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Thermal performance of the new hall of the historical hospital in Florence

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The aim

The main aim of the present work is the study of the energy performances of the new hall of the Old *St.Maria Nuova* Hospital in the center of Florence (Italy). In particular this study aims to evaluate thermal, energy and environmental performances of the refurbishment project for the new hall of the historical hospital and to evaluate the significant reductions of energy consumption obtained.

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The system studied

The S.Maria Nuova Hospital is the oldest still operating hospital in Florence, the only one in the historical centre, with the main entrance in the homonymous square. It is the first example of a building and plant refurbishment on a protected historical building. The new hall of the hospital that is the object studied is a bioclimatic greenhouse made of triple low emissive glazed façade used as thermal buffer.

The access to the new first aid, located in the west side of the lodge, the object of present study, is realized with a steel structure and glass and equipped with two portals of access to the ambulance service and transportation of sick and a pedestrians. This new hall fits into the Buontalenti's porch with respect, preservation and protection for the architectural, historical feature and cultural value of the building

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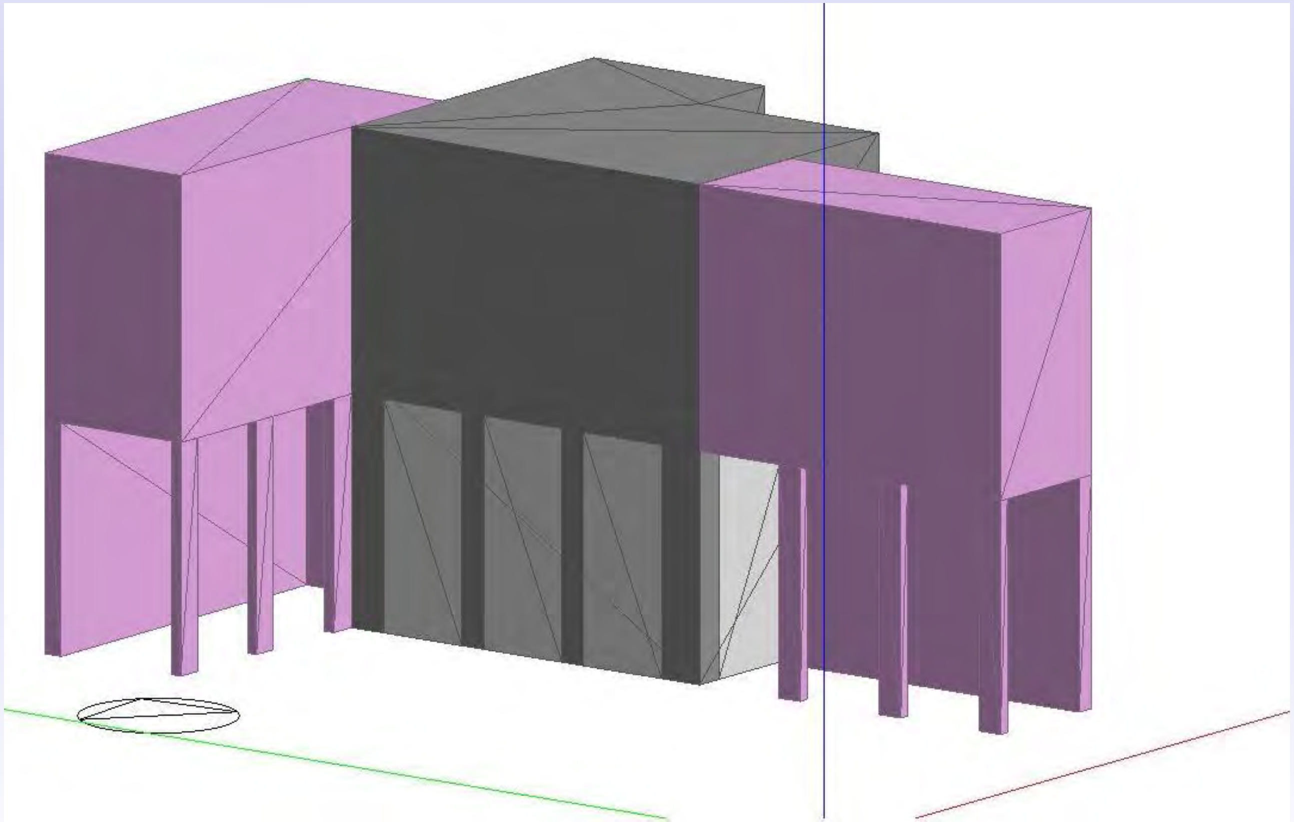
The solid model

A 3D model was carried out. The hall is 114 m^2 and its total interior volume is 980 m^3. The main glazed façade is oriented at South-West and it is 135 m^2; two side windows are exposed to the NW and SE, both of 56 m^2, are provided by two sliding doors with motion sensor. The wall at the entrance to the first aid of the hospital building is plastered by mixed stone.



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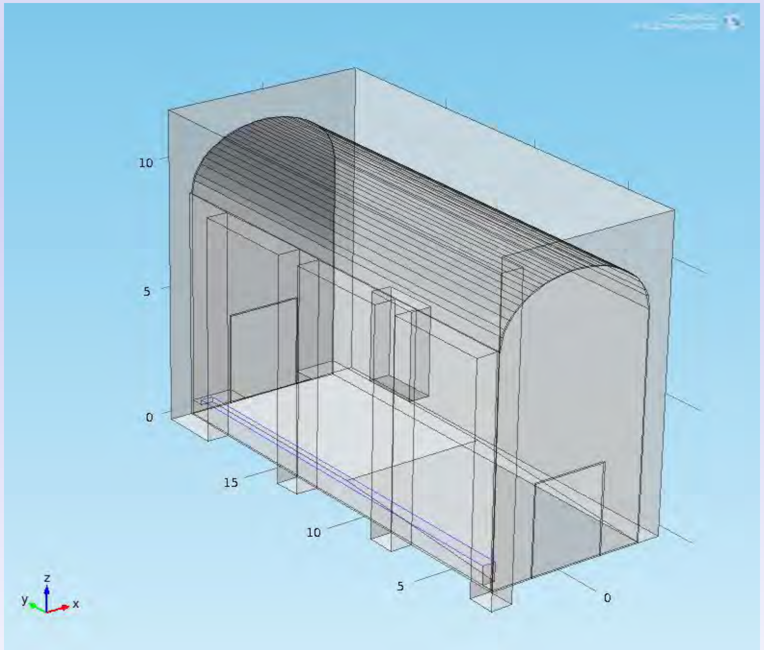

