Thermal Analysis of Discrete Water supply in Domestic Hot Water Storage Tank

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Abstract

Energy and water are very important commodities to human life. The world is suffering from a critical shortage in water and energy; the researchers must work hard to find sources of potable water and renewable energy. Energy and water saving techniques has a great importance especially in this transmission period. In this paper analyses were done for discrete water supply in hot water storage tanks, aiming to reduce energy and water losses. The analyses were based on an experimental study for the temperature distribution in the hot water storage tank for different flow rates and off periods, 3, 6, and 9 lpm, and 5, 10, and 15 minutes were considered for flow rates and off periods respectively. It has been found that increasing the hot water consumption rate reduces the total delivered hot water to the consumer. The analyses indicated increase in the usable hot water for small and medium off periods. This increase results in water and energy saving for the consumer. Also optimum off periods for the different flow rates were obtained after which the total usable hot water starts decreasing as expected.

This optimum off period is valuable to save water and energy, and can be integrated with the solar radiation in winter and summer to determine the new optimum off periods for the different locations and time.

Keywords: *discrete Water Supply, Domestic Storage Tank, Hot Water Management, Energy Saving, Usable energy.*

1. Introduction

As overall the world is suffering from a critical shortage in water and energy resources. The water and energy costs have reached new levels and are expected to continue to rise. The ramifications of this large increase in water and energy costs, will pose serious challenges to the economies of most developing nations, and this may results in an undesired serious conflicts between nations. It’s the role of researchers to minimize the energy and water consumption and seek new resources. In the way to minimize heat losses and reduce hot water consumption, different researchers over the past years investigated hot water systems, use patterns, and consumption loads [1,3,5,6,8]. SA.

Ahmed et al.[2], in their study to understand the reasons of wasting water by contamination, examined different methods of collection and storage, and found that mostly safe water is contaminated during storage periods. Other researches studied insulation to reduce heat losses in the Hot Water Storage Tank (HWST) [4,9], special heat exchangers were considered by Industrial Technology to recover the energy wasted during usage, on the same direction the role of women and modern water supply systems were discussed [7].

N. Beithou in 2006[10], analyzed the mixing nature of the cold and hot water inside the storage tank, he observed that high turbulent mixing occurs especially at high flow rates which resulted in a lower amount of the available hot water for customs use. The supply features of cold water and methods to minimize turbulences in the HWST were discussed in [11], approximately 17% saving in usable hot water was achieved by using a round curved cover on the bottom supply line.

Conservation of resources can be defined as more efficient use of these resources. In this study the thermal analyses of the discrete water usage from a HWST were investigated. 3, 6, and 9 lpm, and 5, 10, and 15 minutes were considered for flow rates and off periods respectively. The analyses were dependent on the temperature distributions all over the HWST and the amount of usable hot water out of the HWST.

2. Experimental Test Rig

In order to investigate and analyze the nature of hot water temperature variations within the HWST, data on the variation of the hot water temperatures should be collected under the different variable conditions. To achieve these data, an experimental rig has been constructed as shown in Figure 1. This rig consists of hot water reservoir, cold water reservoir, water pump, flow meter, hot water storage tank, and Data Acquisition System (DAS) (Lab-View software). The DAS automatically collect the temperatures from the storage tank at different times and positions then stores them in a separate excel file.

The dimensions and the important parameters of the HWST are listed in Table 1. This tank has a total capacity of 108 liters and is provided with 15 thermocouples mounted at the middle of the HWST to record the temperatures throughout the tank. Different supply flow rates and off use periods were considered to understand the effect of discrete water supply on the usable hot water inside the HWST.

2.1 Experimental Procedure

In the experiments performed, hot water is filled into the HWST from the hot water reservoir, circulated until having a uniform temperature of 62 ^{o}C inside the tank; then the cold water is pumped from the cold water reservoir at a specific flow rate into the HWST through the supply line, different flow rates were investigated with different off use periods, the temperature-changes resulting from the mixing process are then recorded for analyses purposes.

