Energy Conservation in Buildings and in Community Systems

Annex 20: Air Flow Patterns Within Buildings
Subtask 1: Room Air and Contaminant Flow

Research Item No 1.46

Simulation of Simple Test Cases

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1. Introduction

As proposed in IEA Annex 20, a two-dimensional case, for which detailed experimental data are available, has been specified by Nielsen [1] to test different CFD codes. This report presents the results computed by the FLUENT code and the comparison between the computed results of this report and Chen [2] and between measured results presented by Nielsen [1].

2. Simulation Method

2.1 Equations

To take into account the turbulent effects of the flow, the standard k-ε turbulence model for high-Reynolds-number flows [3] was solved in addition to the equations of momentum, continuity and energy. In addition to the Power-law differencing scheme [4] the isothermal test case was simulated by using the QUICK differencing scheme [5].

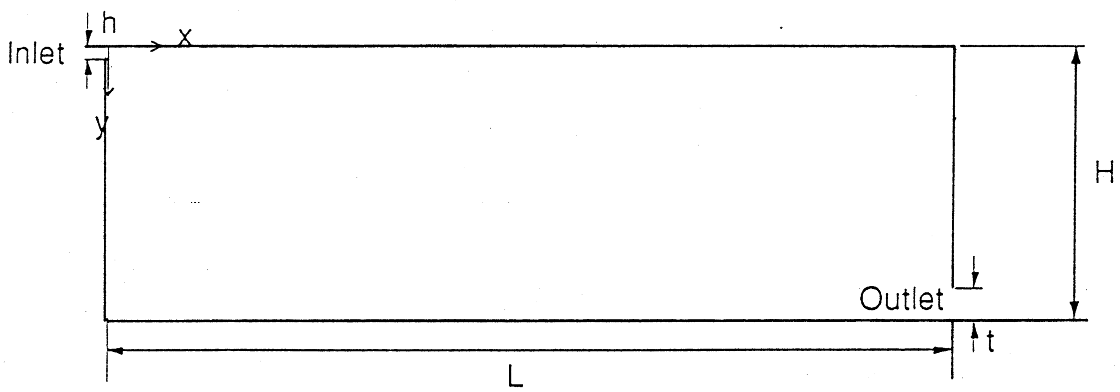

Figure 1: Sketch of the two-dimensional test case

2.2 Wall Functions

To save computing time and memory, wall functions for turbulent flows have been used. FLUENT employs the log-law of the wall according to Launder and Spalding [3] to compute the wall shear stress in the turbulent flow.

3. Test Case

The computations are carried out for two test cases: an isothermal case and a non-isothermal case as shown in figure 1. The geometry of the test case is L/H=3.0, h/H=0.056, and t/H=0.16, where H=3.0 m. The inlet conditions are specified by a Reynolds number:

$$Re = \frac{h\ u_o}{\nu} = 5000$$

where the kinematic viscosity ν for air is 15.3 $10^{-6} m^2/s$ at 20°C. The inlet velocity can then be determined as u_o=0.455m/s.

The inlet conditions for turbulent kinetic energy k and dissipation rate ε are given by:

$$k_o = 1.5\ (0.04\ u_o)^2$$

and

$$\varepsilon_o = \frac{k_o^{1.5}\ 10}{h}$$

For the non-isothermal case, the aim is to predict flows with strong buoyancy effect. A constant heat flux is added along is added along the floor so that the cold jet may deflect from the ceiling before it reaches the end wall. The buoyancy effect is weighted by the Archimedes number defined as:

$$Ar = \frac{\beta\ g\ h\ \Delta T_o}{u_o^2}$$

where β, g and ΔT_o are volume expansion coefficient, gravitational acceleration and temperature difference between return and supply, respectively.

The simulation of both test cases, isothermal and non-isothermal, was performed in a finite difference grid of 56 cells in x-direction, 62 cells in y-direction.

