Product concept study case for thermal batteries incorporation in housing area according to technical and functional requirements

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Abstract: The present research aimed to develop a product concept that integrates a disruptive solution for instant water heating based in thermal batteries in the housing area with minimal impact and adjusted to the construction practices widely used. The conceptual solution provide instant hot water with no energy waste associated with continuous use of domestic hot water recirculation circuits, the conventional solution used for decades with a significant impact on the inefficiency of buildings.

The concept developed considered the construction practices and the aesthetical limitation of a new element within the contemporary housing area. Several scenarios relating to current construction practices in different buildings typologies were analyzed, which resulted in the identification of two different general approaches with the respective requirements necessary for their implementation: 1) a vertical solution to integrate within a technical wall 2) a horizontal solution to integrate in the false ceiling. Within the two approaches, the development and design team projected and prototyped two versions of each approach: 1) the integration within a technical wall with access and without access to the batteries 2) the integration within the false ceiling with access and without access to the batteries.

With these prototypes it was concluded that the final product is suitable for current construction practices, respecting the necessary technical requirements without aesthetical impact in the general architecture of the space and in the conception of the buildings.

Keywords: Product design; Domestic Hot Water; Instant hot water; Conceptual Design; Energy Efficiency; Water Saving.

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1. INTRODUCTION AND OBJECTIVES

Centralized heating systems for domestic hot water in buildings is a common construction practice that is also recommended; however, this practice has a problem related to the distance between the consumption points and the heating system, implying a reduction in efficiency caused by the response time of the hot water circuit with a reduction in the temperature of the stagnant water on the pipes. Conventional solutions fix this problem using continuous recirculation systems that force water to flow into the hot water pipes, even when there is no consumption of water. The use of these systems raises a problem related with the energy losses of the recirculation circuit, which on average represent 30% of the total energy consumed for heating the sanitary waters in buildings (in some cases there are even higher losses). In smaller buildings (apartments with individual heating systems, small houses, etc.) that normally do not require this expensive comfort, this problem is assumed at first as inevitable, implying waiting time for hot water and several liters of wasted potable water. However, in larger buildings (hotels, gyms, hospitals, apartment blocks with centralized heating networks, etc.) this waiting time is unacceptable due to the comfort and functionality often required and inherent to this type of buildings. In such cases, it is almost mandatory to use conventional solutions for recirculation circuits that take a large share in the operating costs of such building/services.

With the identification of this possible opportunity, Heaboo proposed to develop a disruptive and innovative solution, compatible with any domestic water heater (DWH) distribution network and that could ensure constant and instant supply of hot water at the consumption points without the use of external energy sources. Thus, avoiding the continued use of recirculation circuits and the consequent waste of associated energy (more than 50% of energy consumption for sanitary water heating). Based on a method of accumulating heat at the hot water distribution points, this solution heats stagnant water on the piping and instantly delivers hot water throughout the building DWH network. The development of such solution with so many innovative requirements and specificities, brought several challenges for the development and design team in terms of technical matters and specific design requirements that had to be ensured. We made sure that all technical details were ensured and adapted to all the DHW networks available, and also that the design requirements, such as dimensions, materials, installation methods and other functional specifications, were suitable for the type of application. Further the development of a disruptive and non-existent solution in the current market, the development of such solution equally contributed to the development of tools that allow the analysis of the investment returns that increase the value proposition of such solution on the national and international markets.

2. STUDY CASES

In the present research, the development and design team identified and analyzed the typology of buildings and possible DWH network configurations, in which a bigger potential of integration of such solution will be more predictable, to create possible research cases. Those research cases were tested and contributed with results not only regarding the solution performance as also regarding a possible configuration of the overall system. For each of the research cases, variable consumption profiles were characterized throughout a week that led to the solution constituted by three main elements.