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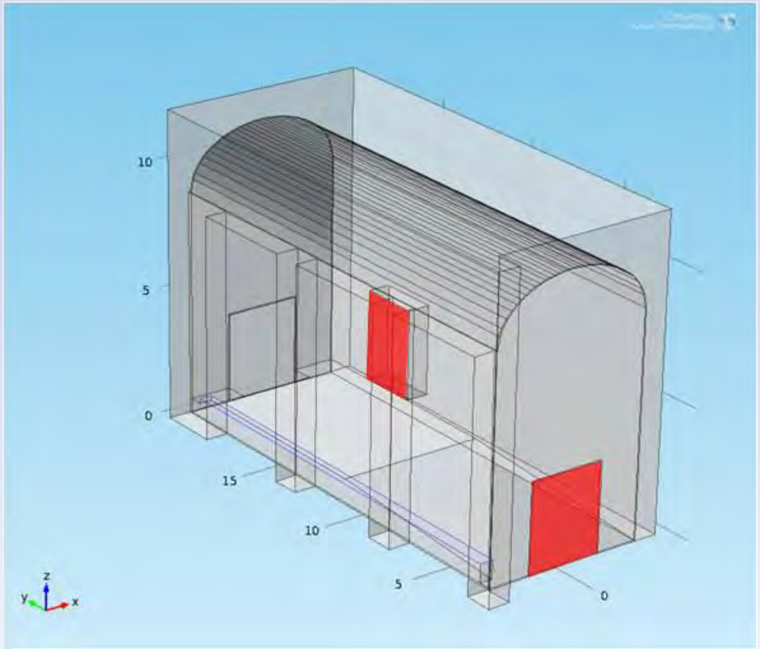

This thermal buffer, actually called *hot room*, was considered as one-zone model made by the large glazed surfaces supported by steel profiles connected to the structure.
The N-W sliding door was kept closed, but the S-E and the first aid sliding doors were considered opened.
At this condition the one-zone 3D model was assumed to have a boundary faced to the first-aid indoor ambient and an external boundary defined by the external ambient, characterised by the hourly values of temperature and solar radiation variations, that concerns the three N-W, S-W and S-E walls.

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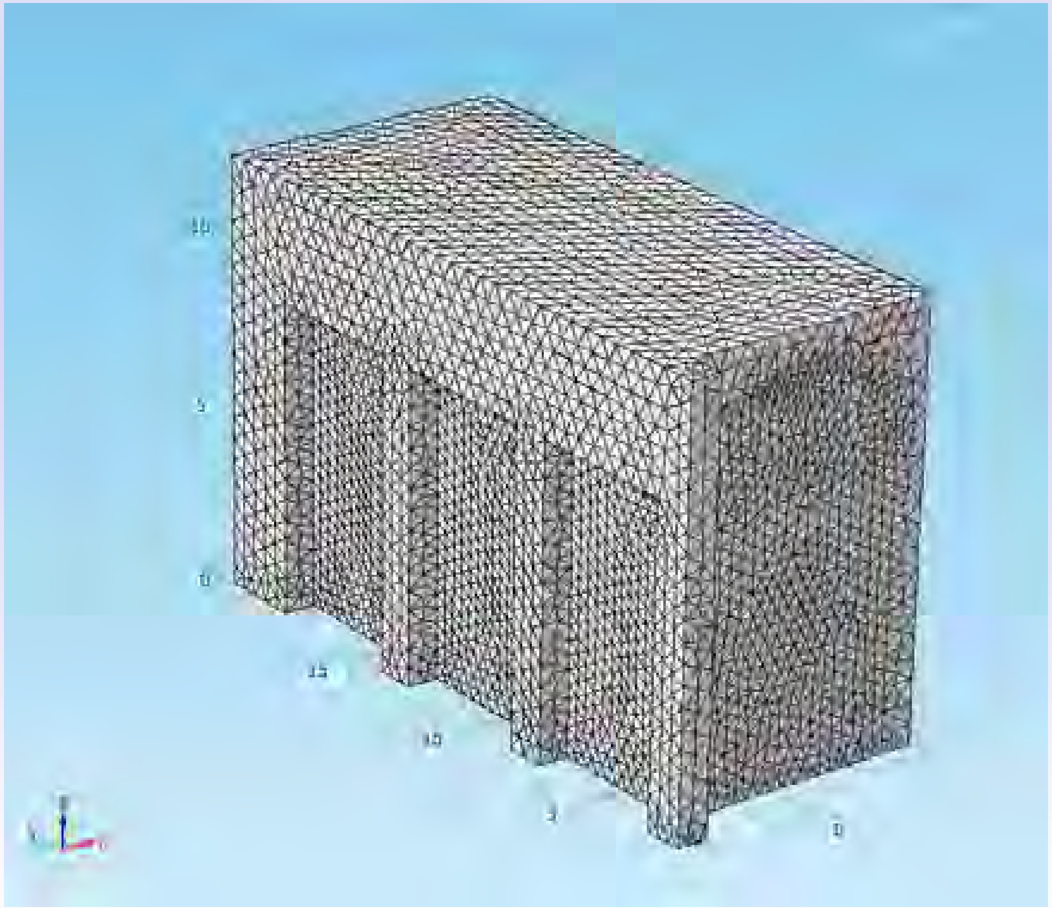
The internal boundary of the 3D model studied was assumed at the fixed constant temperature and at slight over total pressure. The three fan coils (with a four pipes system) located in the floor, with their grilles adjacent to the S-W glazed façade, were modelled assuming an initial inlet constant velocity and inlet temperature values.

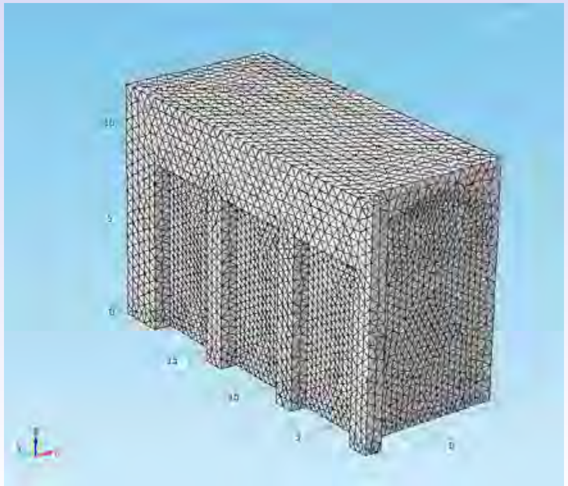
THE TRANSIENT SIMULATION

To investigate the development of the ventilation flow and the air temperature distribution inside the system studied, a time dependent simulation based on general heat transfer combined with the turbulent k-ε flow model, was performed using COMSOL.



