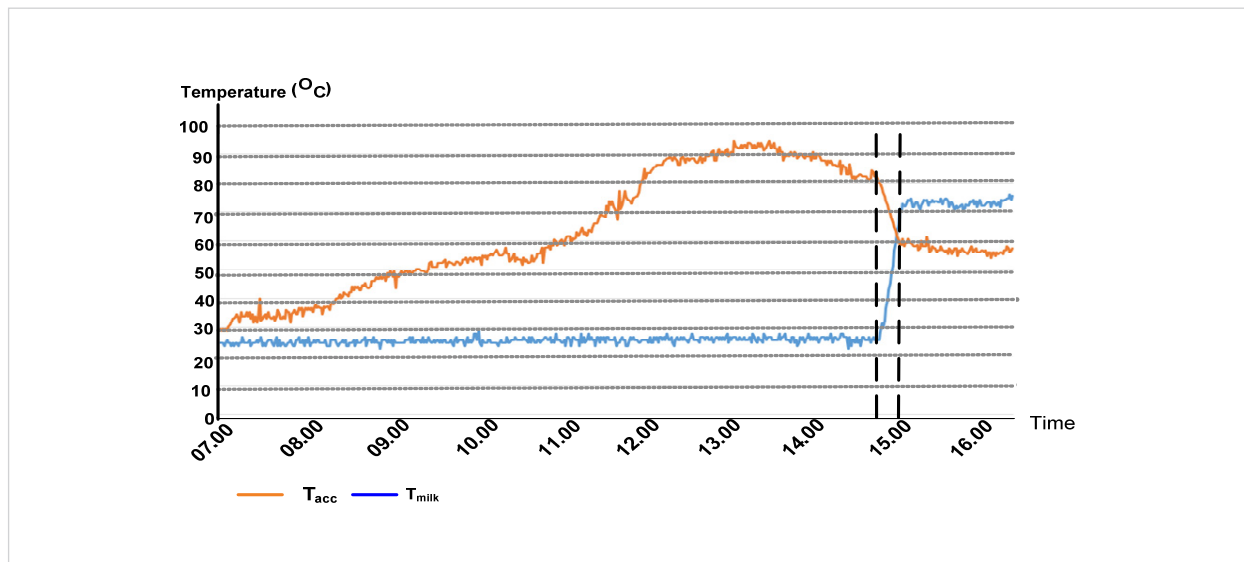


Fig. 4. Reflective ability of a solar water heater to increase the temperature of milk



attainment of the temperature can be increased by increasing the water discharge from the accumulator to the pan used in the pasteurization process.

And from Fig. 5 it is known that to increase the milk temperature, the accumulator's heat energy decreases by 1.9 kWh. This value can be calculated by Equations (2) and (3). The decreasing energy is large, which is 43% of the

energy absorbed in the accumulator. This decrease can be reduced by increasing the volume of water in the accumulator so that the energy that can be absorbed by the accumulator is greater.

From the data above, the calculation of the frequency of peak solar energy used to heat 6.75 litres of milk using the accumulator reflective array software [14] is shown in Fig. 6.

Fig. 5. Heat energy required by milk in the accumulator

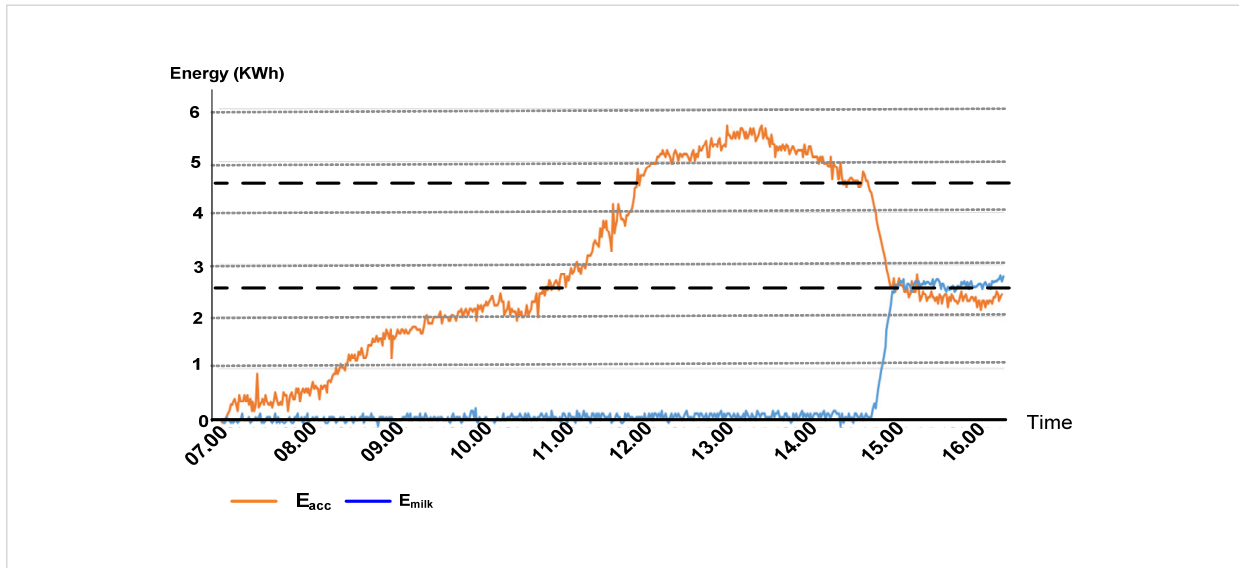
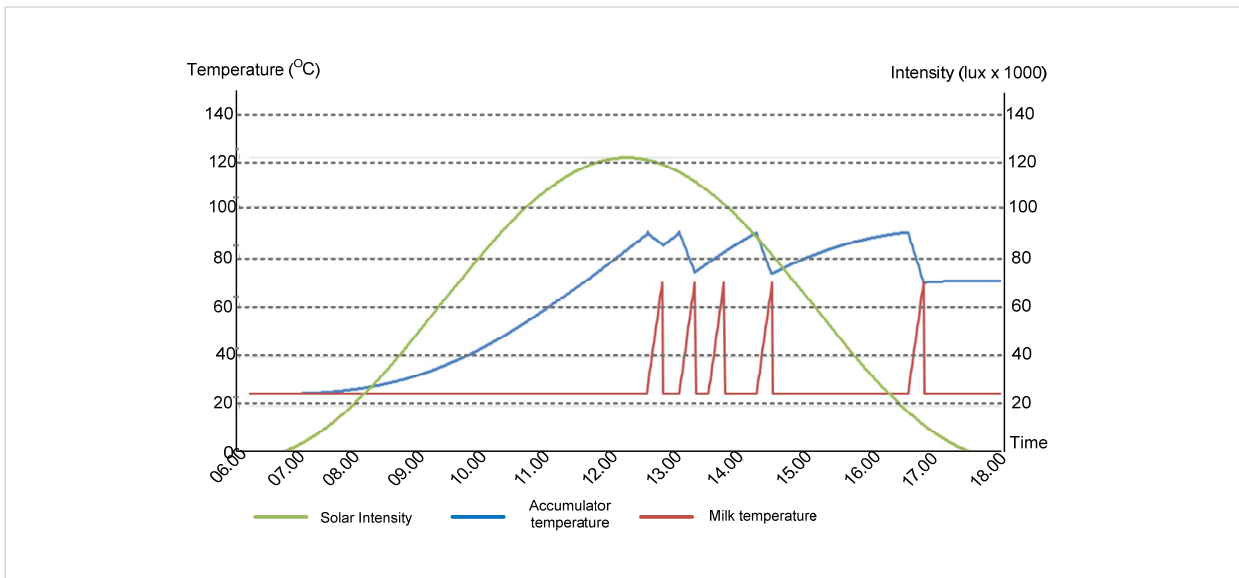


