EXPERIMENTAL STUDY OF A DOMESTIC HOT WATER STORAGE TANK THERMAL BEHAVIOUR

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Abstract

Much work has been carried out on hot water storage during the last 20-30 years, particularly on solar heat applications. Theoretical and experimental studies on the internal heat transfer have been made at laboratory scale and at larger scales. Current study, which was conducted in order to understand the stratification phenomena, involved an experimental study on the thermal behaviour in a hot water tank during charging and discharging for domestic hot water storage. Results showed no effect of stratification due to the injection fluid from the bottom of the tank and the effect of mixed convection induced by the temperature difference which created a mixture inside the tank, where the temperature was uniform across the height, and the apparition of stratification due to the fact of discharge from the bottom of the tank.

Keywords: Storage, stratification, temperature, charge, discharge, thermal behaviour

1. Introduction

Many scientists have recognized that the thermal stratification is required to obtain better performance in heat storage in solar applications. Stratification in a thermal storage tank is determined mainly by the volume of the tank, the size, location and design of fluid inlet and outlet. There are four primary factors of destratification, contributing to the loss and / or degradation of the stored energy:

(a) Heat losses with atmosphere;

(b) Heat conduction from the warm to cold layer;

(c) Vertical conduction walls of the tank with which the heat loss induced currents convectors (mixture);

(d) Mixture presented during cycles charge and discharge which is usually the main cause of destratification.

The improved performance of thermodynamic systems involves the greatest degree of stratification, which is studied by temperature field measurements and hot water storage flow rate. Knowing the movement of a fluid such as water and heat transfer in an enclosure operated by an outside system or by natural flow has been the subject of several studies both numerical and experimental.

Studies have been done on phenomena that affect the degree of thermal stratification (R. Hermansson, 1993), and the thermal behaviour of water solar heater at low flow rate. The experimental results obtained revealed the thermo-hydraulic phenomena for various phases of operation of the tank (injection of fluid at several levels, drawing, and auxiliary energy heating), (L. Kenjo, 2003).

Bouhdjar (2005) numerically studied the phenomenon in a stratified thermal storage tank to determine the thermal performance and set the most efficient compared to the efficiency of thermal storage.

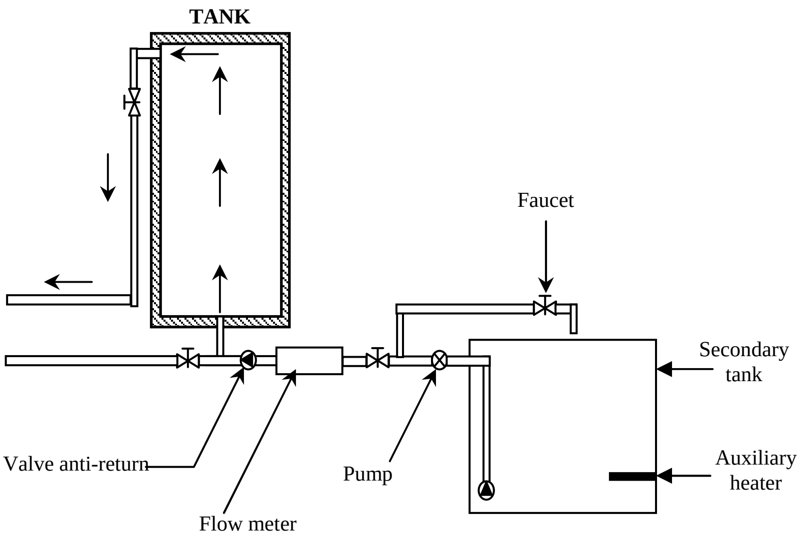
Regarding the influence of inlet temperature studied through the influence of the number of Richardson, storage performance was obtained with high temperatures in the top and minimum temperatures in the bottom of tank (K. Johannes et al., 2004).