3. Experiments Performed

In this study, experiments were performed for different flow rates (3, 6, and 9 Lpm) and for different off use periods (5, 10, and 15 min) simulating the domestic hot water consumption.

3.1. Continuous versus discrete flow:

A single case was considered to compare the continueous and discrete flow rates. Figure 2 shows the temperature distributions of the 15 thermocouples inside the HWST for 3.5 liters per second for the case of continuous flow [11].

The figure shows smooth temperature distributions as the flow rate is relatively small. This can be compared to the case of discrete supply shown in figure 3. for flow rate 3 L/min with 10 minutes waiting period. The heat transfer between the layers is clear especially at the beginning of the water supply where the temperature differences are large, as the time passes heat transfer between layers is reduced as the temperatures differences comes to be closer. This heat transfer affect the total amount of usable hot water user can achieve.

3.2. Flow rate variation:

Increasing the flow rate in the continuous supply feature reduces the amount of usable hot water [10]. In this study different flow rates were considered as well to analyze the effect of flow rate on the total usable energy from the HWST. For a moderate waiting period of 10 minutes Figure 3. shows the temperature distributions inside the HWST for 3 L/min. and Figure 4. shows the temperature distributions inside the HWST at 6 L/min.

The variation in temperature distributions shows longer periods of heat transfer at the lower flow rates but between close temperature differences. Figure 5. shows the effect of flow rate variation on the total usable energy for waiting periods 10 minutes. It is clear that increasing the flow rate reduces the amount of usable hot water delivered to the consumer.

3.3. Discrete Use Effect:

To understand the effect of off use periods on the total usable energy received from the HWST, different waiting periods starting from 5 to 15 minutes were considered. Figure 6. shows the temperature distribution for a flow rate of 9 L/min, and 5 minutes off use period. The fluctuation in the figure is due to high flow rate used. The heat transfer occurs between closer temperatures. The effect of the off use periods on the usable hot water is shown in figure 7.

Figure 7. indicates an increase in the usable hot water for small and medium off use periods because heat transfer between the hot and cold water layers. This increase results in water and energy saving for the consumer. The curves in figure 7. state that for each flow rate there is an optimum off period which produce a maximum usable hot water. The amount of usable hot water is decreased after while for the different flow rates as expected.

This optimum off use periods is valuable to save water and energy, and can be integrated with the solar radiation in solar heating systems in winter and summer to determine the new optimum off use periods for the different locations and times in the world. Such information can be very helpful for consumers for maximizing the usable hot water in the HWST.

4. Conclusions

To help saving water and energy resources in the world an experimental study of the usable water in the domestic hot water storage tank for the case of discrete water supply was performed. Different experiments with different flow rates and different off use periods have been done. The temperature distributions for the different cases were analyzed. It has been found that for discrete flow, increasing the flow rates decreases the amount of usable hot water exactly as been found for continuous flow cases in the previous studies. The distinguished result of this study was the increase in the usable hot water achieved at small and medium off use periods. Also the optimum off use periods for different flow rates after which the usable hot water is decrease as expected.

It is recommended to integrate the results of this study with the solar radiations absorbed by the solar heating hot water tanks, this integration will result in determining the optimum or permissible off use periods in summer or winter seasons at different latitudes and solar time.

