XXXVII IAHS – PROTOTYPE THERMOELECTRIC CLIMATE SYSTEM FOR ITS USE IN RESIDENTIAL BUILDINGS

César Martín Gómez [a], María Eguaras [a], Natalia Mambrilla [a], Joaquín Torres [a], Juan Carlos Ramos [b], and Alejandro Rivas [b]

[a]Department of Construction Science – Installations and Energy
[a]Universidad de Navarra
[a]e-mail: instetsaun@unav.es

[b]Department of Mech. Engineering, Thermal and Fluids Engineering Div
[b]TECNUN (Universidad de Navarra)
[b]e-mail: jcramos@tecnun.es / arivas@tecnun.es

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Abstract

The School of Architecture of the University of Navarra has begun a project which consists in constructing a prefabricated module, consisting of a simplified inhabited housing unit, and monitoring over the course of one year the behavior of a thermoelectric installation that provides service to this module.

The principal objective of the project is to quantify the response capacity of a thermoelectric climate control system applied to a prototype, and evaluate its energy and economic costs in the case that the system were applied in an apartment building.

The development of this project represents the application in the field of construction of a technology that already is in use in other areas, fundamentally the military and aerospace. Therefore, we do not seek to demonstrate the performance of Peltier cells per se, but rather to evaluate how they function when applied to the residential area, and to analyze both the positive and negative aspects of their use.

In this regard, it must not be forgotten that Spanish regulations also require the evaluation of the maintenance needs of climate control equipment, and, in this regard, Peltier cells offer an important advantage: Despite the fact that the initial investment is greater than with a conventional method of climate control, the maintenance costs are nearly zero.

For these reasons, an objective of the project is to estimate the construction and amortization costs of the application of this technology in the residential area.

1 Introduction

The Thermoelectric Conditioning System (TCS) is designed to reach a high confort level for people living in the local. Without mechanical parts like pumps or compressors, there is no necessity for maintenance, reducing the possibilities of failures. The only mechanical elements are the dissipation heat fans placed in the external face of the prototype. There are also some minifans to evacuate the heat from the power elements.
Currently, the prototype is being constructed in the School of Architecture of the Universidad de Navarra, according with the following plan:

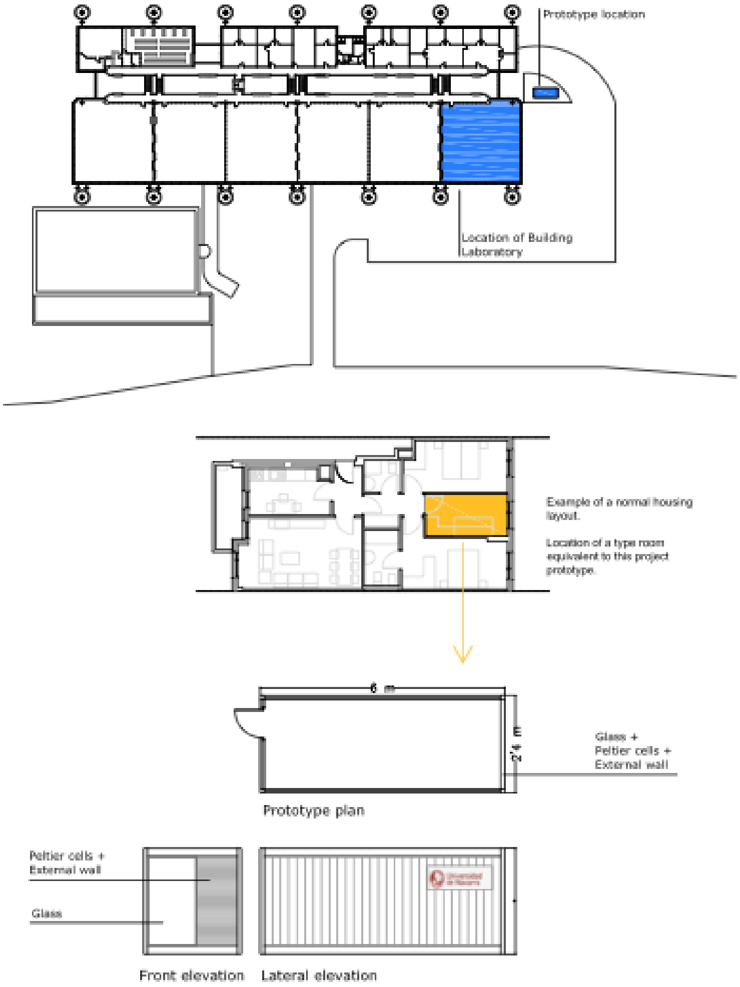

Figure 1: Prototype building considerations.