During the development of the solution the development team reached key conclusions that would influence the definition of the final concept of the solution, considering the case studies and analysis of the typical DHW distribution systems of the buildings considered for the case studies. It was concluded that in large buildings, the focus of energy loss in recirculation circuits would be associated with the secondary distribution circuits (at floor level) and not in the main distribution circuits (upstream supply column). Based on this conclusion, it was defined that the product would be standardized and mandatorily installed close to the room, optimizing the DHW distribution circuit in areas where waste is more significant. Considering the application of this product in a domestic/residential context (houses, apartments, etc.) or in a public building context (hotels, gyms, hospitals, etc.), two possible product concepts were presented that could fit the needs/requirements of these two types of buildings without changing the product concept (structural) and that could locate in each compartment instantaneous heating capacity of the stagnant water upstream: 1) IN | Integration into technical wall – built-in solution with or without access 2) UP | Integration into false ceiling – ceiling solution with or without access.

Each of the concepts proposed included 3 element groups:

1. Thermal battery IN – Consisting of the batteries and surrounding structure, respecting specific dimensions, and consisting of a water inlet and outlet.

Figure 1 – Example of a thermal battery concept to integrate in wall

2. LFC Module – Box that connects all the DHW points of the room and the connection to the power supply and return network. Composed of 6 connections in total, 1 controller and an access cover that it's the user interface.

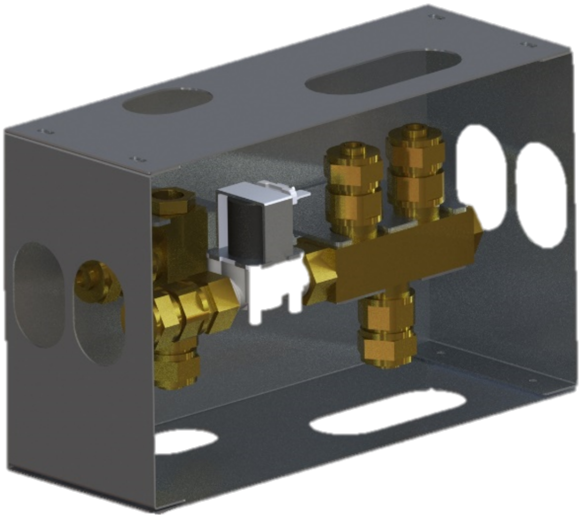

Figure 2 – Example of LFC module concept to integrate in wall

3. **Master Module** – Consisting of the central Master controller for activating the return circuit in specific situations (backup system) and the recirculation pump.