4. Results and Discussion

4.1 Isothermal Test Case

Figure 2 shows the field distributions of air velocity and turbulent kinetic energy.

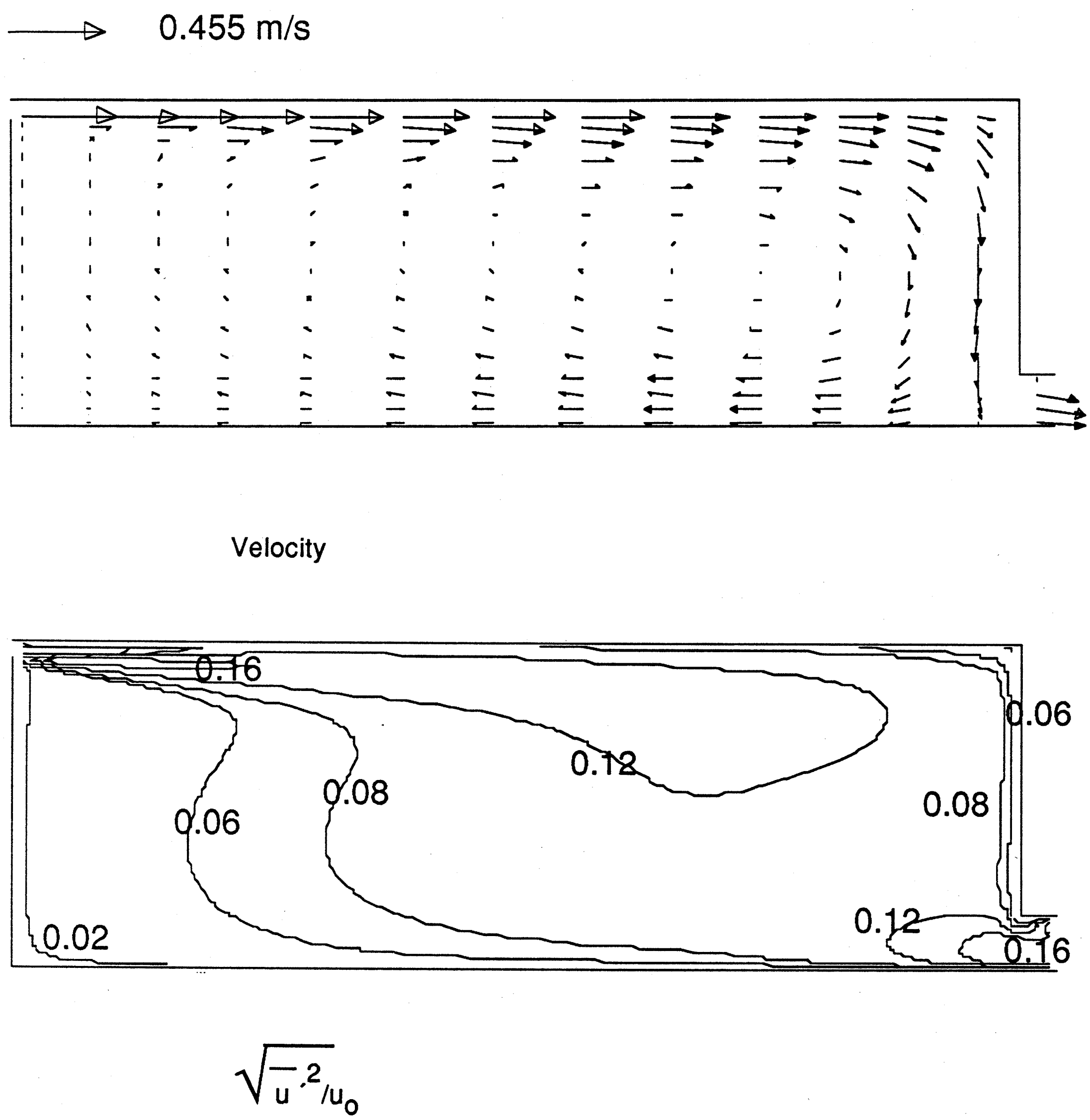

Figure 2: Field distributions of air velocity and turbulent intensity.