Nevertheless, the optimistic architectural results have made possible the start of the necessary patent steps. So the authors can not show in these moments the technological interior of the interior but a sketch with its dimensions and main characteristics.

Figure 2: Prefabricated module in the School of Architecture of the Universidad de Navarra.

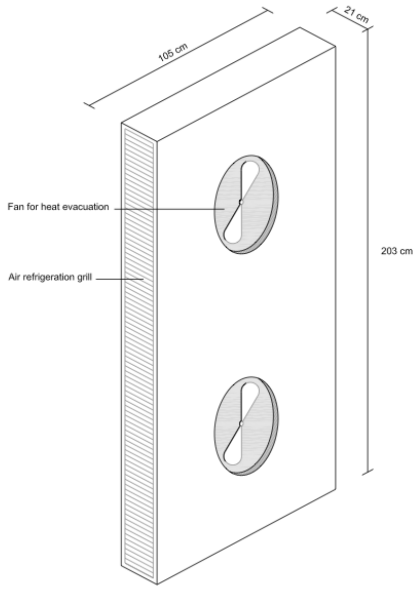

Figure 3: Prototype external view and dimensions.

Characteristics:

- Power consumption: 30 A
- Heat transfer capacity: 3 kW
- Number of Peltier cells: 42 (Marlow Industries, Inc)
- Manufacturer: Berotza (Spain)

The TCS is compact, and it is only necessary a reserve space in the building façade for its collocation as an prefabricated element. The external view is for the metallic frame with the dissipation fans and the air grills. The TCS internal view (from the user's point of view) is an aluminium surface, with the filtration air system and the adjustable air exit grill.

The TCS dissipation elements (before the external fans) are made using heat-pipe technology, which result is an important rise in the heat dissipation capacity reducing the surface necessities. In this way the air-flow is lower and so the noise level. This technology determines the vertical TCS position design. Power units that serve the TCS are placed on the external dissipation heat side.

In the local interior there is an electric board with the protection elements necessaries for its running. These elements are connected to the monitoring and control system. The electric supply is 230 V single-phase with an 30 A estimated consume in the maximum operational mode.

2 Mathematical modelling and simulating

2.1 Approaching the problem

Some earliest approaches to modelling the thermal behaviour of our housing module have involved the analysis of several simple case studies simulating every specific aspect of the overall thermal behaviour. Those have been done by the finite volume method, using Star CCM+, a commercial software of computational fluid dynamics (CFD) developed by Adapco. These case studies allow us a separate analysis for each one of the processes of heat transfer.

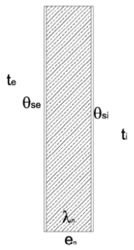

Figure 4: Case Study 1. Stationary one-dimensional conduction through a homogeneous solid.

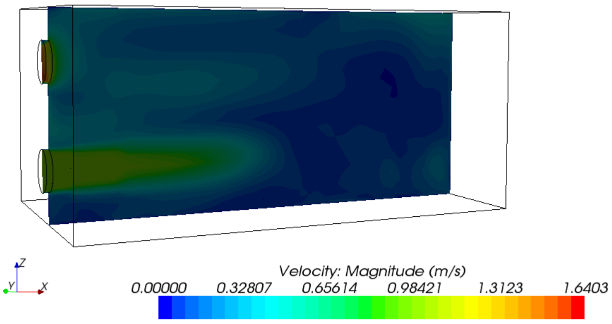

Figure 5: Case Study 2. Mechanically forced convection.

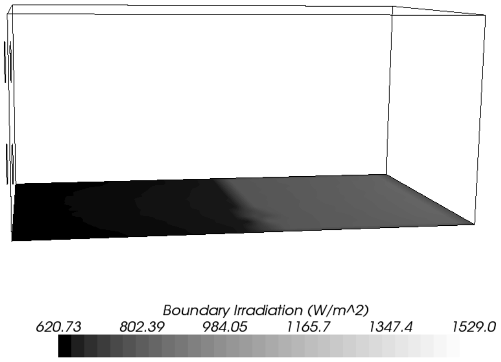

Figure 6: Case Study 3. Direct and diffuse solar radiation at a time throughout the day.

