Wind Effects on Atrium Fires

2d & 3d Generic Studies

May 2010

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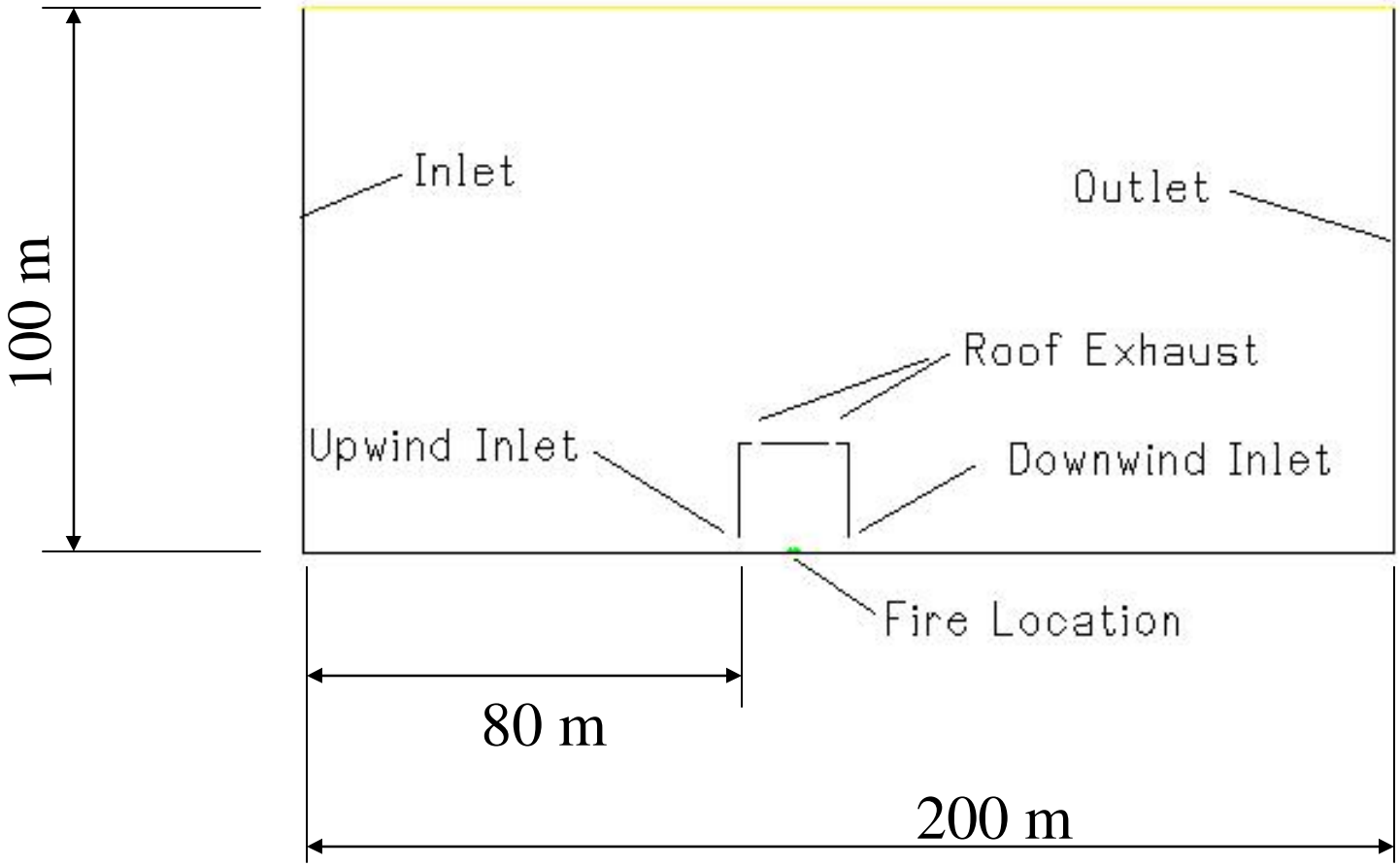
CWE2010
Durham NC

