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New type of valve for solar thermal storage tank stratification

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Abstract

This paper describes the working principle and characteristics of a new type of valve with a unique self-actuating principle that actuates based on observed temperature difference, which is intended for use on solar thermal storage tank inlets, where it compares the temperature of the flow coming into the valve with the temperature inside the storage tank, and switches the flow based on the observed temperature difference, in order to achieve maximum thermal stratification inside the storage tank. The novel working principle, based on mass-transfer inside the actuator driven by vapour pressure differences, is explained in detail, and results of tests with the valve are presented, which show that the valve switches very effectively, and is a very useful tool for storage tank stratification.

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Keywords: stratification; thermo-differential valve; solar thermal; storage tank; solar combi-system

1. Introduction

Good stratification in thermal storage tanks for solar thermal systems can contribute significantly to the efficiency of solar thermal systems [1]. To achieve a high degree of stratification in a thermal storage tank when adding heat from a solar thermal heat source, which typically has a highly variable output temperature the heat should be added to the thermal storage tank at different positions, for which different approaches have been developed in the past [2] [3].

This abstract presents a new type of self-actuating valve, named the Thermo-Differential Valve (TDV), that can be used to achieve stratification through a different approach, one that doesn't rely on electronics, and that doesn't rely on thermo-siphon flow effects, allowing it to be used reliably and effectively, over a large flow range and independent of the temperature gradient inside the thermal storage tank.

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2. Valve working principle & design

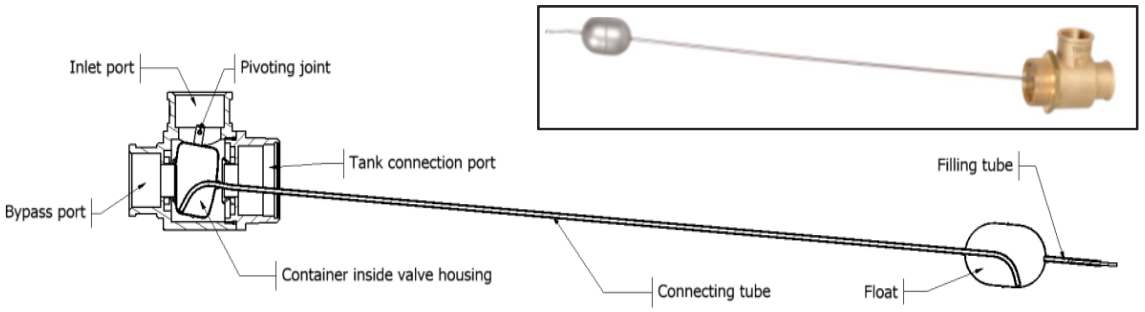

Fig.1. Cross-section drawing of the Thermo-Differential Valve, and an inset picture of the Thermo-Differential Valve

Figure 1 shows a cross-section drawing of the valve used in this work, with an inset picture of the actual valve. The valve is a 3-way switching valve, with an inlet port, a tank connection port and a bypass port. The flow is switched by an actuator, consisting of a container inside the valve housing, a connecting tube, and a float that sticks into the thermal storage tank. The actuator is evacuated of air and partially filled with a working liquid before being sealed, so that inside the actuator the working liquid is in thermal equilibrium with its vapour. When the temperature of the container inside the valve is higher than the temperature of the float that sits inside the thermal storage tank, the vapour pressure in the container is higher, and all the liquid is pushed through the connecting tube into the float, which becomes heavier and sinks in the storage tank fluid. When the temperature of the float is higher, the liquid is pushed into the container, and the empty float will rise in the storage tank fluid. The actuator pivots around a pivoting joint in the valve, so that the actuator closes off the bypass port when the float sinks, and closes the tank connection port when the float rises, using a high degree of mechanical leverage, with the rigid connecting tube acting as a lever arm.

Figure 2 displays graphically how this can be used to direct the flow from a solar heat source either into the tank, or bypass it to a different level of the tank, depending only on the temperature difference.

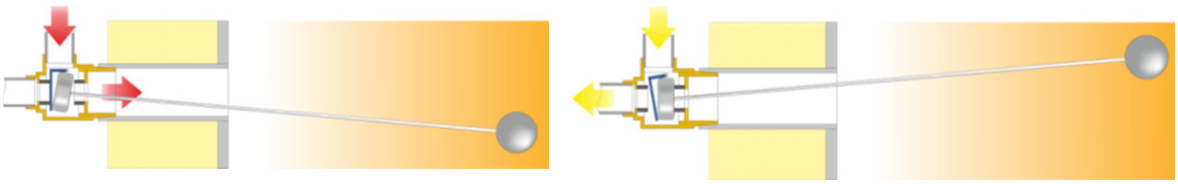

Fig. 2. Graphic depiction of how the Thermo-Differential Valve switches the flow based on temperature difference with the storage tank.

3. Experimental

The TDV used in the experiments to determine the switching and flow characteristics has a 1-1/2” male tank port connection and 1” female connections for inlet and bypass port, has an actuator length of 52 cm, with a leverage factor of 20, the volume of the float and the container is 32.9 mL and 25.4 mL respectively.

The TDV was tested in a 200 Liter transparent tank, where water could be circulated from two supply vessels at different temperatures, to test the switching behavior following instantaneous temperature changes.

Qualitative experiments of stratification performance were performed using color-dyes, using valve with straight actuator tubes, and bent actuator tubes, to qualify the influence of the float position within the tank.