2.2 Full Model

Flow domain

A single and homogeneous fluid is considered. (Euler flow domain). Boundary conditions are stated (Dirichlet condition).

The space modelled is a parallelepiped shape of 600 x 240 x 260 cm (length x width x height). Its faces are defined bellow:

Table 1: Dimensions and orientation of the module

Surface	Orientation	Dimensions (cm)	Area (m^2)
Façade 1	N	240 x 260	6,24
Façade 2	S	240 x 260	6,24
Façade 3	E	600 x 260	15,60
Façade 4	O	600 x 260	15,60
Ceiling	-	600 x 240	14,40
Floor	-	600 x 240	14,40

One inlet and an outlet air surface are defined on the south side. These allow simulating the thermal input from the Peltier cells panel. An area of 3.12 m^2 is also defined as a glazed area. An orthogonal structured mesh is chosen because of model geometry. Cell size becomes smaller near the walls and near the holes that allow openings and exhaust.

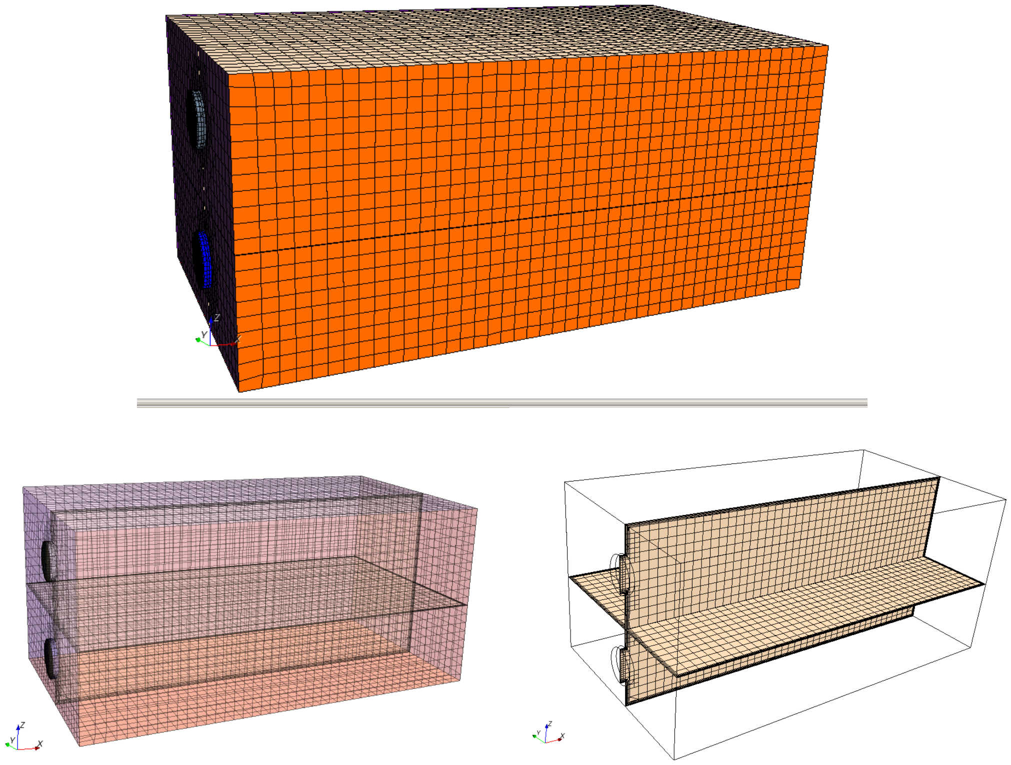

Figure 7: Orthogonal structured mesh.

Starting conditions:

- Outside air temperature 35ºC
- Indoor temperature 15ºC

Inside air temperature is considered pleasant in 25°C.

Boundary conditions:

- Facades, roof and floor are `walls´. Every coefficient of thermal conductivity for global transmittance is defined for each enclosure.
- The sidewalls of cylinders are considered adiabatic.
- The area of the air outlet is defined as velocity inlet: velocity flow and temperature are stated.
- The area of air return is defined as outlet pressure.

