Statement of the problem of numerical modeling of steady-state conditions in laboratory test chamber (LBL IR box)

1. The geometry and boundary conditions

We defined the geometric dimensions and boundary conditions close to the known values described in the experiment [1]. Figures 1 and 2 show geometry and boundary conditions of the warm-side chamber with a wood casement window used in experiment. We consider a two-dimensional representation of the chamber with inlet and outlet slots at its bottom and mounting of the window along middle section of the chamber. We also consider airflows in the chamber as flows under conditions of mixed turbulent convection. The boundary conditions for inlet slot defined as turbulent conditions with small (< 5%) turbulent intensity. For defined BC we are using features and possibilities of FLUENT 6 software [2].

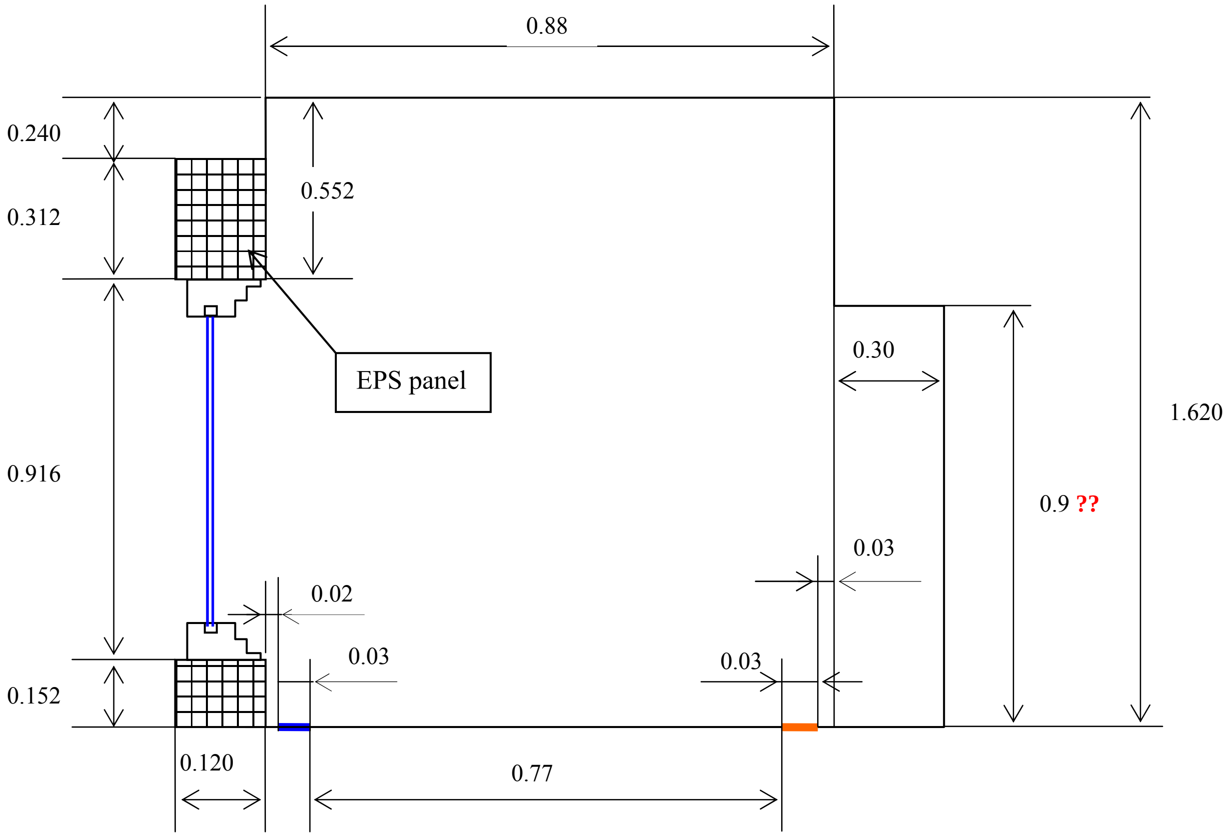


Figure 1. Geometry and dimensions of the modeled warm-side chamber (not to scale).