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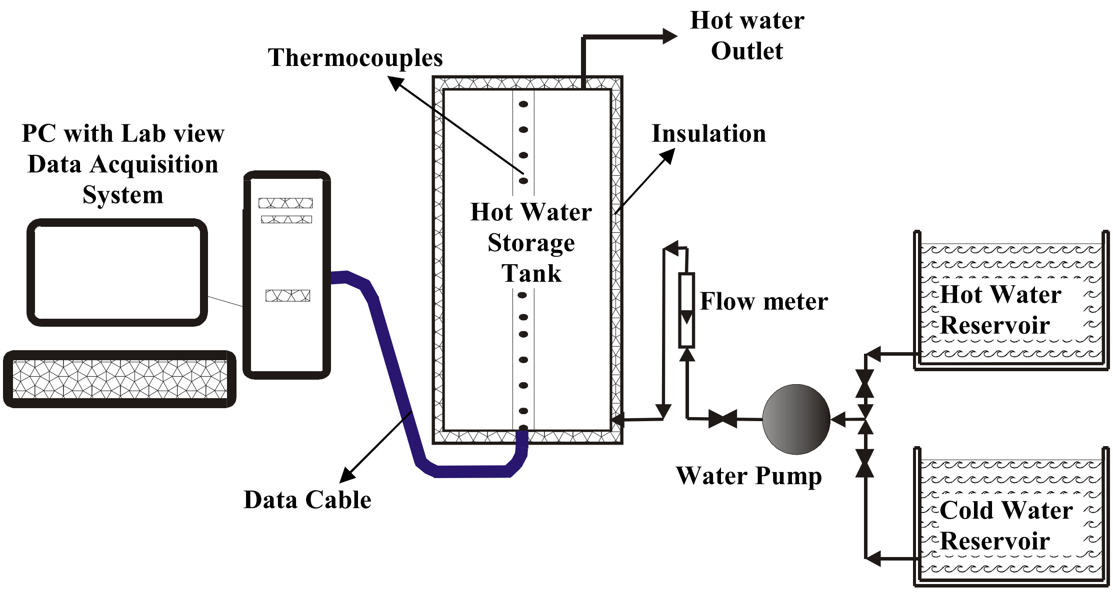

Figure 1. Schematic Diagram for the Experimental Rig.

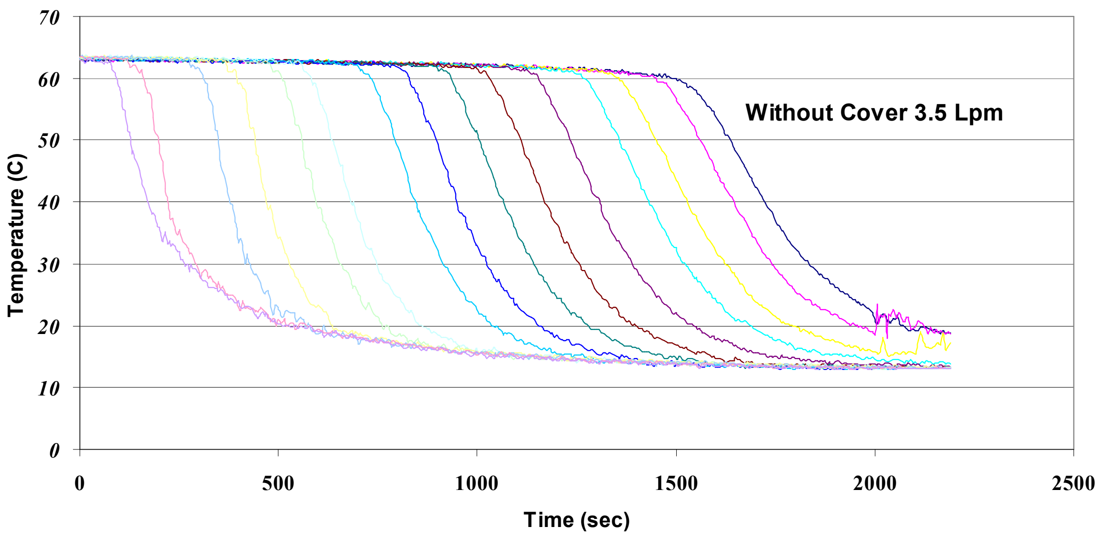

Figure 2. Temperature distributions of the 15 thermocouples versus time. [Side supply without cover, flow rate = 3.5 L/min].

