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# Model development and validation for a tank in tank water thermal storage for domestic application

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**Abstract**

The hot water tanks are the typical thermal storage systems in Solar Domestic Hot Water (SDHW) plants. In this paper a new model for ESP-r has been developed, in order to simulate a tank in tank heat storage. The tank in tank system is made up of two tanks in which the smaller, storing potable hot water, is contained in a larger buffer filled with heating-circuit water. The developed model is an enhanced version of a component already available in ESP-r. Experimental results are used to identify some parameters and to perform the validation of the developed code.


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*Keywords:* tank in tank; energy storage; numerical calibration; plant simulation; hot water systems

## 1. Introduction

A water tank represents a convenient technical solution to boost the efficiency of a Domestic Hot Water (DHW) plant, since it is easy to install and maintain and the consumption of non-renewable energy can be reduced by the storage capacity that characterizes it. This is the reason why this solution represents the most viable choice to store energy in domestic plants especially if renewable energy resources are employed such as in the case of Solar Domestic Hot Water (SDHW) plants.

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The typical water tank employed for such systems is a buffer in which the DHW is contained and is maintained at high temperature through internal heat exchangers which can be fed by solar collectors and auxiliary heaters. In order to enhance the heat storage of such systems some authors have proposed the insertion of Phase Change Materials (PCM) [1] to exploit the latent effect. A model for a PCM enhanced tank component has been developed by the authors [2]. However an optimization the system highlighted the difficulties in obtaining energy savings by this technology [3] and the low effectiveness of these systems for SDHW plants has been identified with the large temperature oscillations inside the tank. An additional problem arises from the leakage danger of PCM at drect contact with domestic hot water. To avoid the aforementioned problems a different approach has been envisioned by using the so called tank in tank system in which the DHW is stored in a tank contained in a bigger buffer filled with heating system water.

Thanks to its construction features, the external tank water temperature is better controllable than in a traditional tank and the cold tap water taken from the grid does not directly affect water temperature stored in the external tank.

The aim of this work is to develop a model of a tank in tank system for the ESP-r code. In future the system will be used for the simulation of SDHW systems and will eventually be upgraded to simulate PCM enhanced heat storage tanks. ESP-r is an open source code for the integrated simulation of buildings and plants, it has been selected to develop the model thanks to the availability of the source code which permits the full control of the developed model. The storage tank component has been developed as a modified version of the stratified storage tank with one heating coil developed by Thevenard et al [4] and stored as component #103 in ESP-r plant components database. The model shares with the original component the same features such as a stratification algorithm, which guarantees the absence of inverse temperature gradients inside the tanks.

**Nomenclature**

| | |
|---|---|
| $A$ | Area [m$^2$] |
| $D$ | Diameter [m] |
| G | mass flow rate [kg/s] |
| $q$ | Heat flux [W] |
| $t$ | time [s] |
| $\theta$ | Temperature [°C] |
| $U$ | Global heat transfer coefficient [W/(m$^2$ K)] |

Subscripts

| | |
|---|---|
| DHW | domestic hot water |
| $j$ | external tank layer index |
| $k$ | internal tank layer index |

## 2. Tank in tank geometry

The tank-in-tank model with one heating coil is presented in Fig. 1. The implemented component permits the user to have an internal tank for DHW inside a large buffer.

The main feature of the model is the internal tank for DHW. Usually the internal tank consists of two stacked cylinders, with the lower one of reduced diameter to accommodate one or more heating coils as shown in Fig. 1. To predict the plant behavior the model has to accommodate in some way all these features. The tank can be connected to others plant components in order to exchange water with the external tank, the heating coil and the internal DHW. An important feature of a thermal energy storage tank is the water stratification, since the hot water tends to migrate in the upper part of the tank while the colder one stratifies at the bottom. The developed model implements this feature for both internal and external tanks.