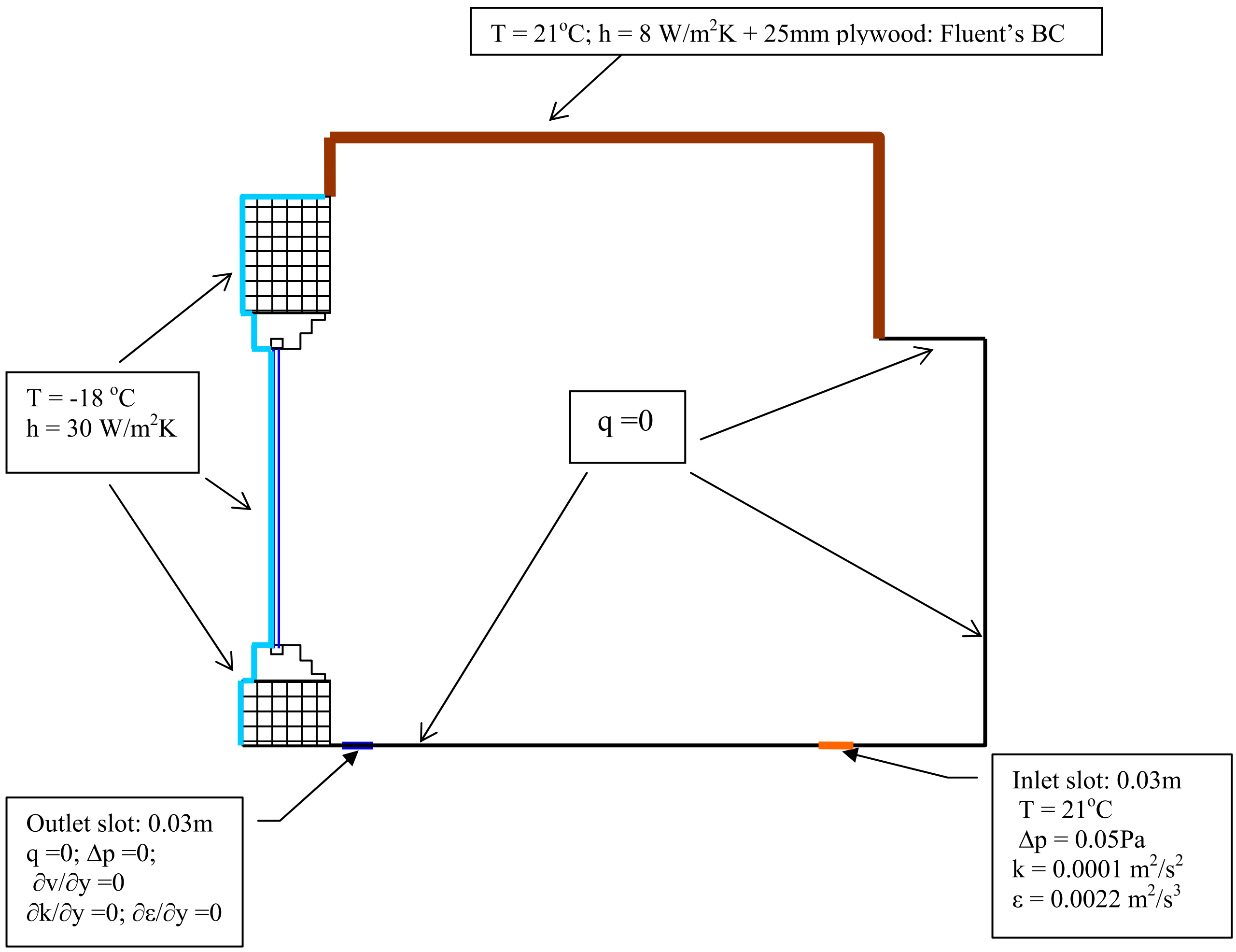


Figure 2. Boundary conditions of the modeled warm-side chamber.

2. The simplified model of the warm-side chamber with window

To tune turbulent low-Reynolds model we intend to use chamber model with simplified geometry of window (it is shown in Figure 3). Boundary conditions will be defined using experimental surface temperatures on glazing and frame. This model can be also used for comparison with available experimental data of heat transfer rate and velocity distribution along glazing and frame surfaces.