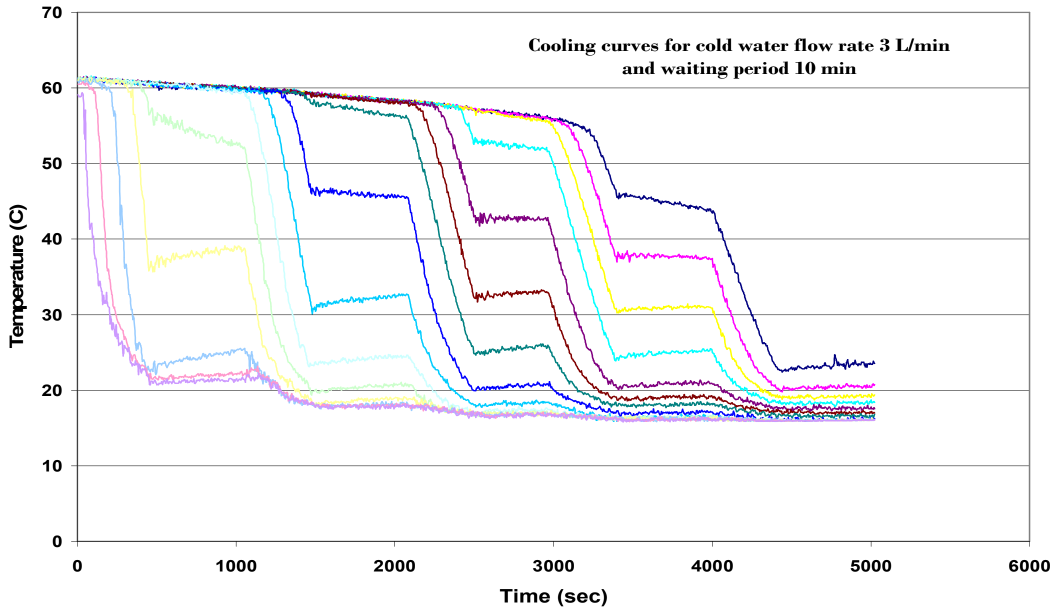

Figure 3. Temperature distributions of the 15 thermocouples versus time.[3 L/min, with 10 minutes waiting period].

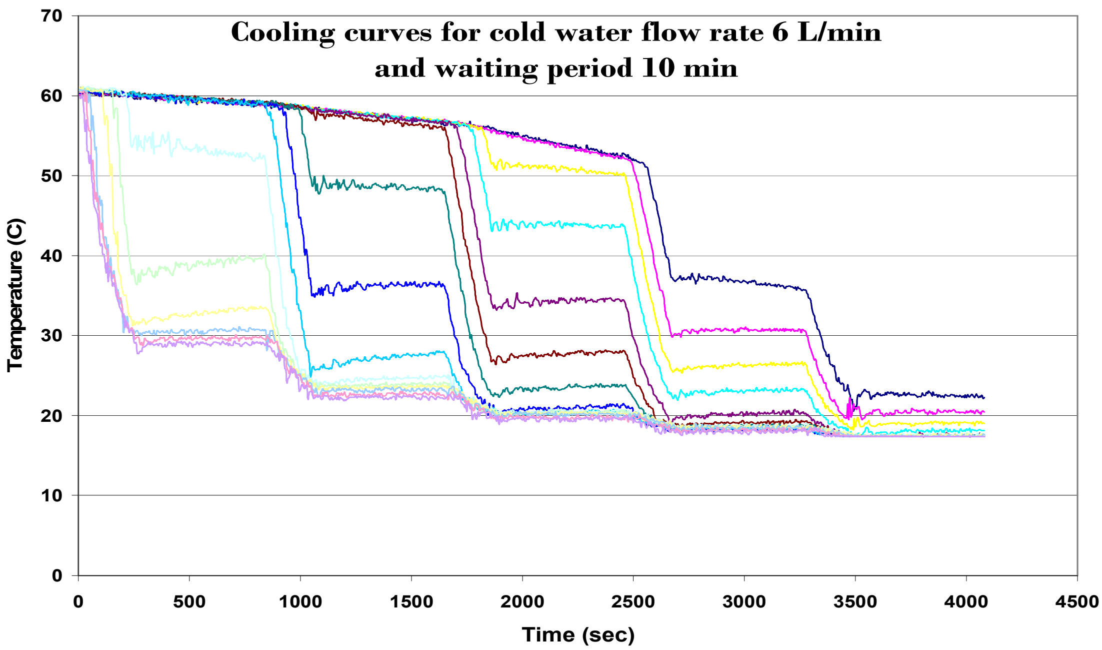

Figure 4. Temperature distributions of the 15 thermocouples versus time.[6 L/min, with 10 minutes waiting period].