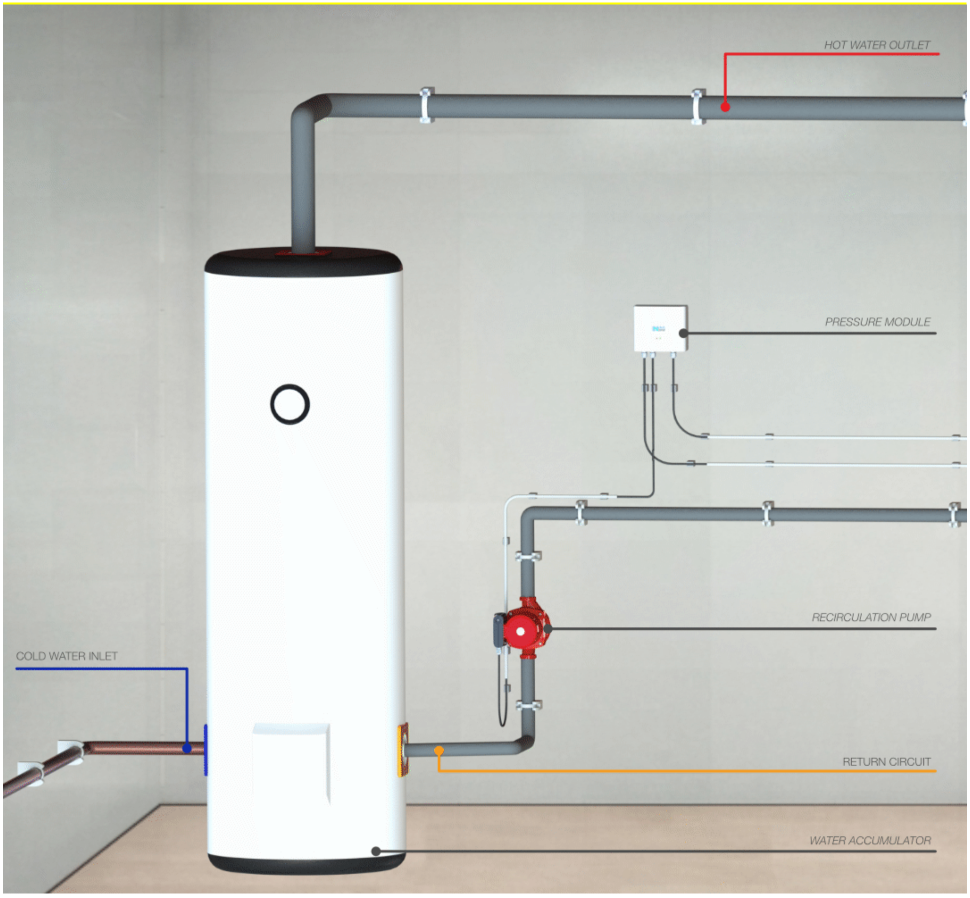

Figure 3 – Example of a master module controller to install near hot water source

The image below shows a generic example of the application of the solution in a residential building used as a case study. The sanitary water heating system is positioned in the technical area (garage) where the Master module is integrated. In the bathroom compartment is the thermal battery and the LFC module for connecting the DHW distribution circuits. The LFC system integrated in the LFC module communicates with the Master module, indicating whether the return circuit needs to be activated or not depending on the system requirements.

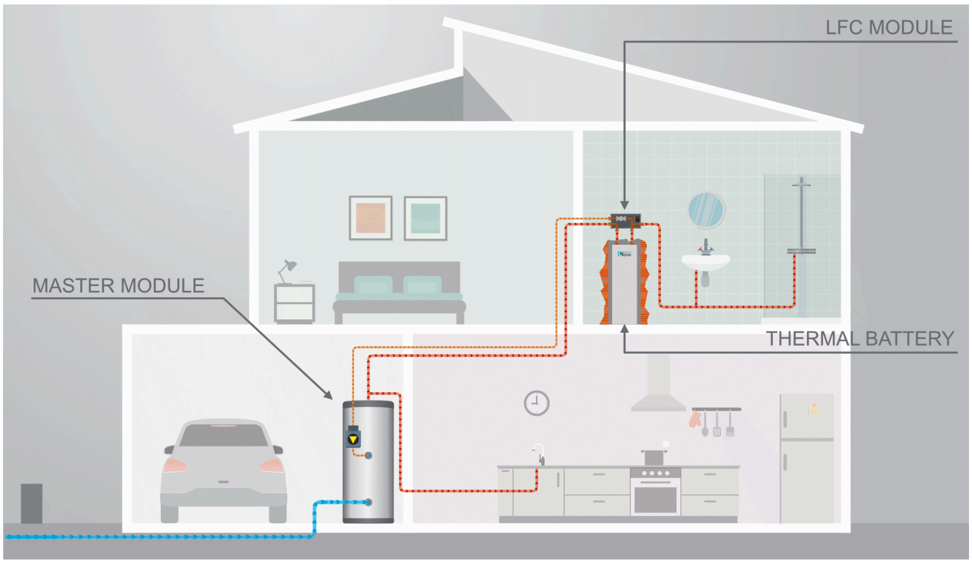

Figure 4 - Example of IN solution applied in a 2-floor residential building

3. CONCEPTUAL SOLUTIONS

3.1. IN | Integration in a technical wall with or without access

The concept for wall integration was suggested by the project team, considering that it is a common practice to use the water distribution box on the wall and in that sense, it would be more intuitive to integrate the product on the wall. The fact that it is a recessed product without user access will reduce the aesthetic impact on the user's bathroom, thus allowing it to pass more unnoticed in the overall framing of the room. The lid of the LFC box is the only visible element of the solution, as can be seen in the image below.