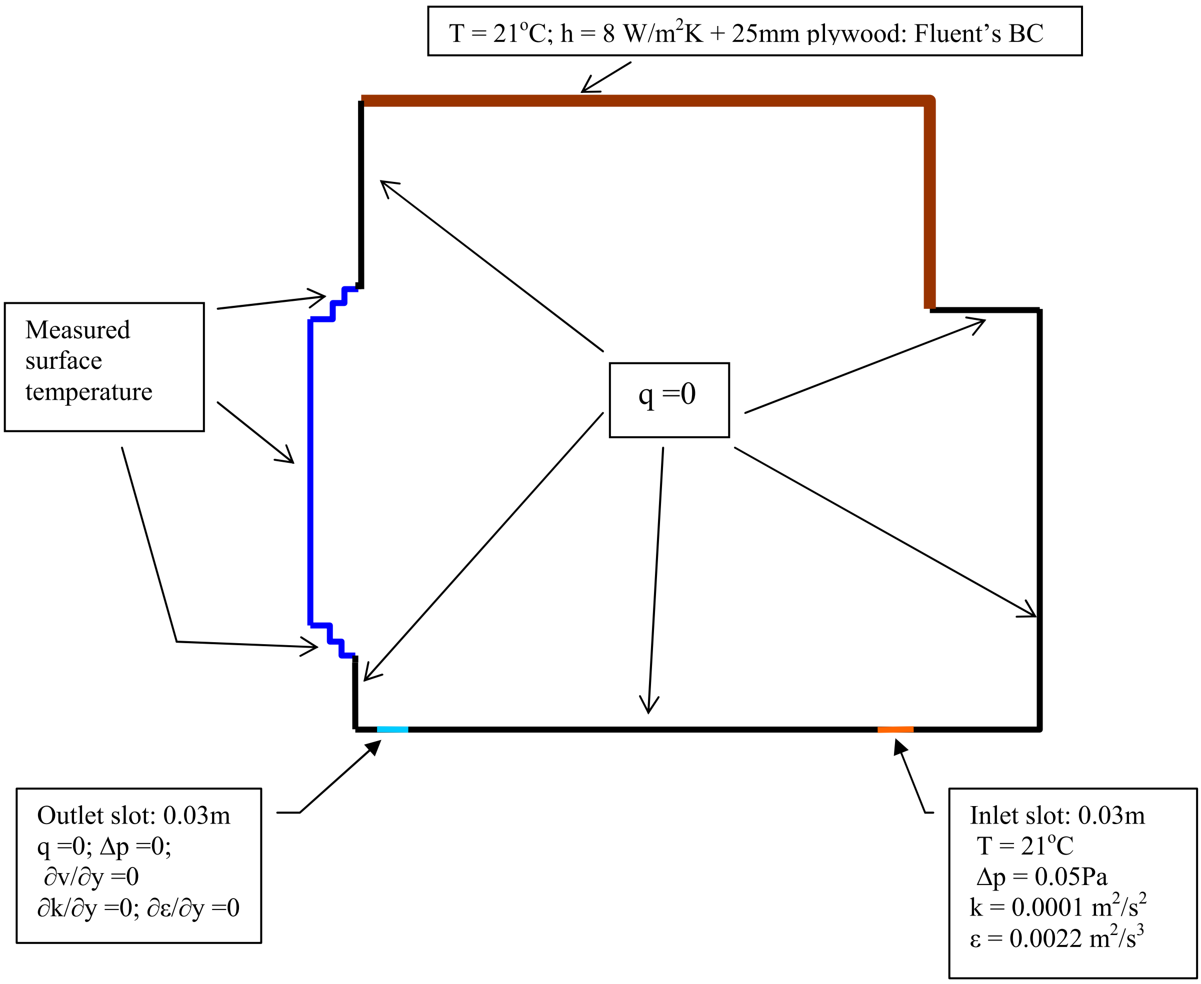


Figure 3. Boundary conditions of the simplified warm-side chamber with window.

3. The approach (method) how to merge separately meshed window model and chamber model to adequate describe convective flows in the chamber

In Figure 4 we represent one from possible variants of combining window and chamber models. The advantage of this approach is that we can describe bounder layer around any window without changing chamber mesh. It is obviously that window area mesh and chamber mesh will have non-conformal boundaries in the place of their intersection (red line in Figure 4) because they are creating independently.

If it is necessary to model windows with various height than we need to use more complicated scheme of connection of the chamber model with window model and beforehand create vertices on chamber model corresponding necessary window sizes because Fluent has some limitations of using non-conformal grids (section 5.4.2 [2]).
The example for two various windows is illustrated in Figure 5.