A study by Ouzzane et al. (1990), permit to understand the phenomenon of heat flow through the distribution of temperature in the sensor and the absence of stratification phenomenon. Dayan (1997) also optimized the solar home. His study showed the influence of number of nodes used to simulate the tank on the cover solar.

This study is dedicated to assess the thermal behaviour of a heat water storage tank.

2. System description

The system included all the elements provided in Fig.1. We measured the water temperature in different parts of the tank Fig.2. These temperatures were measured using 15 thermocouples (K type) connected to the recorder FLUKE HYDRA SERIES II with 20 channels. The water circulating flow rate through the system is measured by a flow meter.



(a) : Achieved system

(b) : Descriptive diagram of system

Fig.1 : System

The system consists of:

• A storage tank with a 150 liters capacity, with a coefficient of loss UA=2.75W/K, with injection of primary fluid from the bottom of the tank.

• A pump 550 Wmax.

• A tank (60 * 60 * 45cm^3) 160l.

• A flow meter.

• **Two resistors 5KW Maximum.**

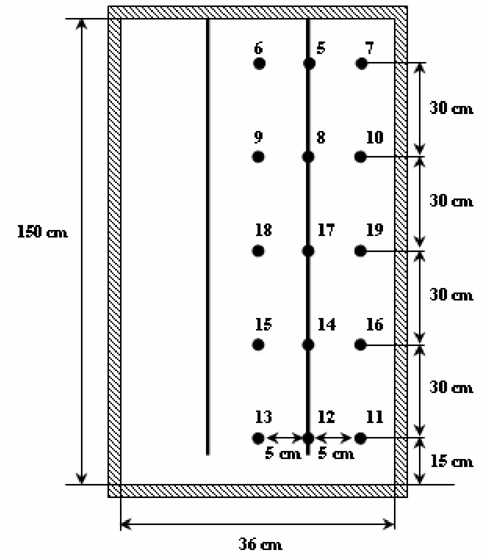


Fig.2 : Diagram representing the distribution of the thermocouples within the tank

To understand the thermal behaviour of the tank, we conducted three experiments (representative of the operation of hot water tanks) on a traditional tank corresponding to the two following scenarios:

• Charge of tank with an auxiliary heating (Resistance)

• Charge + discharge of tank by drawing ECS.

3. Experimental results:

TEST 1: Tank charge with auxiliary heating.

With an entry temperature of 50 ± 3 ° C and a flow rate of 2.6 ± 0.1 L/min, we got the temperature profiles represented here after in Fig.3:

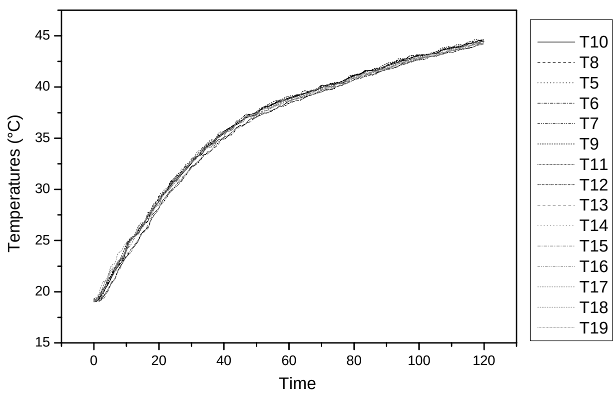
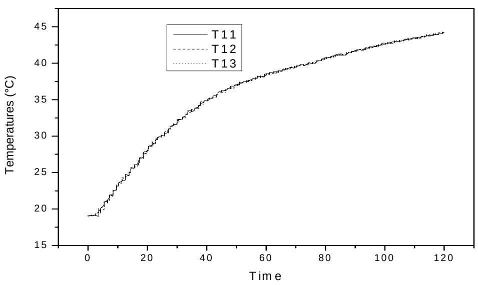
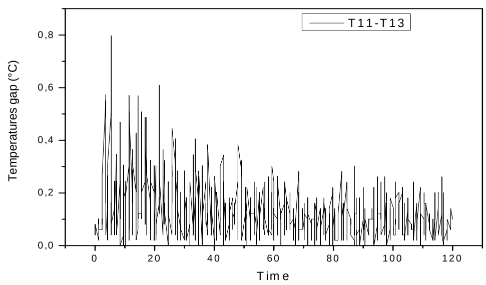