Definition of physical model (continua)

- A three dimensional model.
- Steady state flow.
- Air is considered as an ideal gas.
- Gravity is added to consider the natural convection behaviour of inside air.
- Phenomena of solar radiation, setting azimuth and latitude values, considering the front two facing south.
- k-ε turbulence model.

2.3 **Analysis of results**

Diverse parameters are studied in order to interpret the results through the following figures:

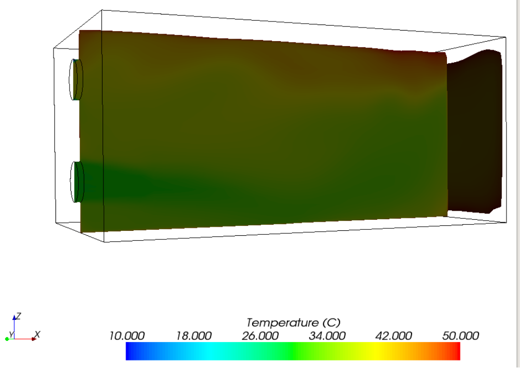

Figure 8: Temperature distribution in the X-Z plane (inside temperature).

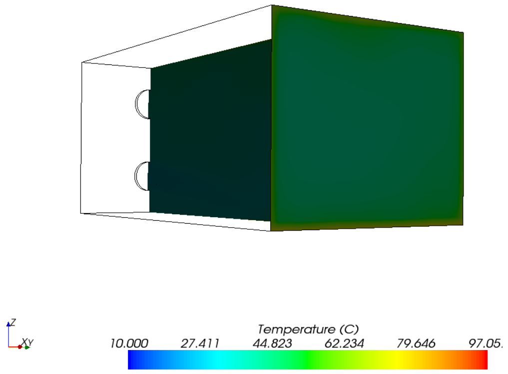

Figure 9: Temperature distribution on the inner surfaces.

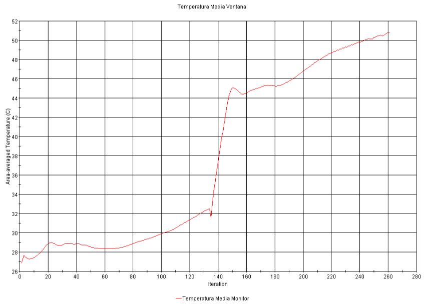

Figure 10: Temperature values on the outer surfaces due to solar radiation.

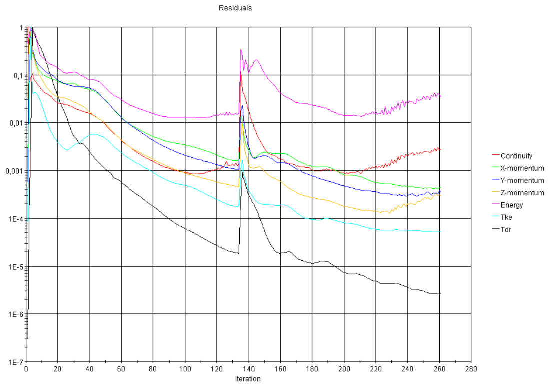

Figure 11: Residual and convergence error control (criteria).

In more advanced steps of the research, we propose the comparison of experimental data (which may have some measurement error) and those obtained by CFD (where error is due to the modelling). The analysis of these results allows evaluating new corrections or greater precision in the calculations in order to improve the façade panel.

3 Engineering Development

The description of this development has been detailed in the *2010 29th International Conference on Thermoelectrics Proceedings Book* published by the "29th International Conference on Thermoelectrics" (May 30 - June 3, 2010. Shanghai, China).

4 Conclusions

This paper has developed the methodology for the theoretical study of a prototype thermoelectric climate system for the residential area. The exact development of this methodology is necessary, because the next steps of the research are orientated to the comparison between these theoretical data, and the results taken during the monitoring of the prototype build in the School of Architecture of the Universidad de Navarra.

In this way, these initial considerations about the Peltier system behaviour is helping the research team to take important design decisions for the prototype building.

Finally, depending upon the results obtained, it will be proposed that the project be concretized in a patent for a "prefabricated and decentralized facade module for the climate control of inhabited spaces".

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