Two Dimensional Atrium

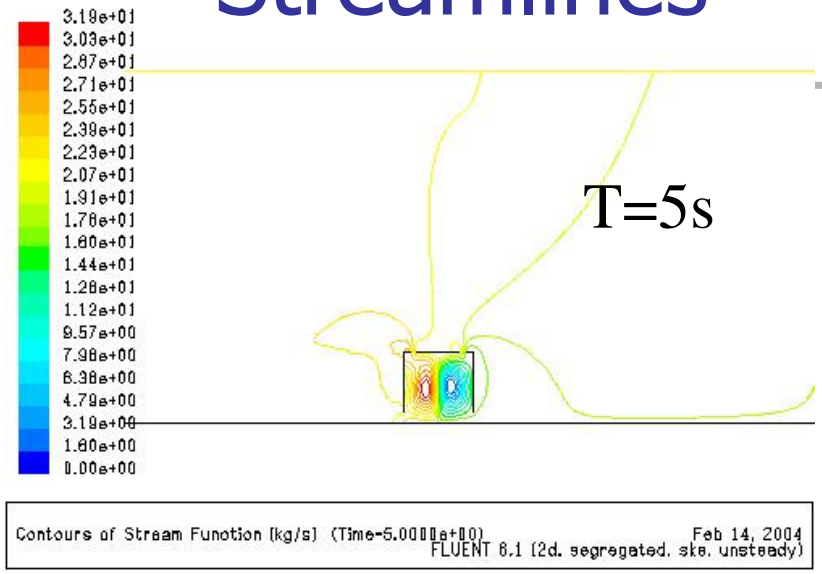
Bldg Size = 20 x 20 m, Inlets = 3 m, Exhausts = 2 m