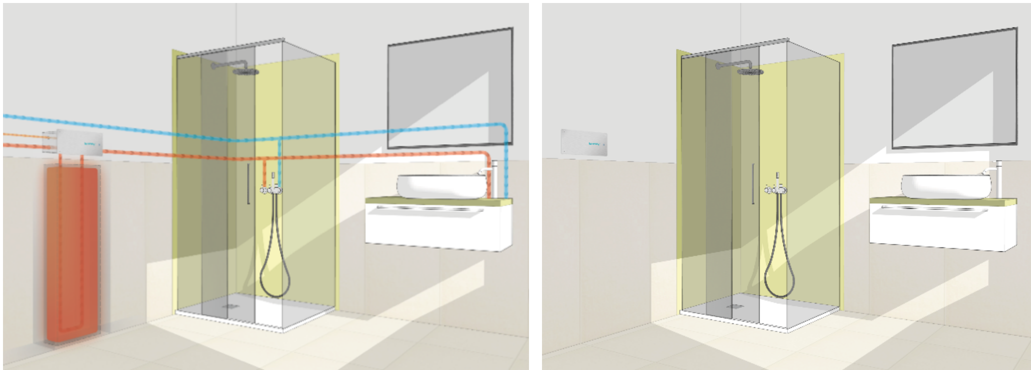

Figure 5 – *Inside and external view of IN solution integrated on a wall without access within a bathroom environment and with a stainless-steel cover*

To minimize the aesthetic impact of the cover in various environments, a situation that may limit the purchase of the solution, the project team developed a geometry that already fits some other solutions used in bathroom environments, namely the flush toilet control panels. In this sense, the cover will be presented with a brushed stainless-steel finish and another option in tempered glass.

Figure 6 - IN solution integrated in a real environment with a black tempered glass cover

The solution developed considers the possibility of the thermal battery being accessible or not after installation. In this sense, two approaches were kept ensuring an alternative, in case of resistance to the fact of not having access to the product and in case of any breakdown where it would be necessary to destroy the wall or false ceiling to access the product.

The project team therefore developed a module structure that includes partial thermal insulation with an EPS monobloc and a box for recessing the product in a technical area (e.g. cabinet), thus ensuring access to the solution. The EPS monobloc serves simultaneously to give the battery structure, confine the phase change material, and provide thermal insulation that can then be reinforced with two VIP panels (vacuum insulation panels) to ensure the best efficiency of the solution. The prototype EPS monoblock under development for EPS injection molding production is shown below.

Figure 7 - First prototype of IN thermal batteries box in EPS monobloc structure (open and closed)

Regarding the recessed box that provides access to the thermal battery (mainly important for the cases were the product will be accessible through a technical compartment or other type of access system), technical and functional requirements were considered, namely:

- Adjustment in depth after finishing the wall
- Fixing the thermal battery to a masonry or plasterboard wall
- Watertightness between the room and the inside of the wall
- Removable hydraulic connection system for equipment removal

The proposed concept divides the installation phase into two moments: 1) installation of the supporting block; 2) installation of the finishing frame. This way, the installer will be able to fix the support module and the piping connection at an early stage of the work and then, after the wall covering is installed, he can install the finishing frame with sealant, ensuring the watertightness of the room for the IN heater. In the final stage, the installer proceeds to install the solution and to connect the room to the network.

The figure below shows a CAD drawing of the developed concept, considering as manufacturing method the thermoplastic thermoforming, an industrial solution considered by the team as adequate considering the size of the part and the structural component.