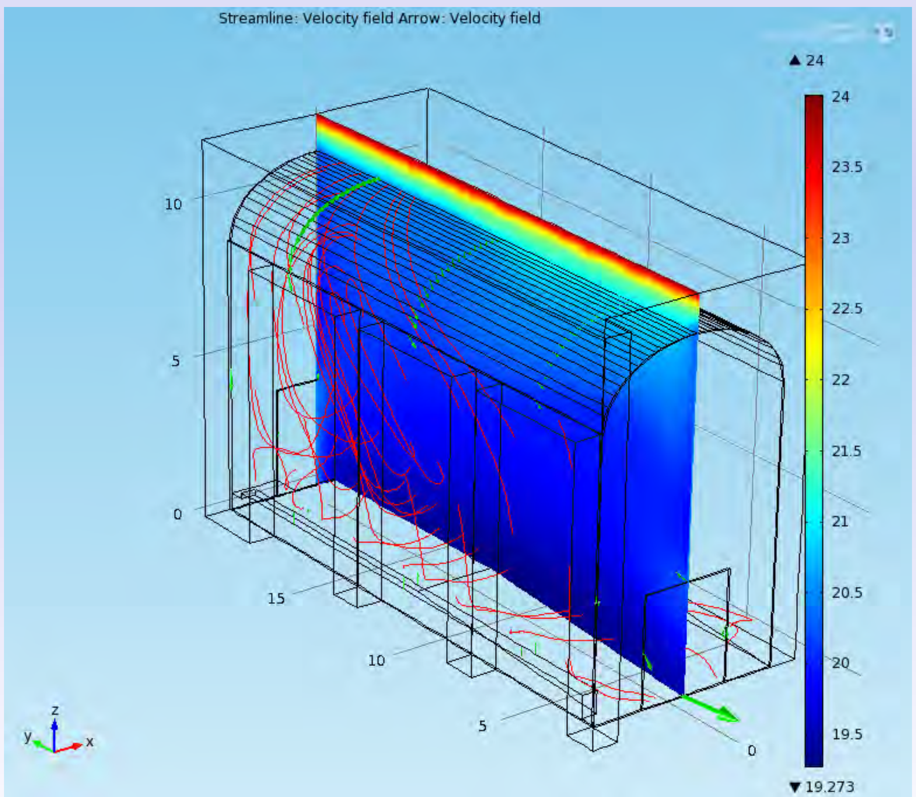
Hourly climatic data of the hottest day provided by the standard year of Florence, were used. For the South-West glazed façade the external air temperature was corrected taking into account the incident solar radiation.

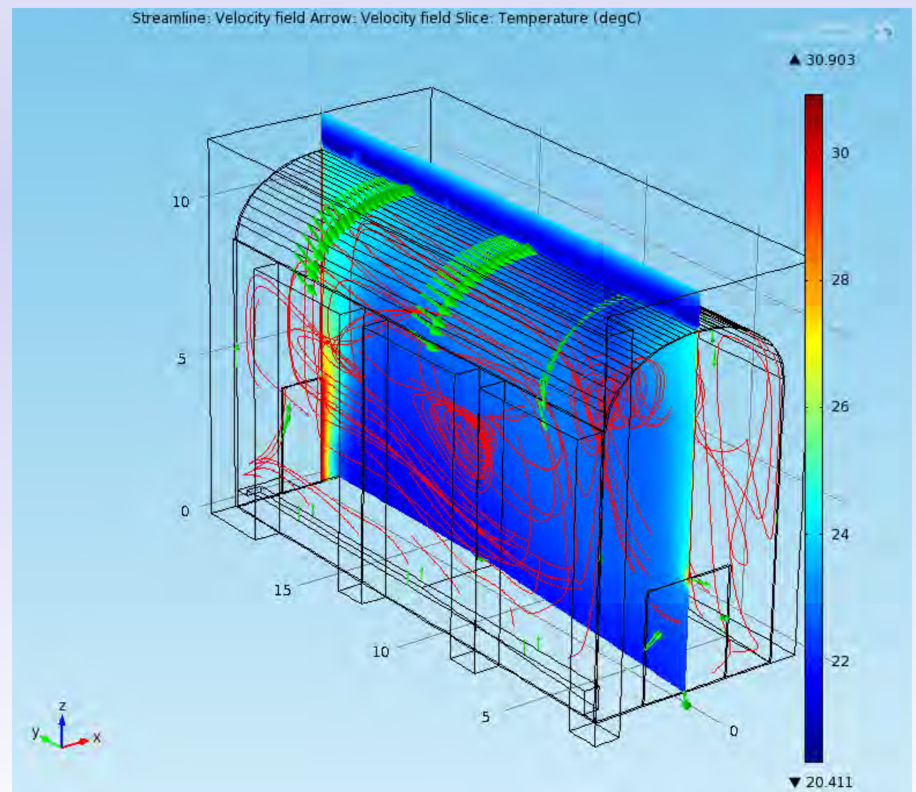
A good quality of the mesh was obtained by 200000 degrees of freedom with 197000 triangular and tetrahedral elements. The linear system solver *PARDISO* was used.