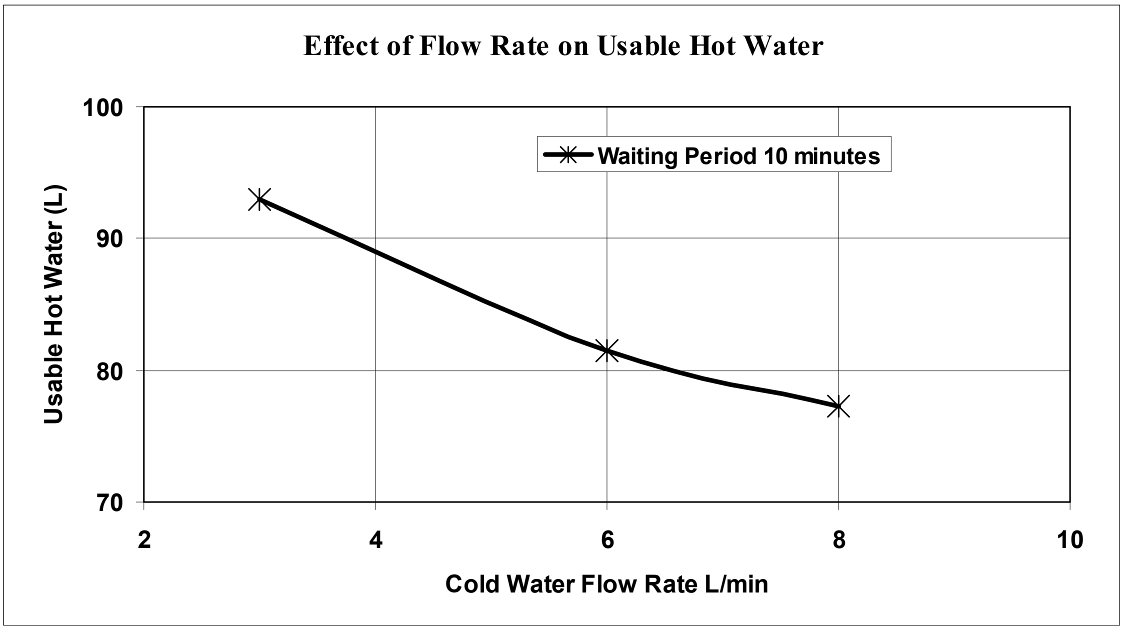

Figure 5. The variation of usable hot water delivered versus flow rate.