Figure 3 compares the computations of Chen, presented in [2], with the simulations performed with FLUENT using the Power-Law differencing scheme [3], the QUICK-differencing scheme [6] and the measurements of Nielsen [1]. Figures 4- 6 illustrate the comparsion between the computed profiles of air velocity and turbulent intensity and the corresponding experimental data provided by Nielsen [1].

According to Nielsen [1] the turbulent intensity is calculated from

$$\sqrt{k} = 1.1 \sqrt{\overline{u'^2}}.$$

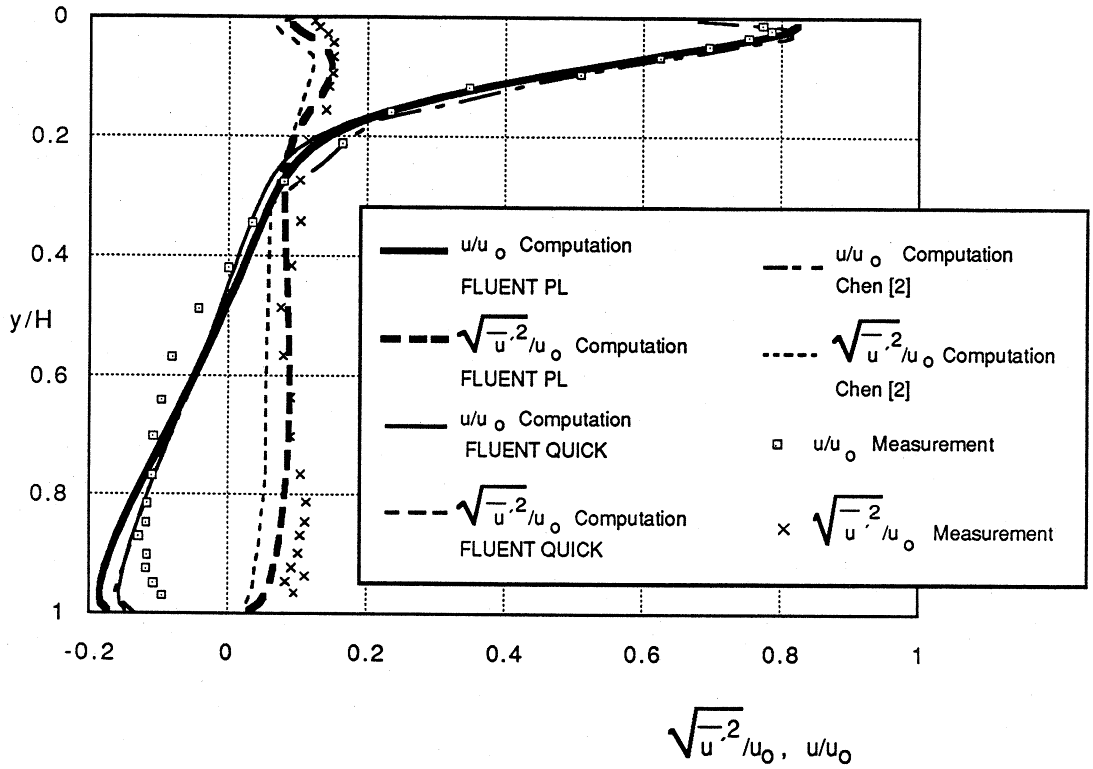

Figure 3: Comparison between the computed (FLUENT QUICK, FLUENT PL, Chen[2]) and measured (Nielsen [1]) mean velocity and turbulent intensity in section x/H= 1.0.