Fig.3 : Evolution of temperatures in the tank for different positions at the load

Layer 1





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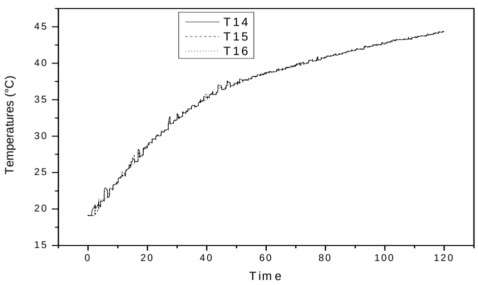

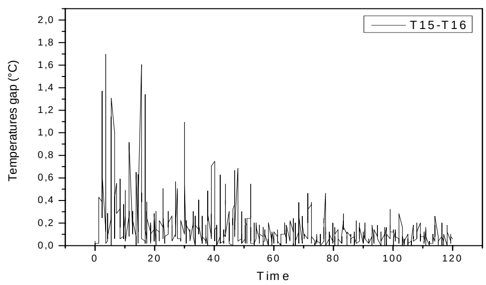

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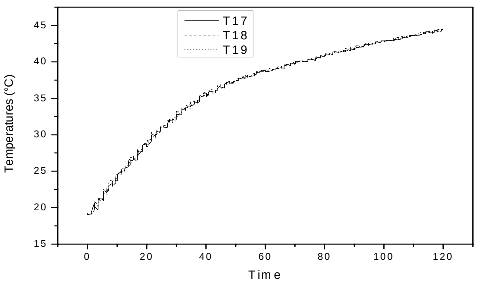

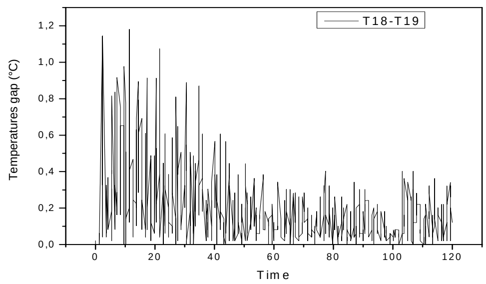

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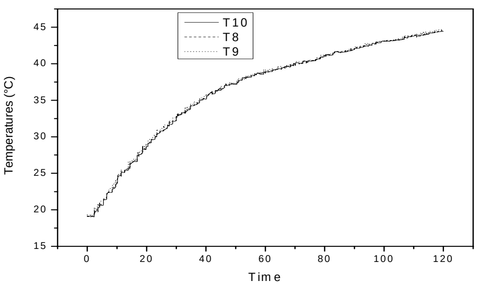

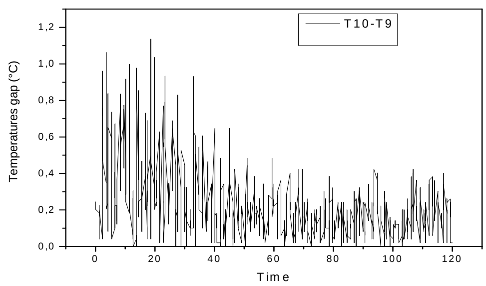

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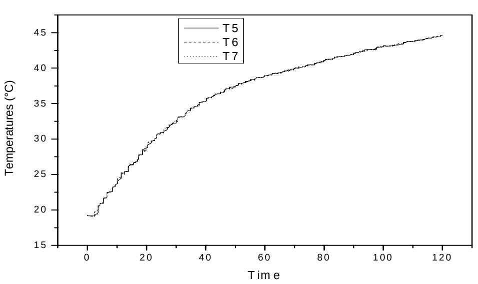