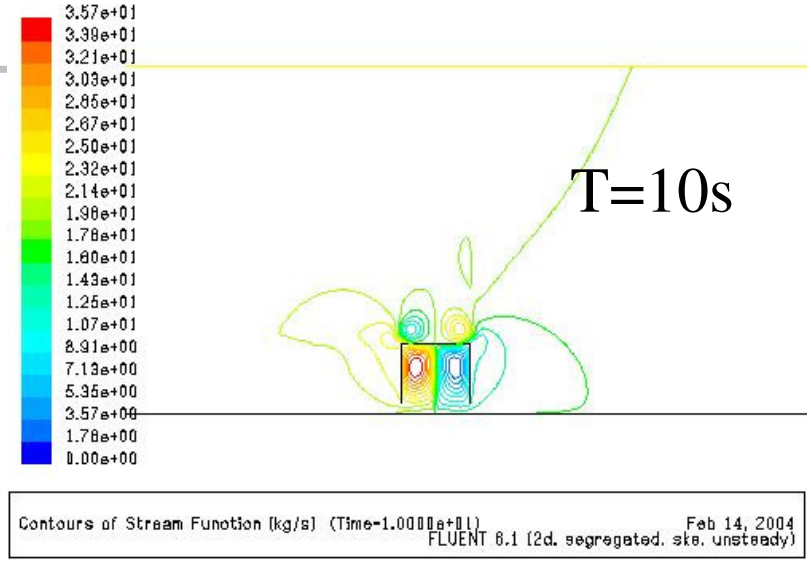


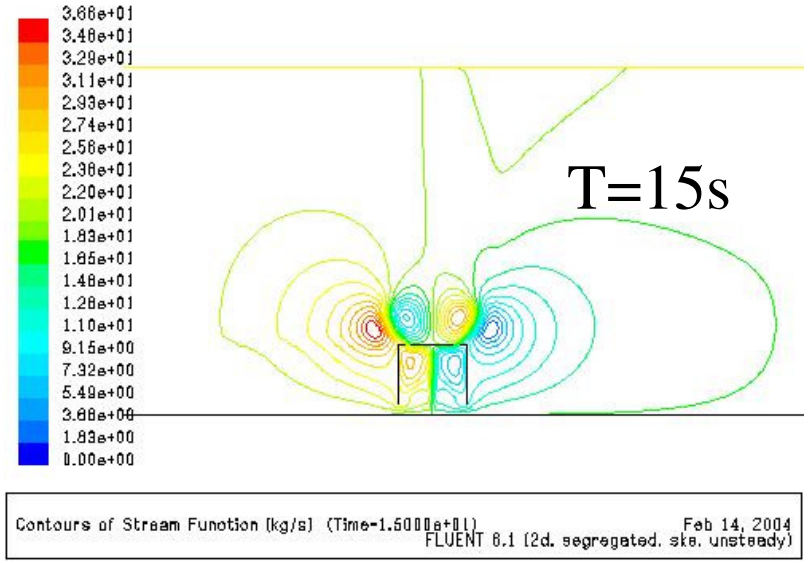
Computational Details

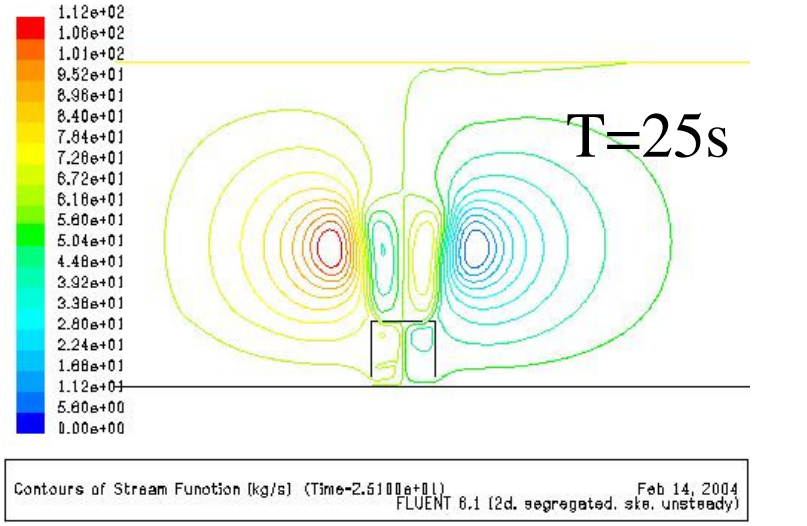
- CFD Model: Fluent 6
- Kappa-Epsilon turbulence model
- First order accuracy
- Uniform flow inlet, U = 0, 0.5 & 1.0 m/s
- Grid: Hexagonal 80,000 cells
- Time step = 0.1 sec
- Fire strength = 1,000,000 $W/m^2/m$