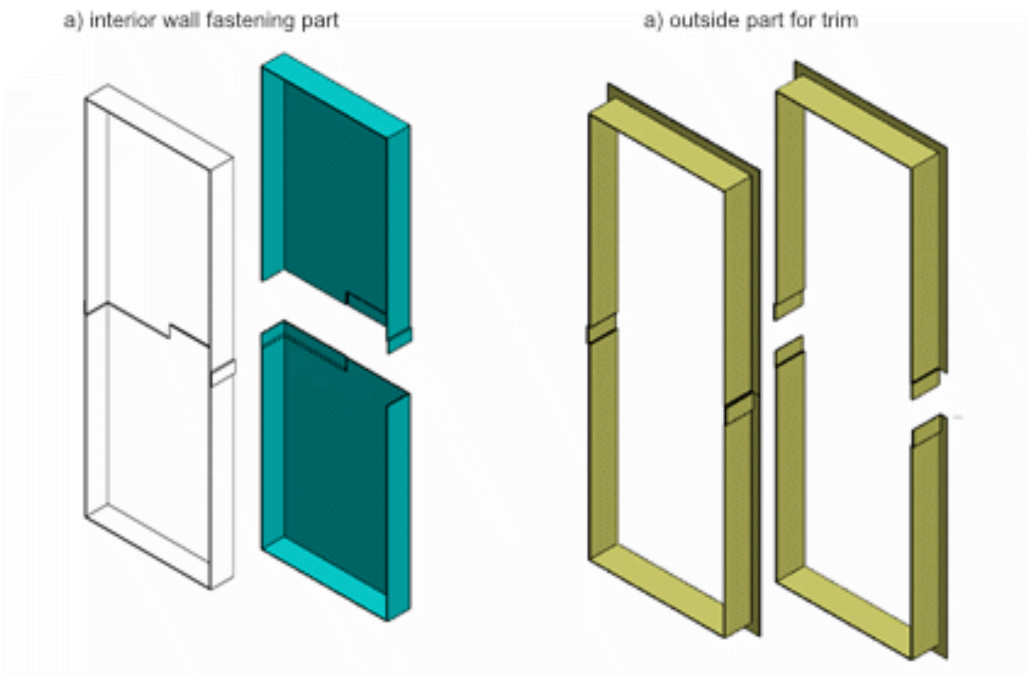

Figure 8 - Project of built-in system through thermoforming for the thermal battery to be accessible within the wall

3.2. UP | Integration into a false ceiling with or without access

The contact with installers, designers, architects and civil engineers and the analysis of several projects identified an alternative to the installation of the product on the wall and suggested the integration of the product in the false ceiling of the rooms. The false ceiling zone is increasingly used in construction for technical areas, namely for the passage of ventilation ducts, electrical network and even for the distribution of sanitary water. The available space near the consumption points combined with the ability to access the DHW network on site was crucial to develop in parallel an alternative to the wall concept for the product. The image below shows the UP concept for integration into the false ceiling:

Figure 9 - IN solution to integrate on the ceiling

The functional concept associated with the product for integration into the false ceiling is similar to the product for integration into the wall, the system works in series on the hot water passage circuit near the point of consumption: the return circuit will be connected to the outlet pipe and the system will integrate a controller that will analyze the consumption profile to decide on the need to activate the return circuit.

This product can also be accessible through a technical door on the ceiling, extremely common in hotels and buildings of larger dimensions that need to have easy access to ventilation and other systems installed on the ceilings. The image below simulates the product installed in the ceiling on a real context environment.