Results

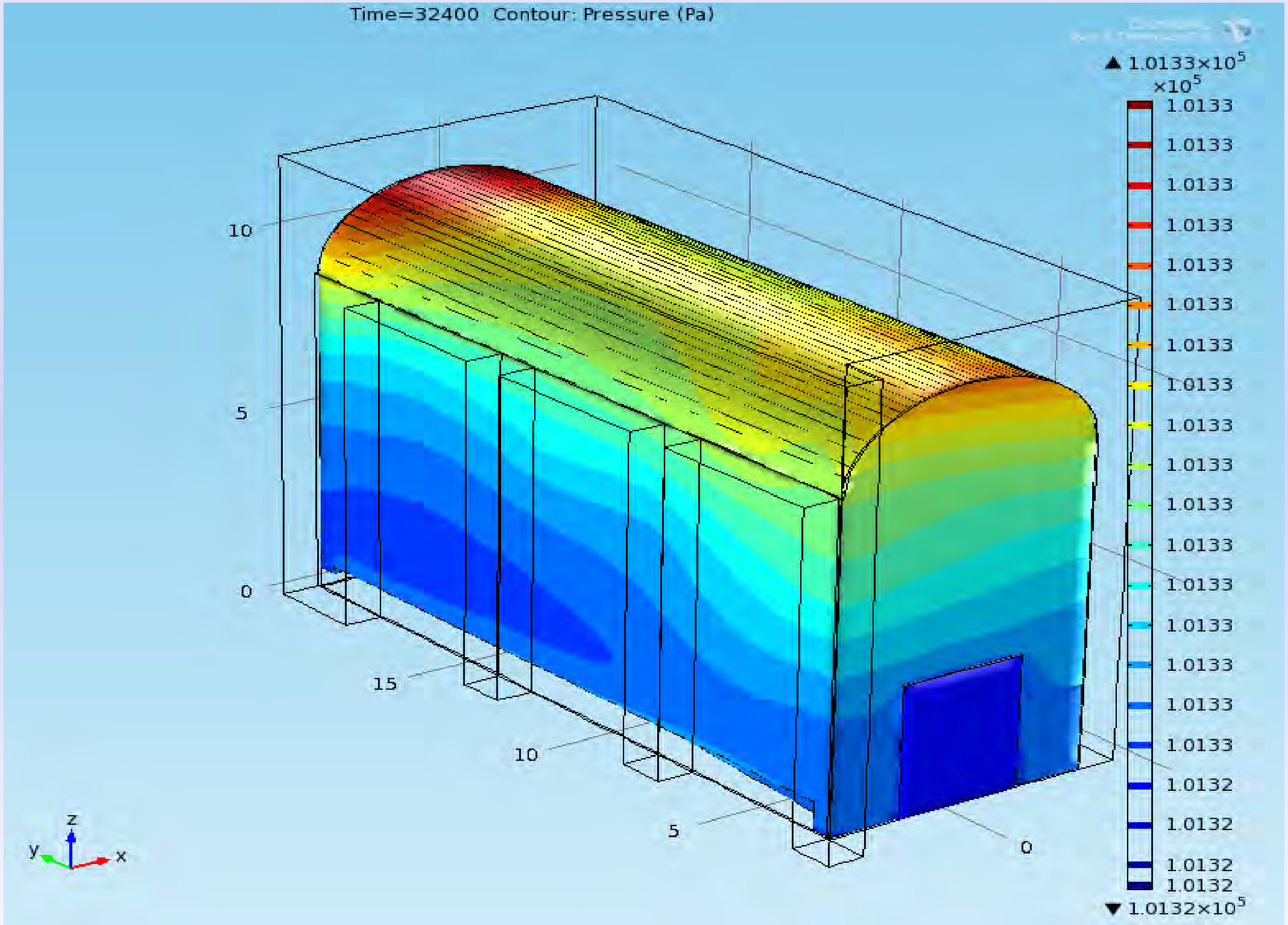
Simulation results highlight the thermal flow and the surface temperature distribution, air temperature and air velocity field in the *hot room* connected to climatic external stress. The internal pressure scheme was also evaluated taking into account the fan-coils air system operating condition (from 7 a.m. until 18 p.m.), and the closed-opened doors conditions.





Results: pressure distribution at different hours

The internal pressure scheme is rather stable due to the small changes of the pressure variation.