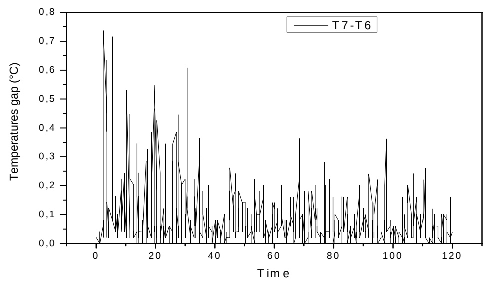
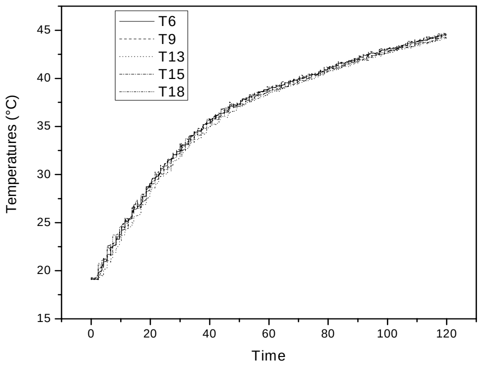
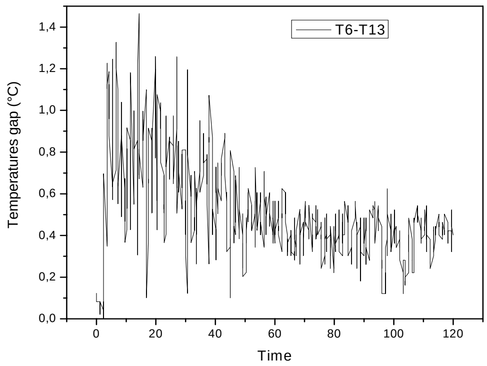


Fig.4 : Radial evolution of temperatures in the tank for different layers

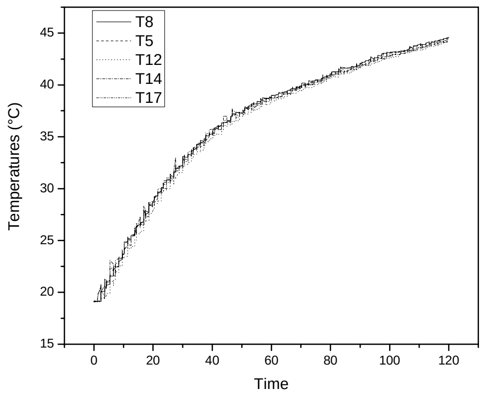
Fig.5 : Radial temperatures gap

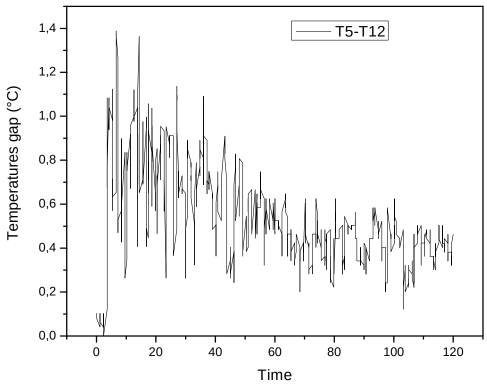
On the axis





To 5 cm from the axis





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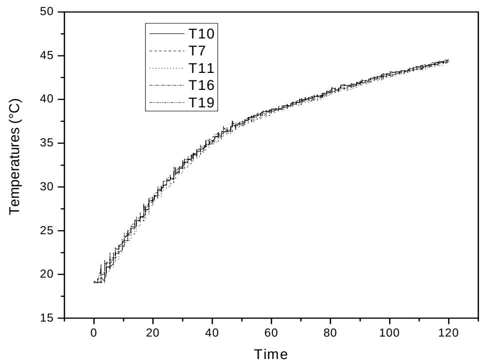