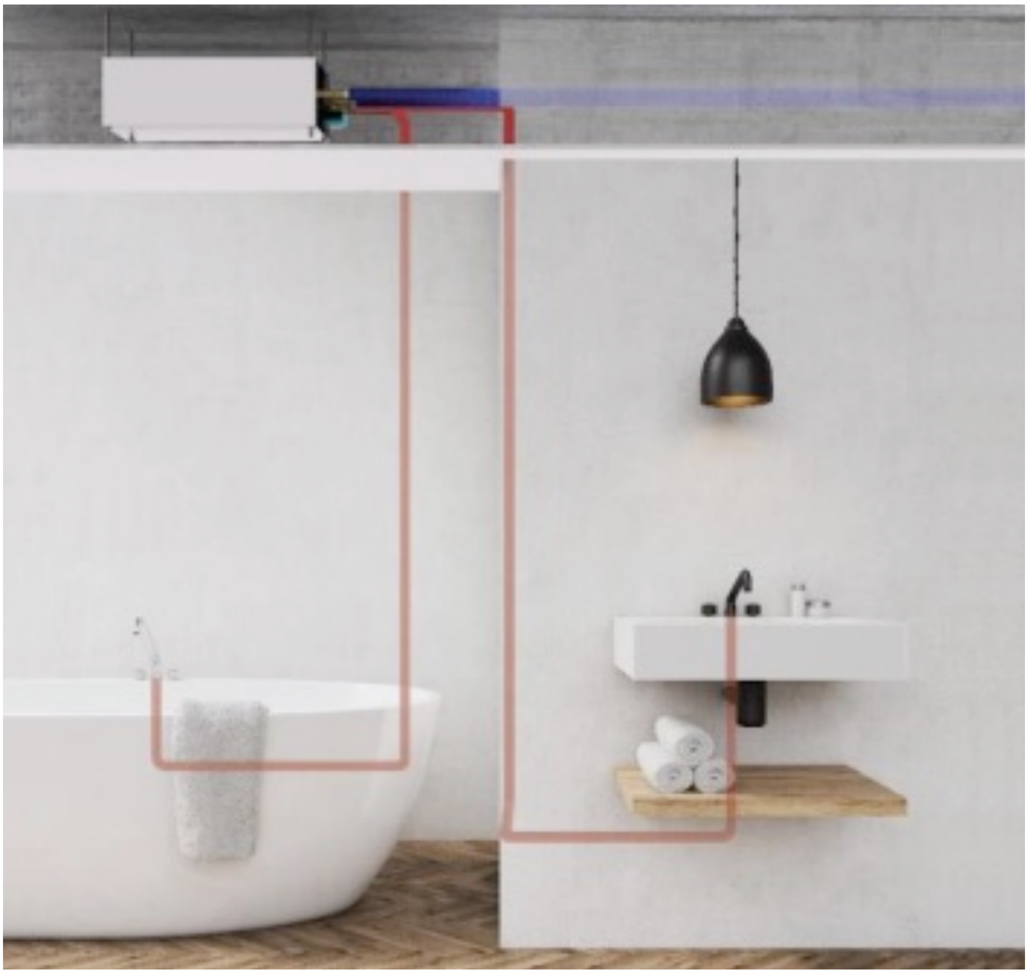

Figure 10 - IN solution integrated on a ceiling within a real-context environment

4. CONCLUSIONS

Within the scope of this project, a total of 4 options for the product were developed to meet the current requirements and construction practices, both in smaller residential buildings and in larger public buildings dedicated to service provision. The 4 versions of the product, Built-in with or without access and integrated in a false ceiling with or without access have successfully meet the objectives of this work as they are able to answer the needs of each typology of building and DWH network system.

However, some limitations in terms of the sealing of the system for the ceiling-mounted version have brought about the need for further future works on this product. Therefore, it became crucial for the closure of this project to achieve a form of sealing of the product that would ensure that the expansion of the polyurethane foam used inside the box would not affect the sealing and closure of the solution.

Currently, the design and development team is working on finding a better product sealing or in the last case in the redesign of the solution for its installation on the ceiling, the latter of which may result in different concept versions. Although it is concluded that the product versions should have different designs and structures to meet the technical requirements of the two types of product integration, it is considered that the project objectives were achieved in terms of the system development part and with the wall integration solution that is finalized and ready to be commercialized.

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