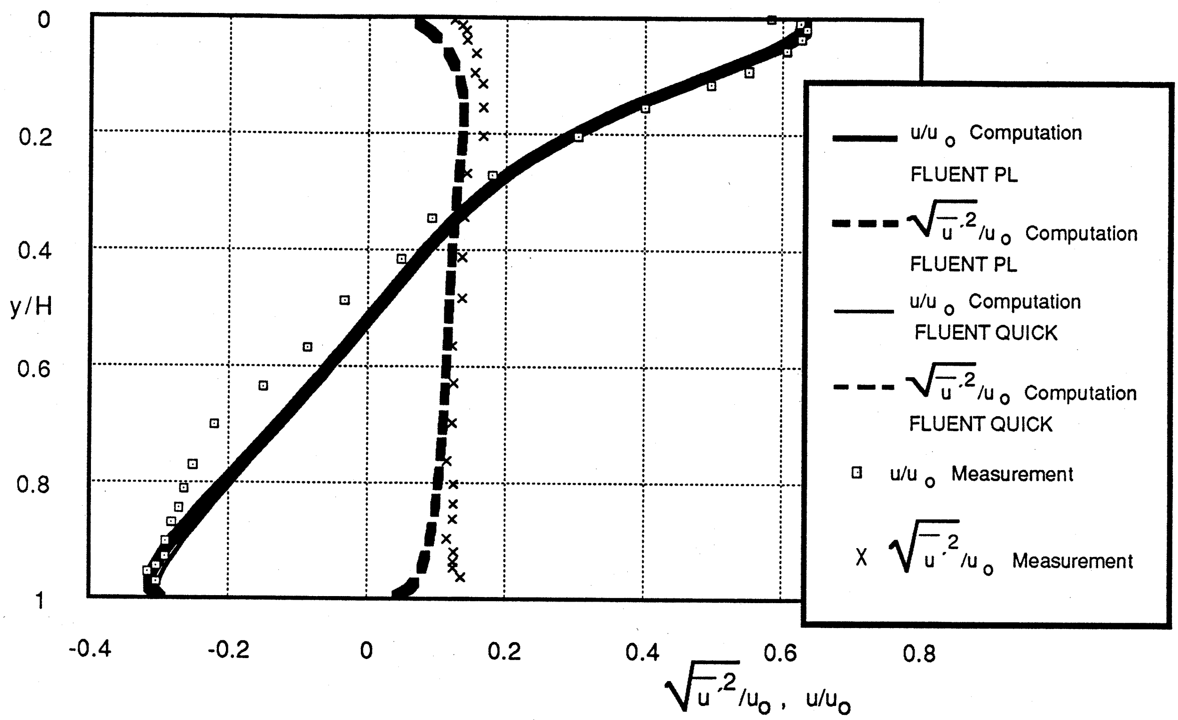

Figure 4: Comparison between the computed (FLUENT QUICK, FLUENT PL) and measured (Nielsen [1] mean velocity and turbulent intensity in section x/H= 2.0.