Up & Downwind Inlets: U=0 Streamlines

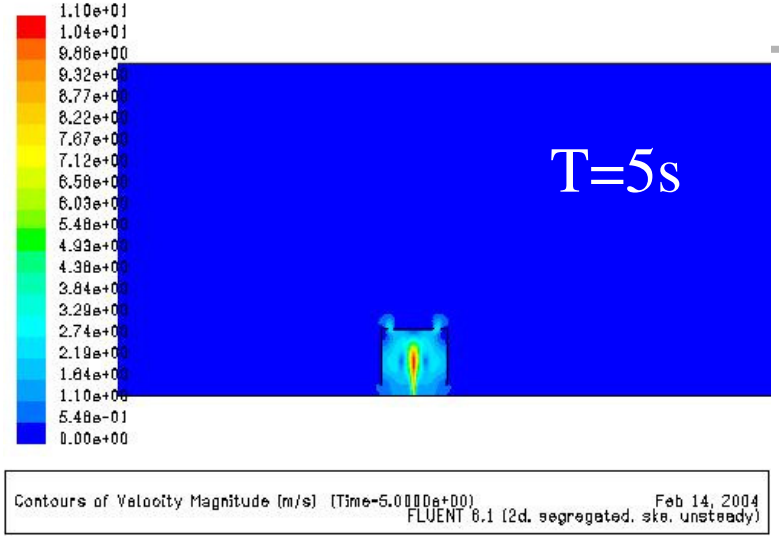


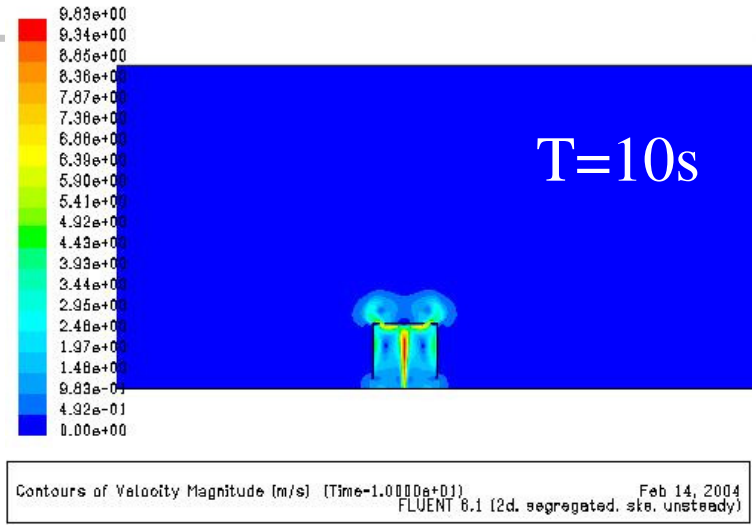


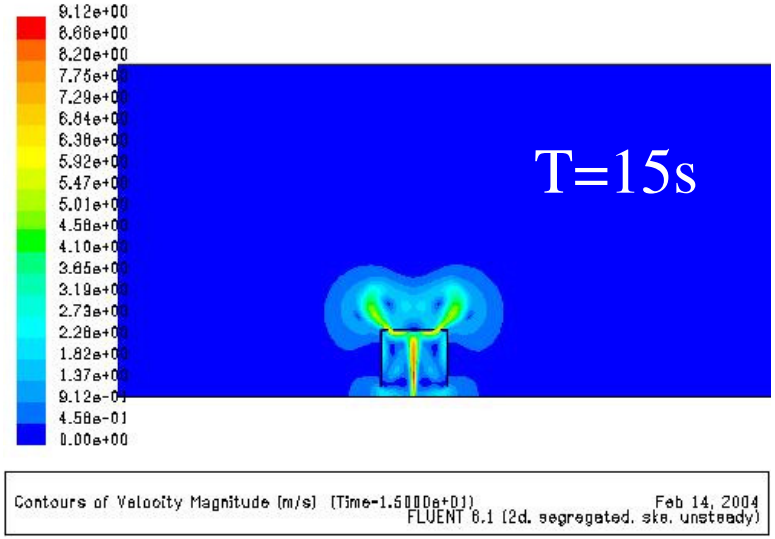


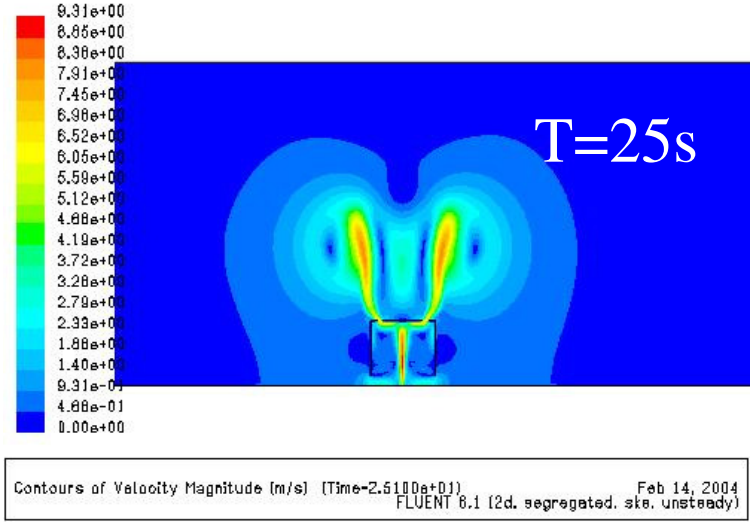