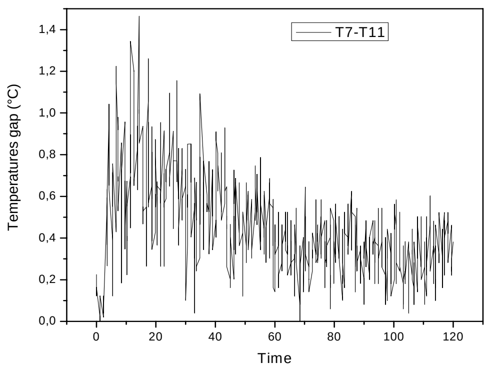

Fig.6 : Axial evolution of temperatures in the tank for different layers

Fig.7 : Axial temperatures gap

The first scenario involved injecting the fluid at the bottom of the tank. At the end of the manipulation, the temperature in the tank was nearly uniform (45 ° C) (Fig.3). We also noted that in Fig.4 and Fig.5, the radial gap was not observed except for layers 2-3 and 4 in the order of 1.7 ° C, which was due to flow inlet fluid. Regarding the axial gap (Fig.6 and Fig.7), it was about 1.5 ° C maximum whatever the distance from the axis. However, we noted the absence of stratification in the enclosure.

TEST 2: Charge + discharge
Inlet temperature of 40 ± 3 ° C
Drawing of 2 times 2.8 l/min for 20 minutes
• The first after 145Minutes
• Then a second, after a rest of 10 minutes.
The flow rate was 2.8 ± 0.1 l / min

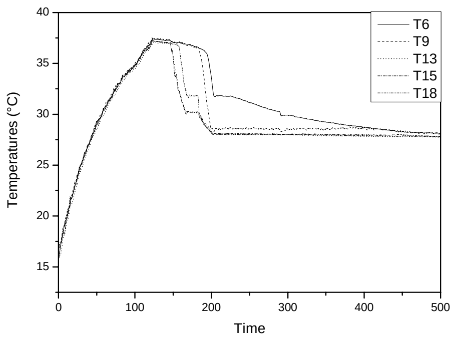

Fig.8 : Profiles of temperatures during the load and discharges

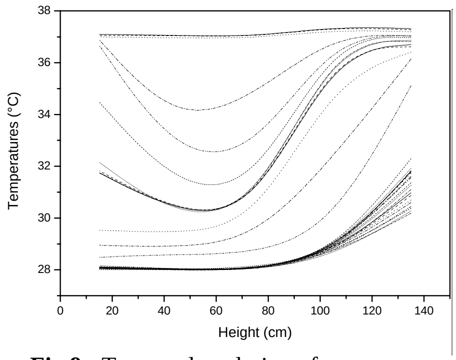

Fig.9 : Temporal evolution of temperatures in the tank at the two discharges of ECS

In the latter case, we found that the temperature of the upper tank decreased 7 ° C, while lower temperatures decreased from 37 ° C to about 28 ° C in the two drawing.

4. Conclusion

The storage tanks were most commonly used in hot water storage are cylindrical form. To highlight the thermal behaviour of the system, when it is subjected to various stresses well controlled, several tests were made on the distribution of temperatures. This distribution, however, was strongly affected by the velocity field in storage that consisted of forced convection induced by the inlet and natural convection due to the heat transport between water and the walls.

We observed the dynamics regime of temperature for heating by auxiliary heater and during a drawing which showed the effect piston induced by tank filling.

The injection of fluid from the bottom of the tank and the effect of mixed convection induced by the temperature difference created a mixture inside the tank, hence the uniformity of temperature on the height. The phenomenon of stratification was never observed.

Looking ahead, it will be necessary to take account of all these phenomena in the modeling of hot water storage tank.

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