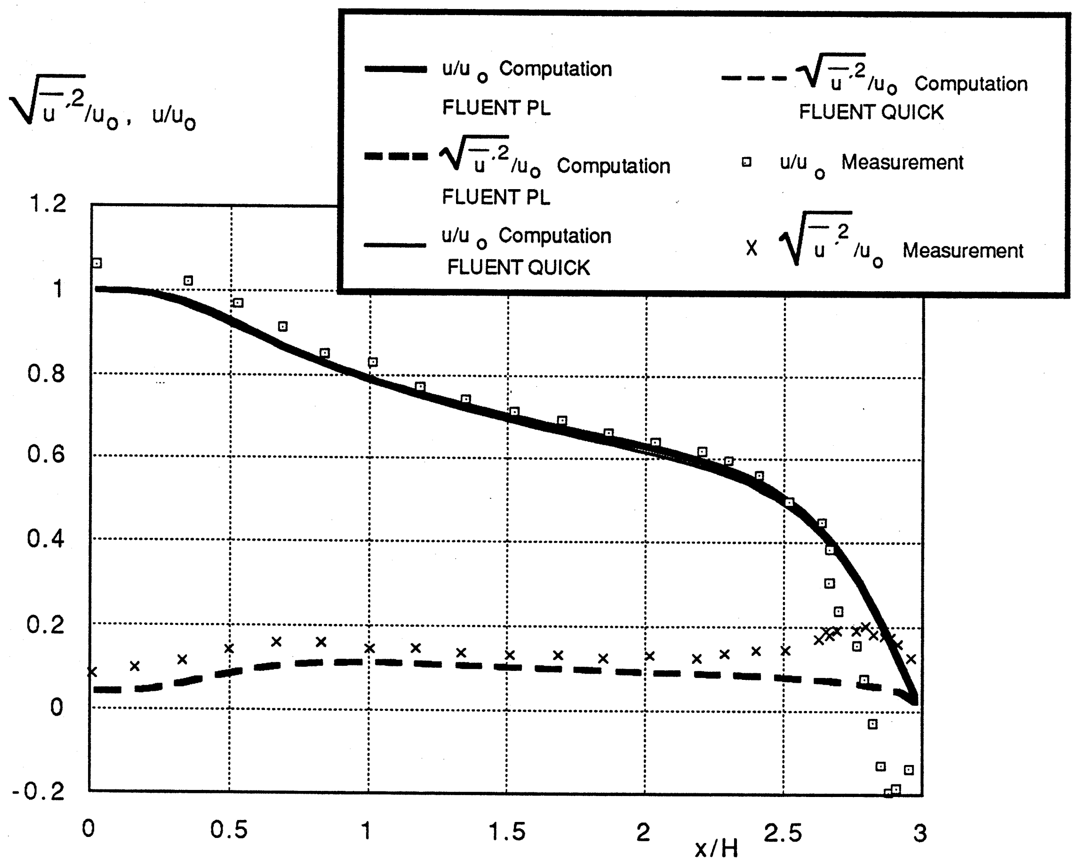

Figure 5: Comparison between the computed (FLUENT QUICK, FLUENT PL) and measured (Nielsen [1]) mean velocity and turbulent intensity in section y = h/2.