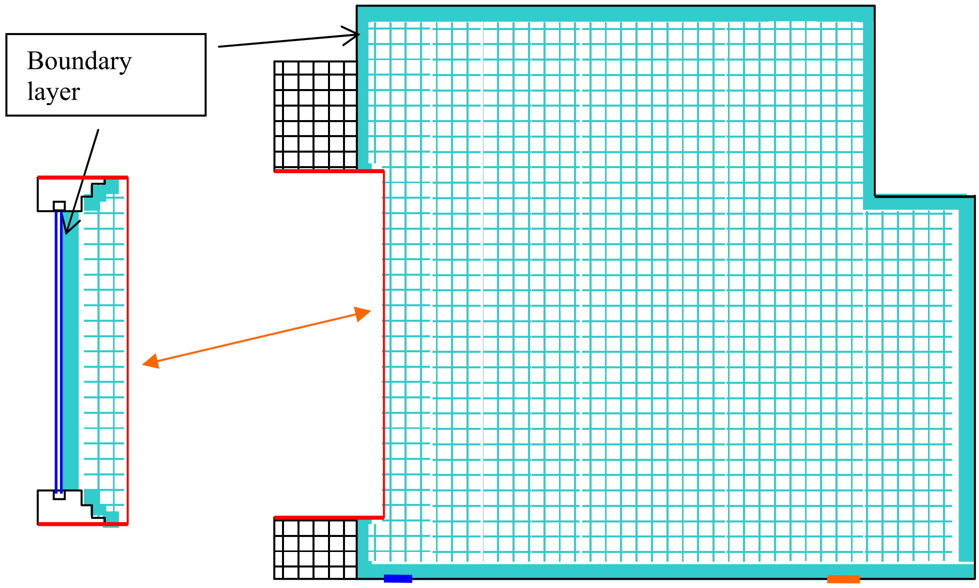


Figure 4. Scheme of connection of the chamber model with window model.

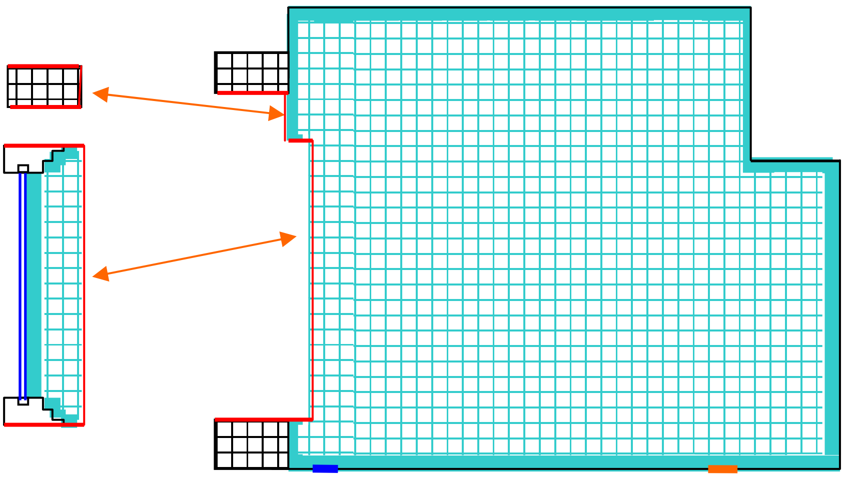


Figure 5. Exploded view of the chamber model prepared for testing of windows of two various sizes.

4. Some exercises of combining separately meshed window model and chamber model

To check what problems and difficulties can be encountered in process of combining and merging of separately meshed window and chamber models with non-conformal boundaries we prepared simplified models of window and chamber very close to Figure 4. We simulated natural laminar convection in the chamber (LxH = 0.3m x 0.4m) with single glass window under temperature difference 10^{o}C. The chamber mesh with boundary layer and window mesh were created by Gambit 1.3 [3] and show in Figure 6. To merge window and chamber meshes we used Fluent's utility ***tmerge*** ([1] Chapter 5. Reading and manipulating grids. Section 5.3.10, pp 5-27,5-30). To specify non-conformal boundaries we used Fluent's features and procedure described in section 5.4.3 of User's Manual [1] (pp 5-31,5-38).
In Figure 7 it is shown temperature distribution in the modeled chamber.