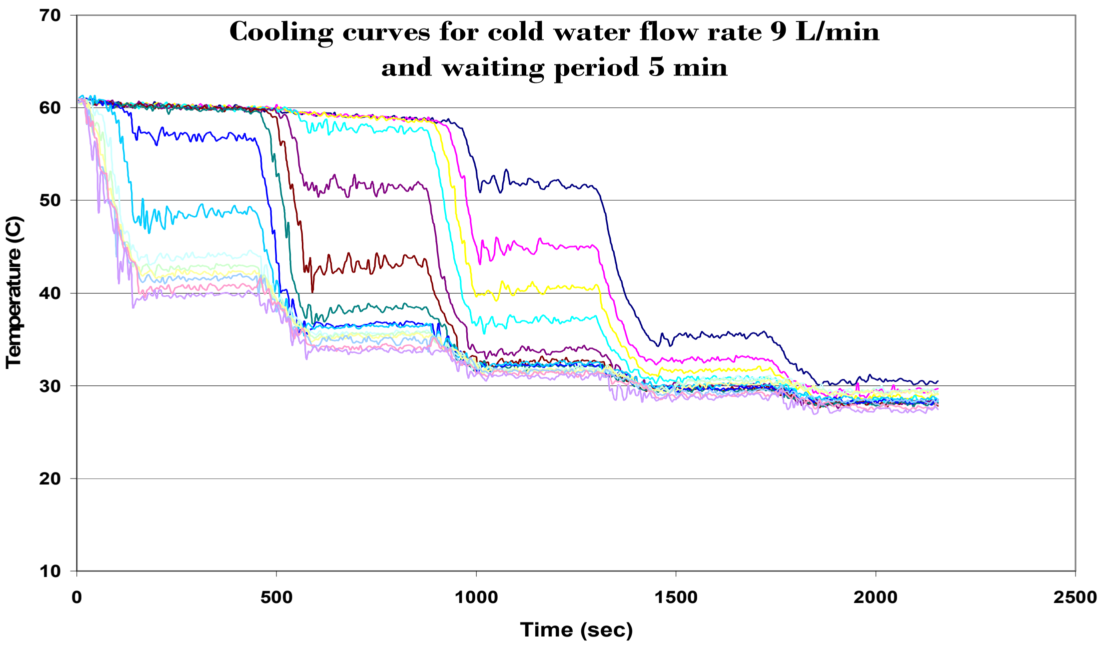

Figure 6. Temperature distributions of the 15 thermocouples versus time.[9 L/min, with 5 minutes waiting period].

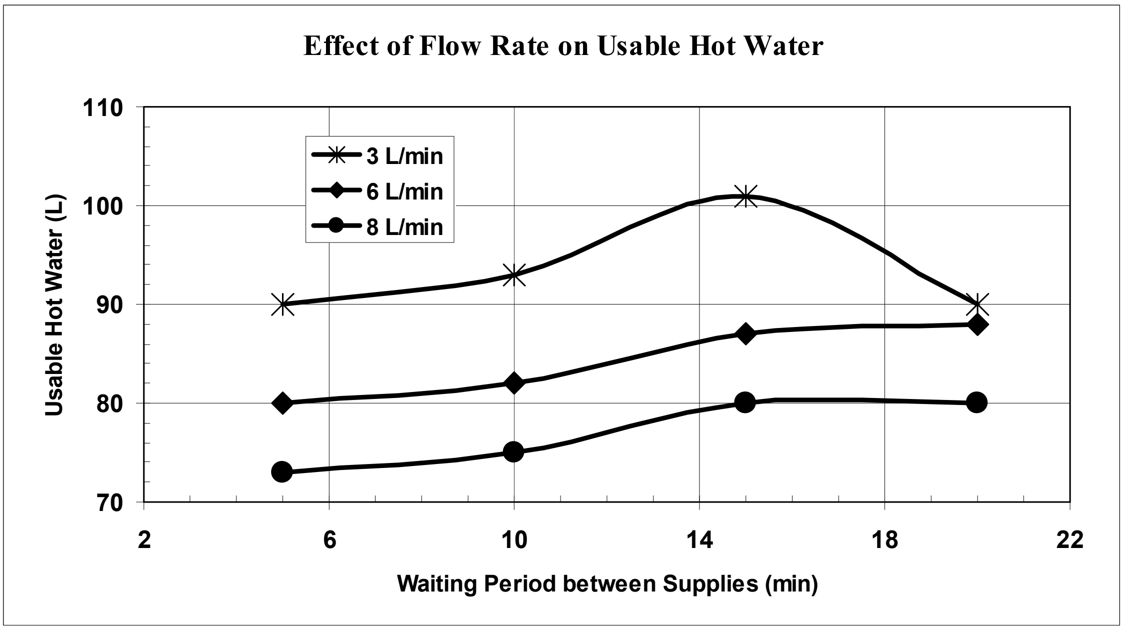

Figure 7. Total Usable Hot water Versus Waiting Periods.

List of Tables

Hot Water Storage Tank	
Height	***0.78 m***
Internal diameter	***0.42 m***
Number of thermocouples	***15***
Distance between thermocouples	***0.05 m***
Insulation thickness	***0.04 m***
Tank total capacity	***0.108 m^3***
Flow rate range	***3-9 lpm***
Waiting Periods	***5, 10, 15 min***
Time step used	***5 seconds***
Piping Diameter	***0.5 in***

Table 1. Dimensions and data for the hot water storage tank Experiments.