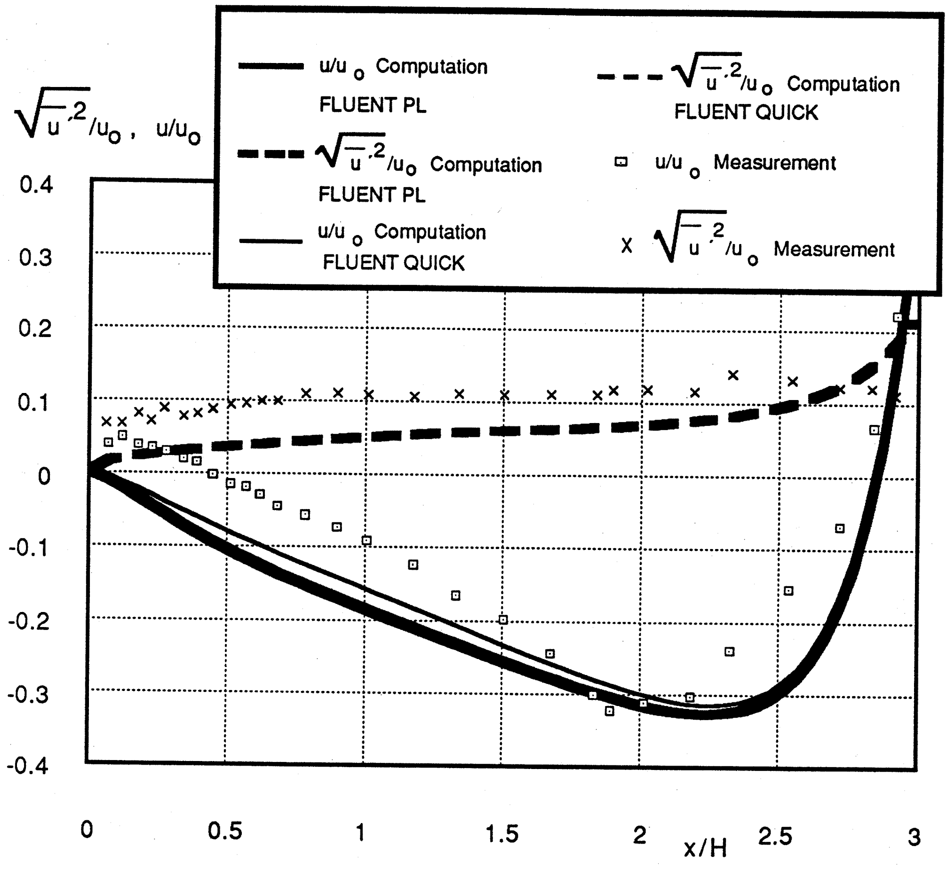

Figure 6: Comparison between the computed (FLUENT QUICK, FLUENT PL) and measured (Nielsen [1]) mean velocity and turbulent intensity in section y = H-h/2.

4.2 Non-isothermal test case

According to the suggestion by Nielsen [1], the Archimedes number is increased until a reduced penetration depth takes place. This is shown in Figure 7 with different opening dimensions. The results of the computations show a different behavior At Archimedes numbers up to Ar=0.15 the jet still reaches to the end of the wall. At Archimedes numbers higher than Ar=0.16 the jet immediately falls down. The results were independent on the starting conditions. Chen [2] get comparable results, with a turning Archimedes number of Ar=0.143, however.

The fields of flow and temperature can be seen in figure 8 and figure 9.