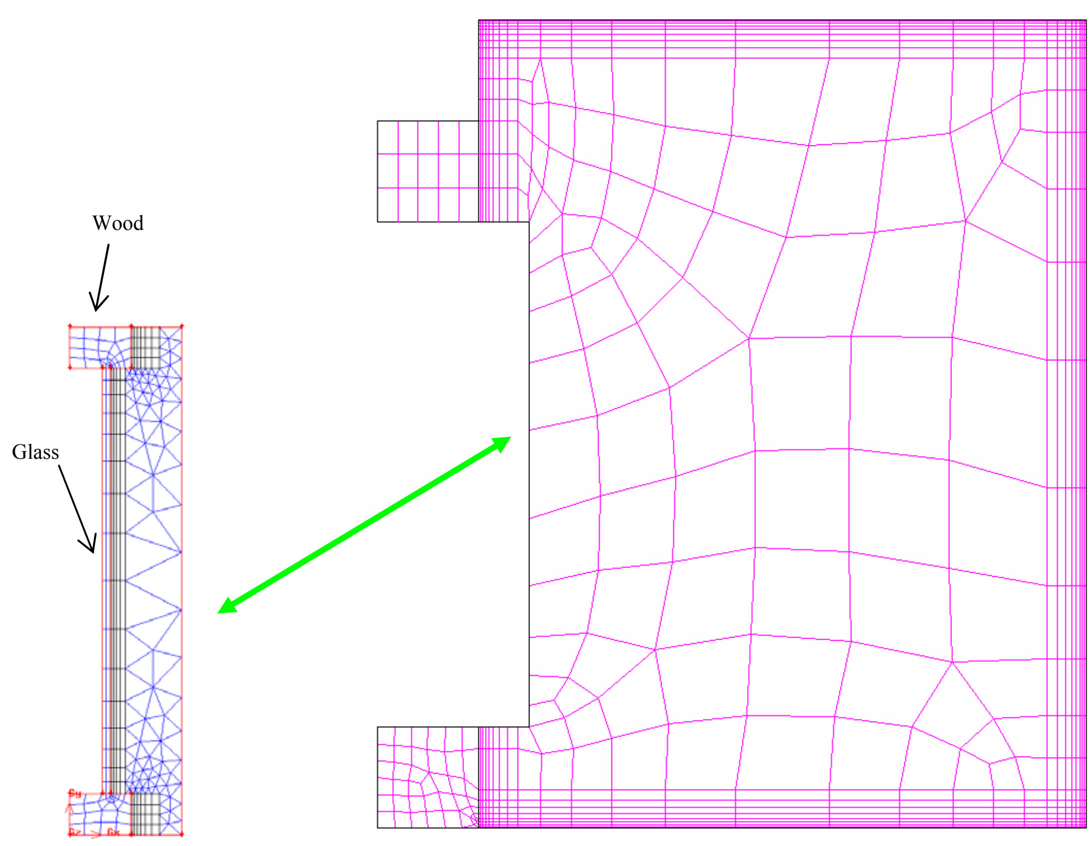


Figure 6. The example of meshing of window with adjoined air zone and chamber with insulation panel.