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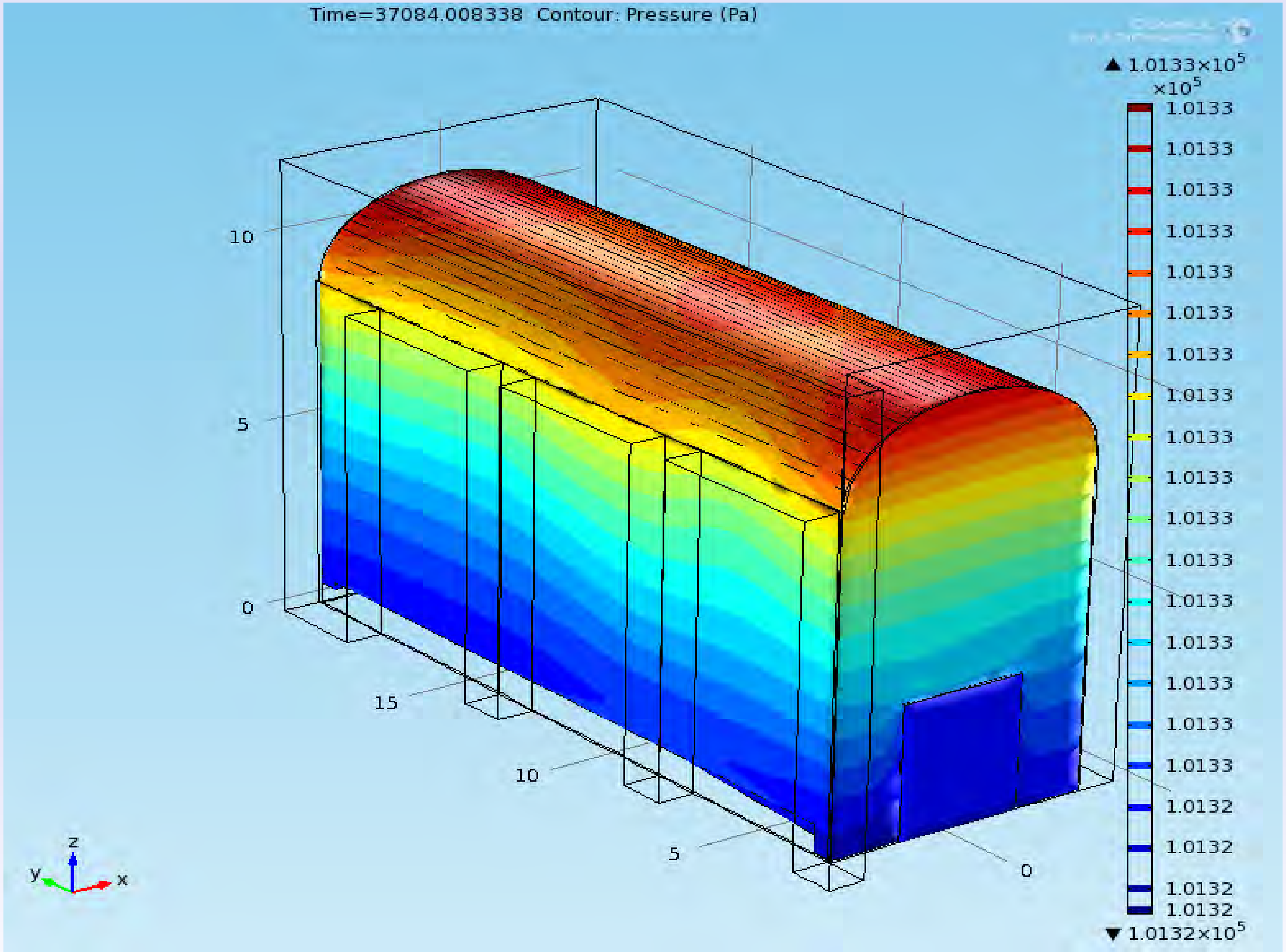
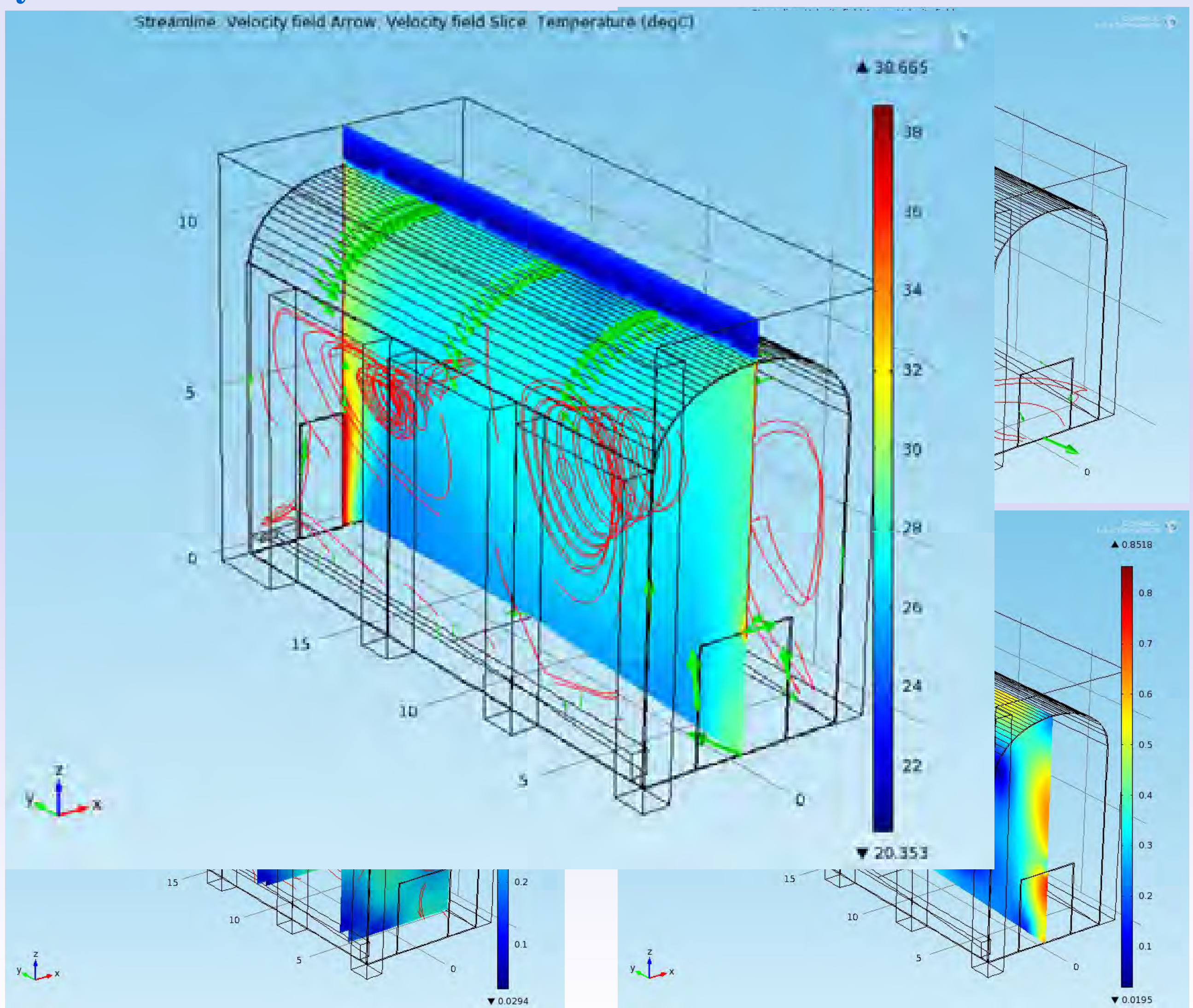


The simulation results concerning the air velocity through the S-E *hot-room* door, considered opened, during the hottest hours of the hottest summer day (h 10 - 15), provide its maximum value of 0.8 m/s; on the contrary, during the remaining hours the air velocity is about 0.1 m/s.



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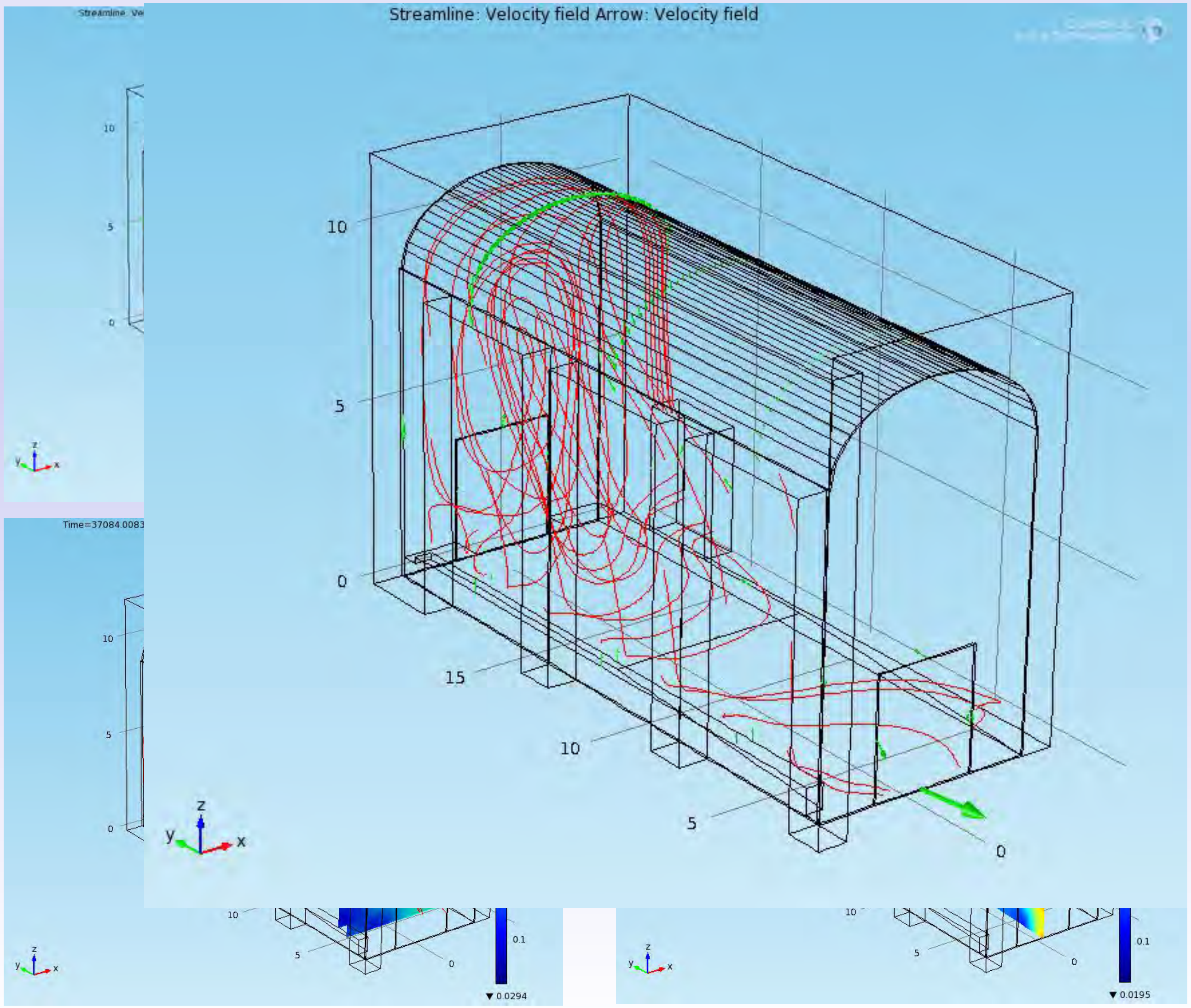