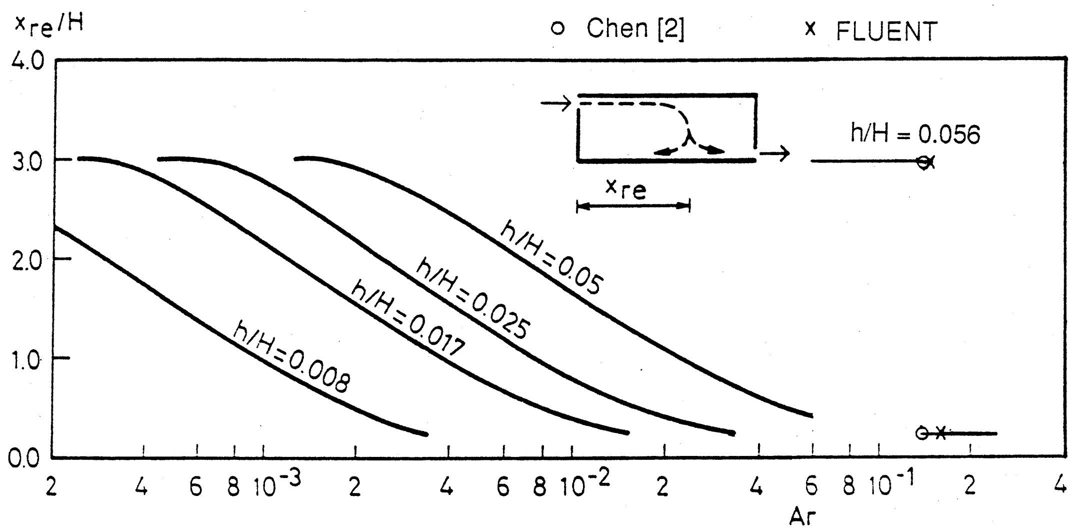

Figure7: Penetration depth x_{re} in models with different geometry

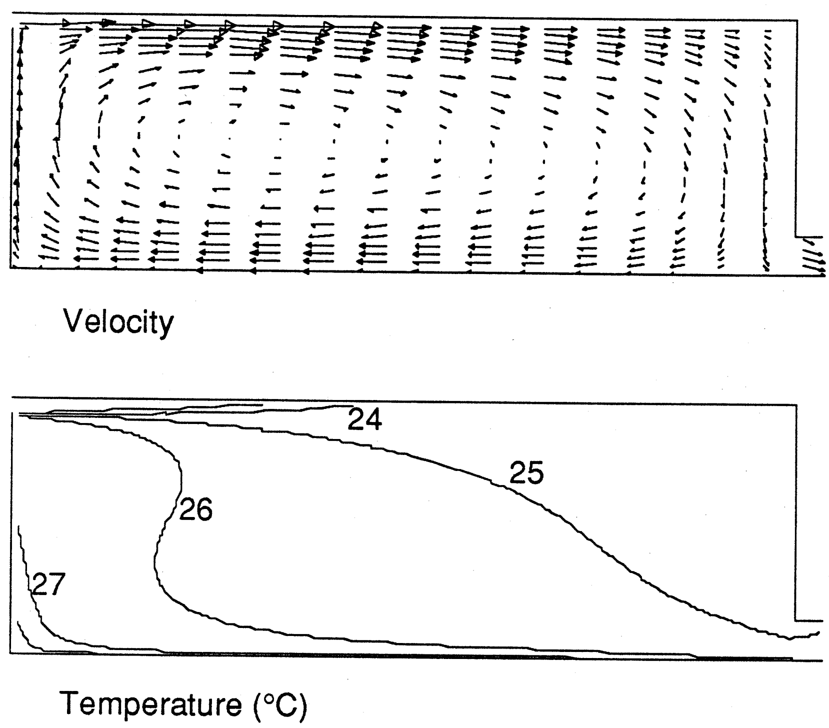

Figure 8: Velocity and temperature distributions when Ar=0.15

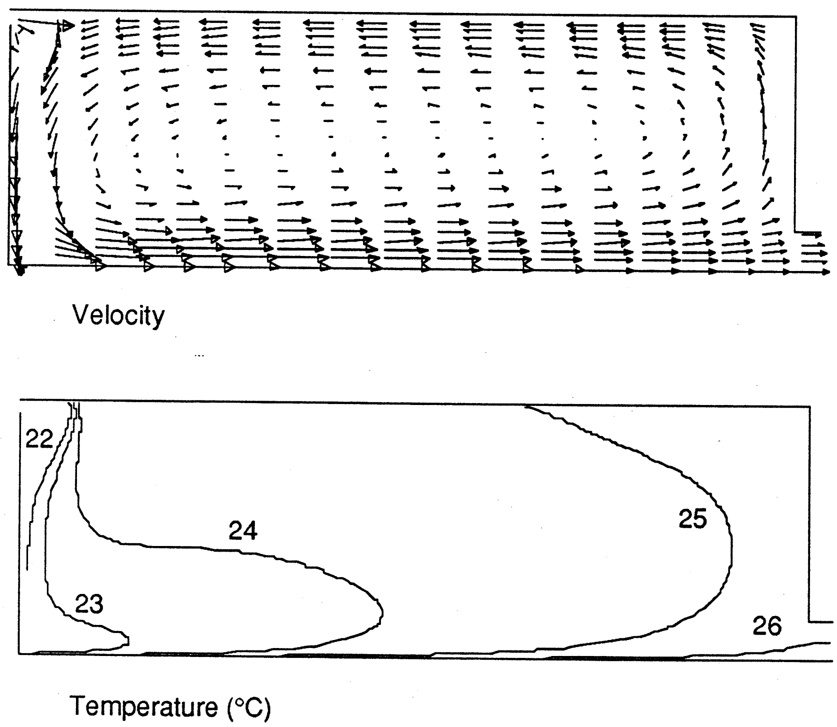

Figure 9: Velocity and temperature distributions when Ar=0.16

References

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