Fig. 6. The frequency of milk pasteurization in a day

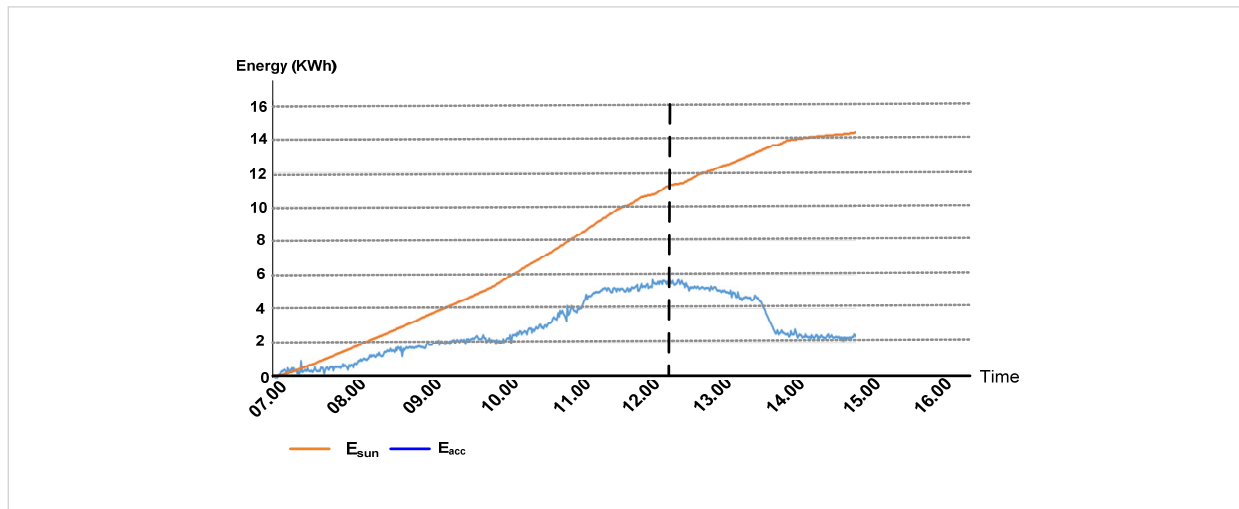


With the ideal intensity, it was found that the accumulator was able to be used in the milk pasteurization process of 6.75 litres of milk as many as 5 times a day. The energy requirements of 6.75 litres of water are 1.9 kWh and the accumulator will be used when the temperature is 82°C.

Absorption of solar thermal energy by accumulators

Fig. 7 explains that the accumulator’s absorption of solar thermal energy is 47%. This value can be calculated by Equation (1). This value can be increased by

Fig. 7. The accumulator capability to absorb solar heat energy by accumulator



increasing the volume of water. With greater absorption, it is expected to decrease the accumulator energy when used for smaller pasteurization processes.

temperature needed in the pasteurization process, which is 70°C for 6.75 litres of milk. Meanwhile, the efficiency of solar heat energy absorption by an accumulator is 47%.

Conclusions

The proposed reflective solar water heater was presented. The result showed that using 82°C of accumulator water, it took 12 minutes (14.48–15.00) to reach the milk

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