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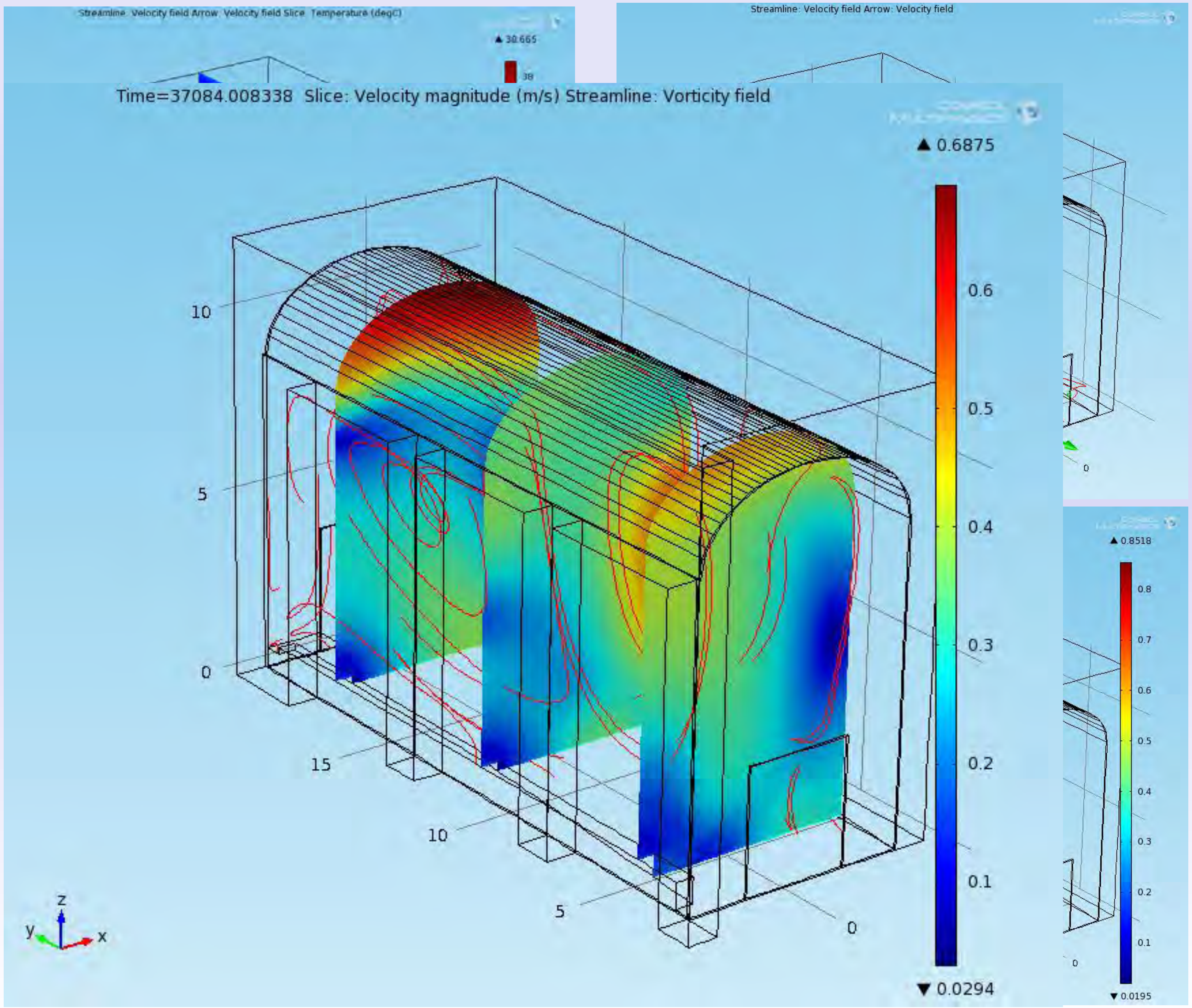