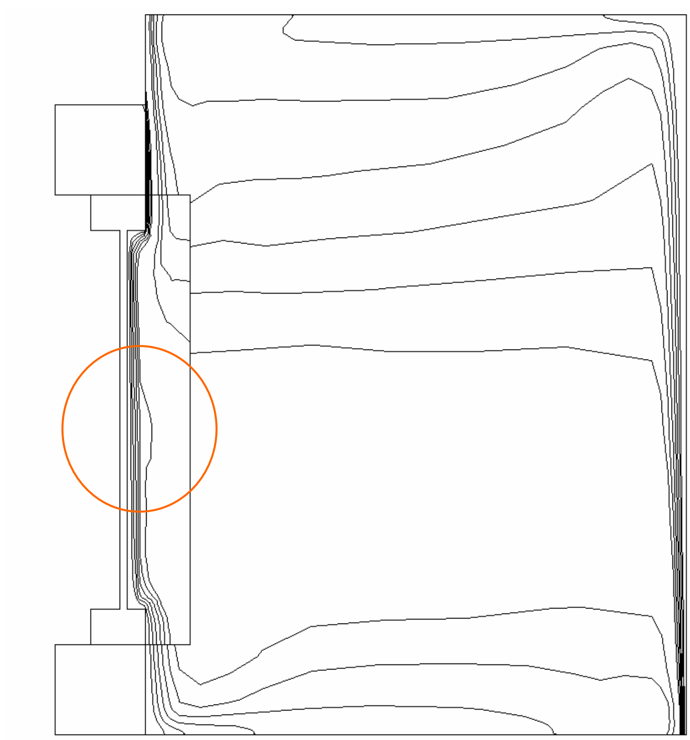
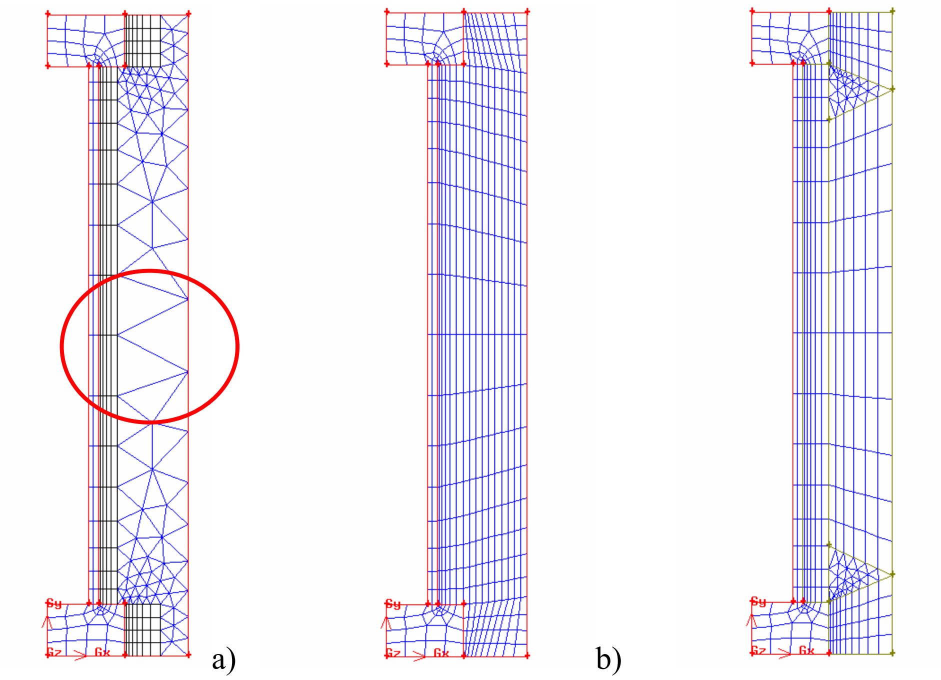


Figure 7. Temperature contours in the model of chamber with window.

It is not difficult to notice that obtained temperature field has distortion in the middle part of air zone adjusting to the window (marked by red circle). The reason is in not correct meshing this zone. In Figure 8 we show possible variants of meshing window and adjusting zone. It is a good tutorial example for student because to make right mesh need to have some experience and understanding of developing fluid flows in enclosure.



a) b) c)

Figure 8. Three samples of meshing window with adjoined air zone.

a) The mesh is simple and not difficult for creating but it is very coarse in the middle part (selected by red circle).
b) This mesh is very fine but require much more memory and time for calculation.
c) This mesh satisfies of all necessary demands but more complicated in creating and used some features of virtual geometry of Gambit [3].

In Figure 9 we show mesh of window (variant c)) that is merged with chamber mesh. Some part of simulation results are shown in Figures 9, 10.