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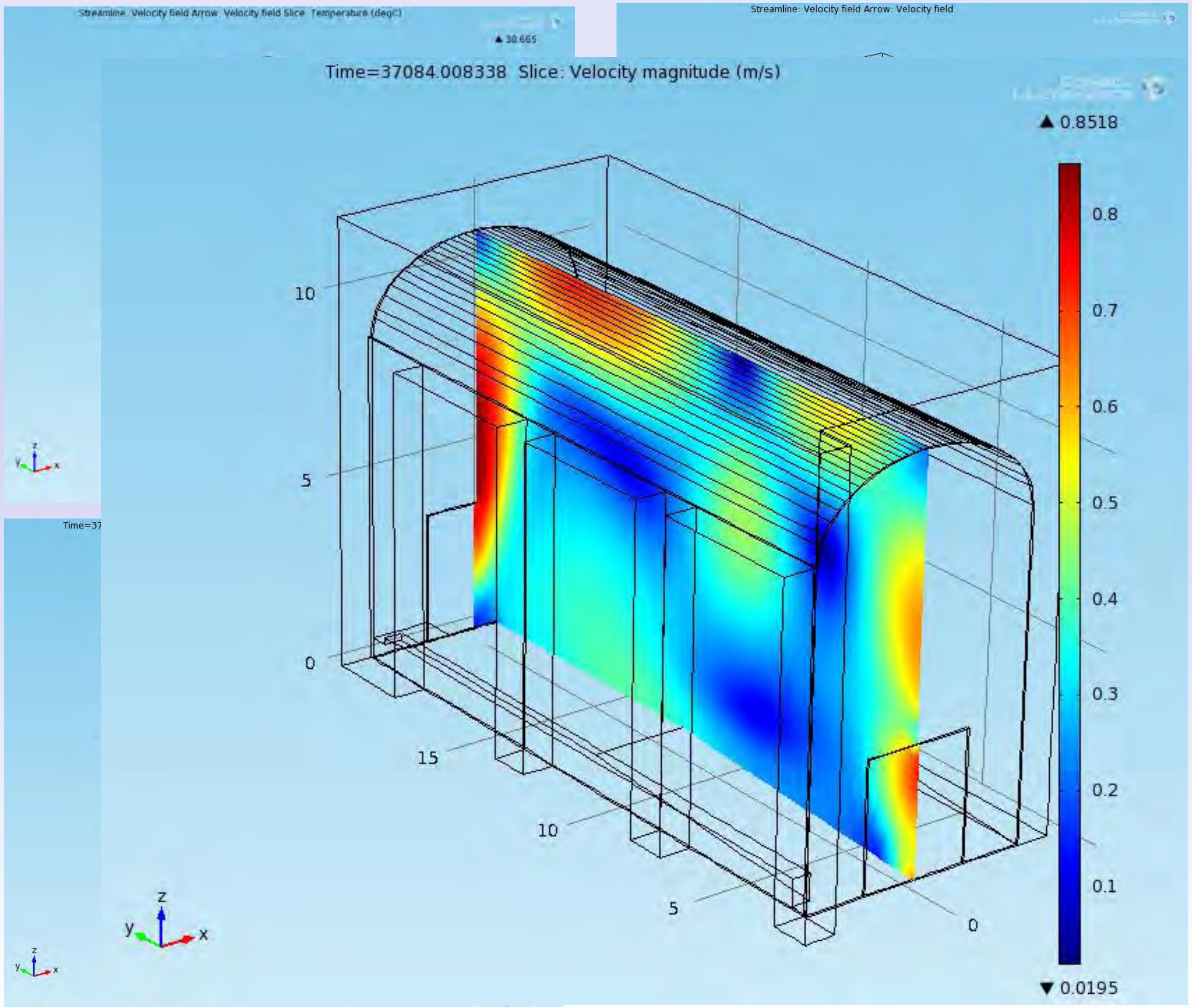
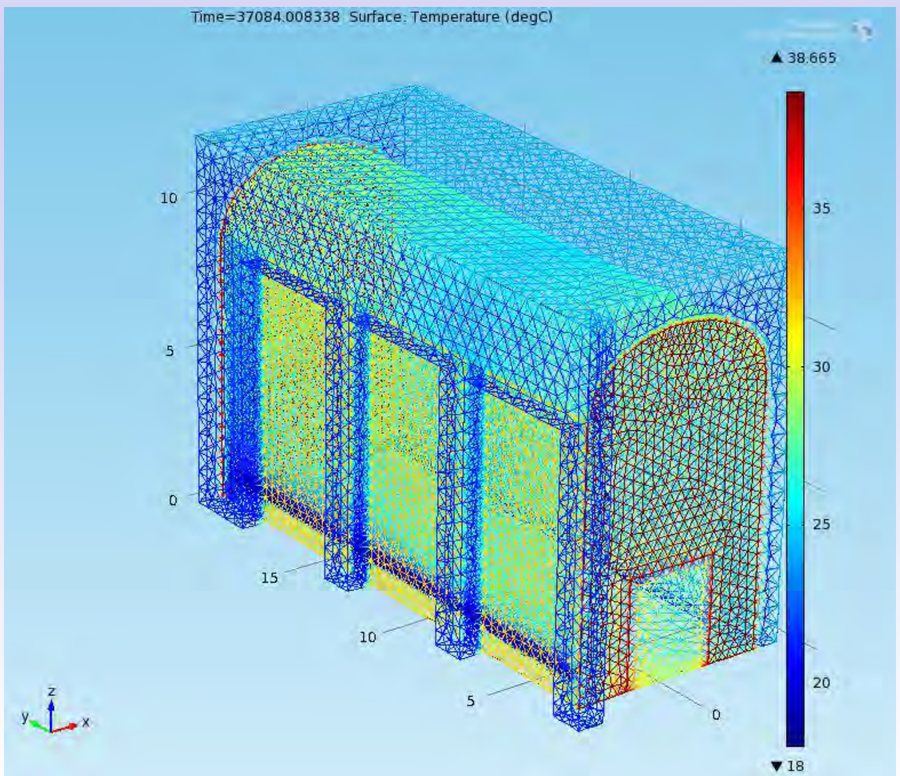
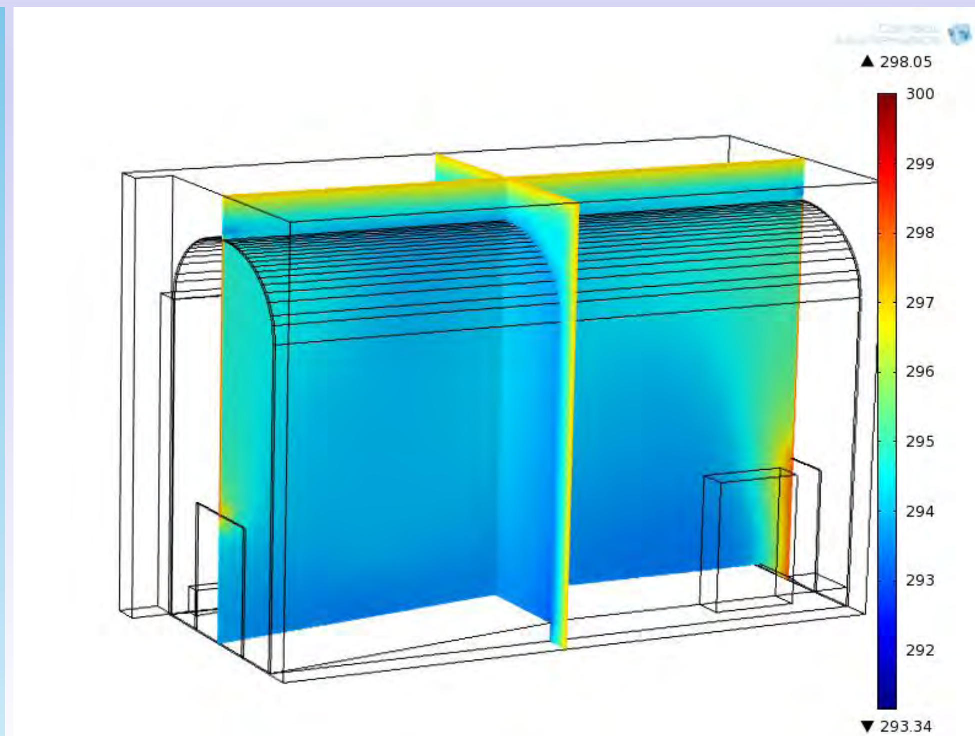


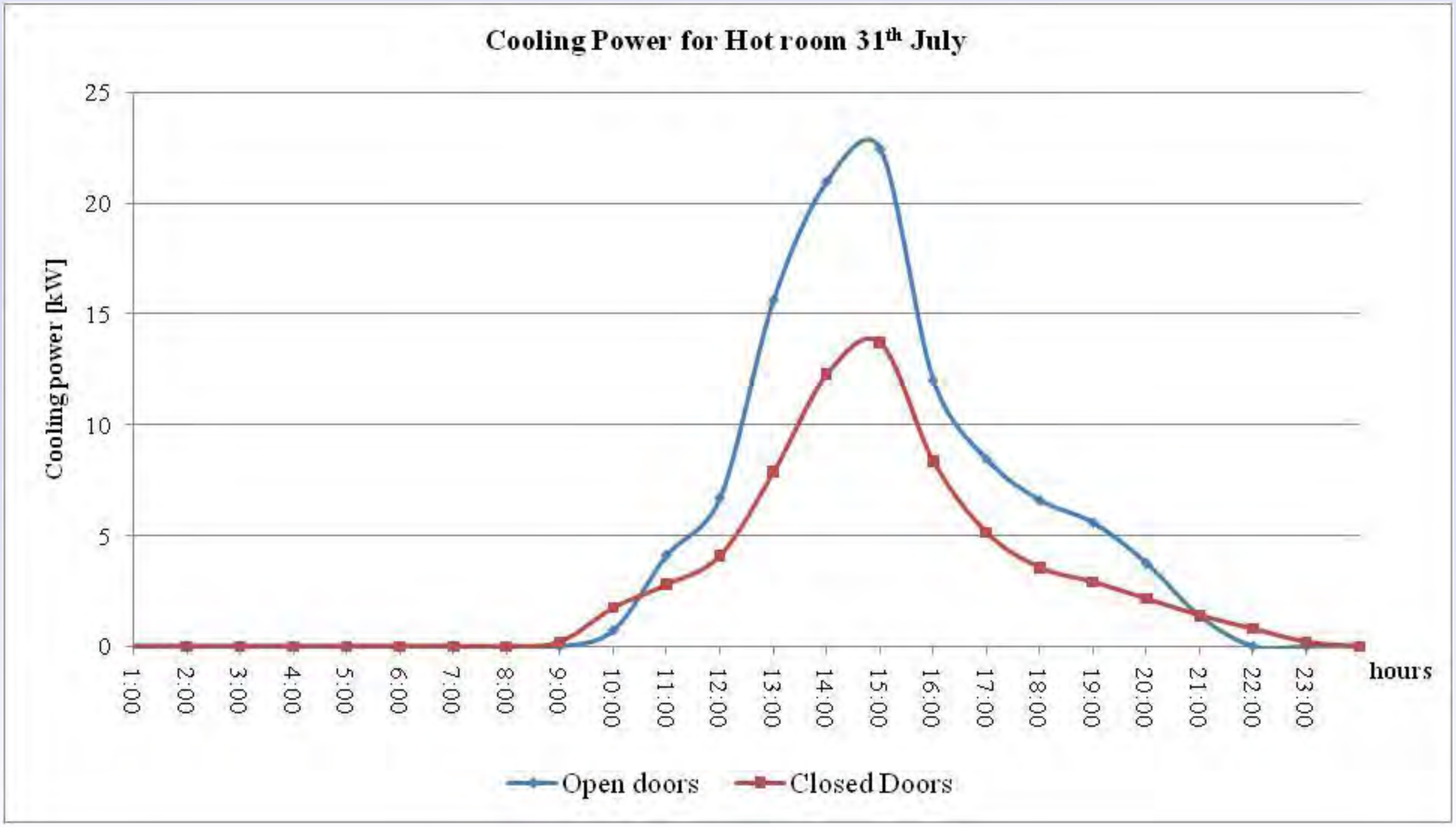
The internal air temperature gradients are important and produce a complex air flow distribution due to the mix between the natural convection, connected to buoyancy forces and the air density variation, and the forced convection provided by the operating fan-coils unit.

For the hottest hour the lowest surface temperature values (from 18°C to 25°C) belong to the massive walls with high thermal capacity, the highest belong to the S-W and S-E façades and then respectively of 30°C and 36°C. The mean internal air temperature remains roughly stable, varying between 22°C and 28°C.





Taking into account that during the door opening and closing, the passage of a person needs about five seconds, the external air flow rate is 1.4 m^3/s during the hottest hours and 0.19 m^3/s in the remaining hours of the day. In particular, at the h 14 (the hottest hour) when the door is open, the three fan-coils unit needs a cooling peak power of 25.5 kW. For the door closed condition, during the whole day, the cooling peak power requested by the plant is 13.7 kW.



Conclusions

We believe that this work can provide important recommendations towards thermal comfort control and careful design and optimization of ventilation in important hall such as of the hospitals.

From the analysis on the air flow patterns, air temperature and air velocity distribution we can draw important indications for the best location of openings and particularly for the sliding doors position and for the best building components (opaque and transparent) solution.

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Transient simulation results provide a qualitative and quantitative evaluation of thermal and energy performances of the *hot room* and then to check its effective thermal buffer effect.

Comsol simulation allows to design ventilation strategies, thermal effects on the cooling plant operating conditions but also to indicate the selection of the best type of the air inlet/outlet diffusers in order to minimize the intermixing between the supply air and the air movement in the room due to door opening and closing, in medium-low latitude when climatic stress mainly due to solar radiation is very important.

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