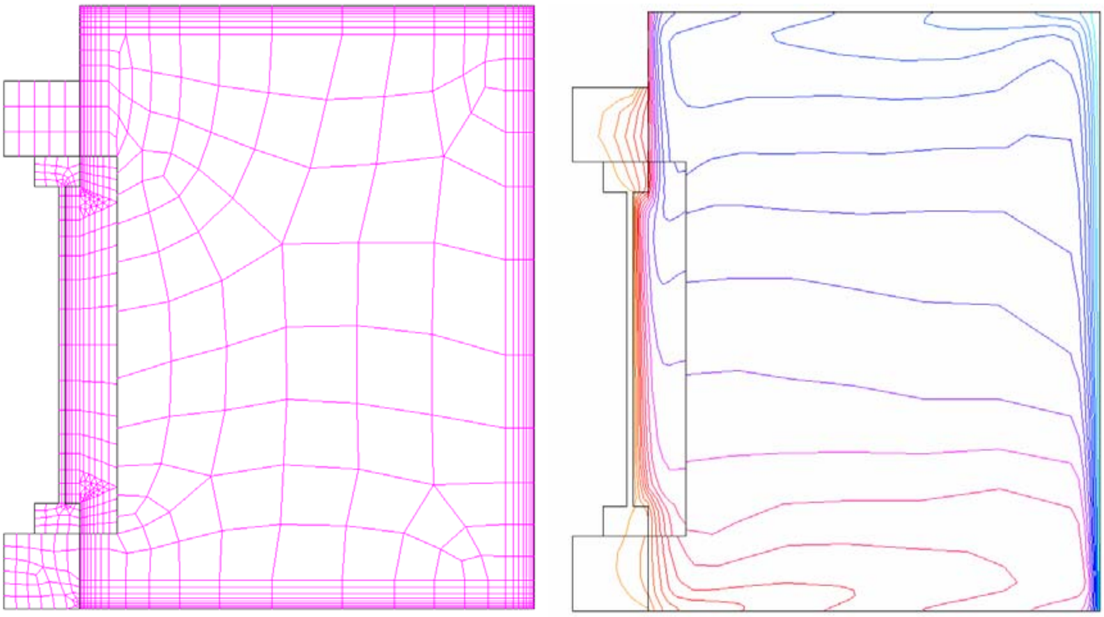


Figure 9. The model of the chamber with window and temperature contours in ones.

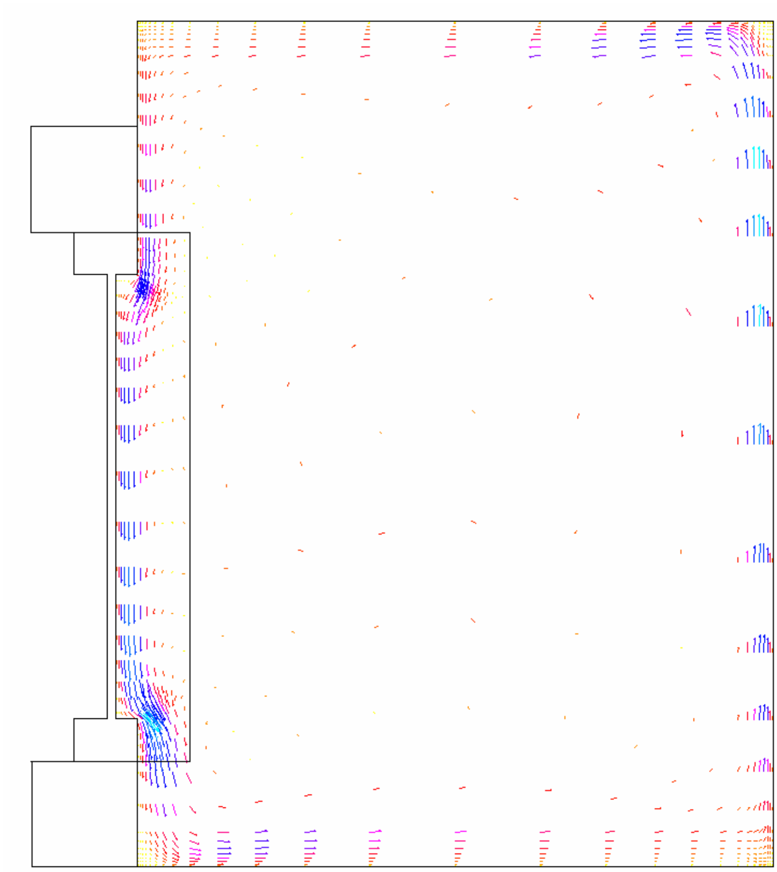


Figure 10. Velocity vector field in the model of the chamber with window.

REFERENCES

1. “Experimental Techniques for Measuring Temperature and Velocity Fields to Improve the Use and Validation of Building Heat Transfer Models”, laboratory report LBL, CEERE UMASS, draft, 199? .
2. FDI 2001. FLUENT 6.0. Users and Reference Manual. Fluid Dynamics International, Fluid Dynamics Analysis Package. Fluent Inc. November 2001.
3. FDI 2000. “Gambit 1.3.2 Users and Reference Manual”. Fluid Dynamics International, Fluid Dynamics Analysis Package Revision 1.3.2, Evanston, IL.