Up & Downwind Inlets: U=0 Velocity Magnitude Contours

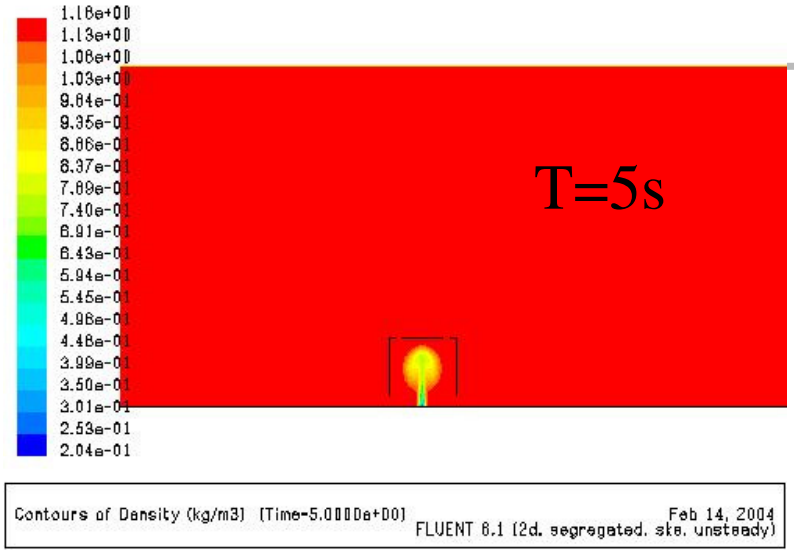


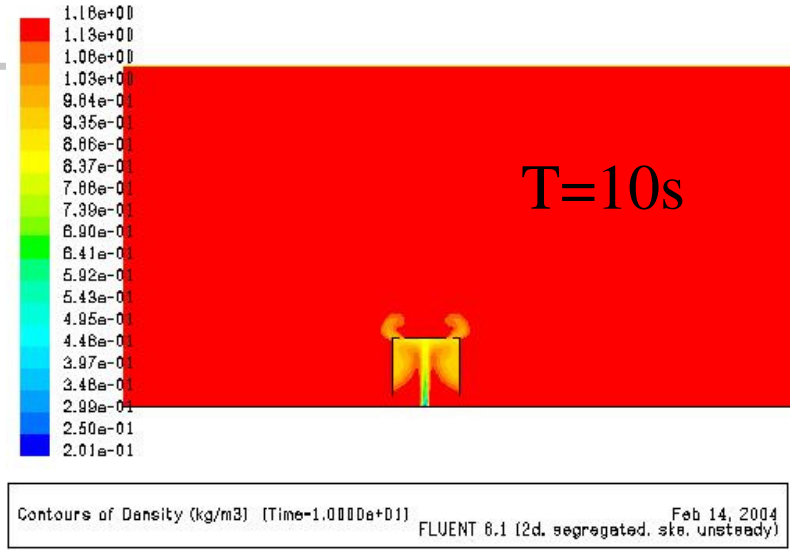


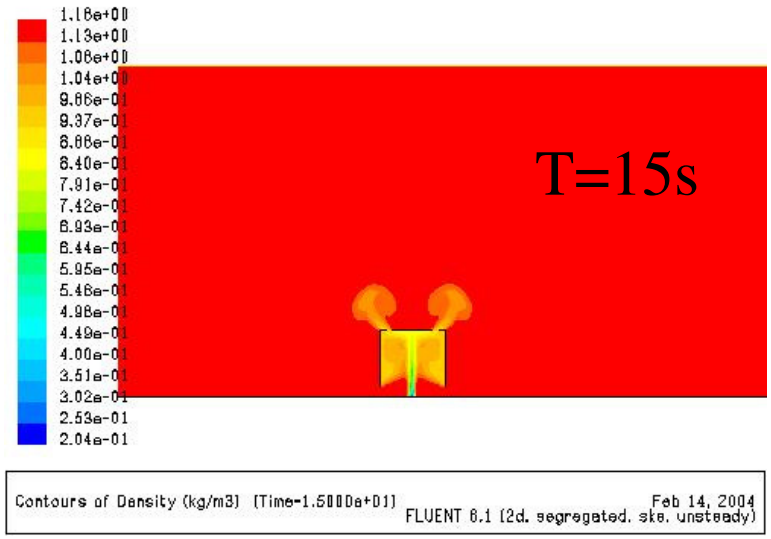


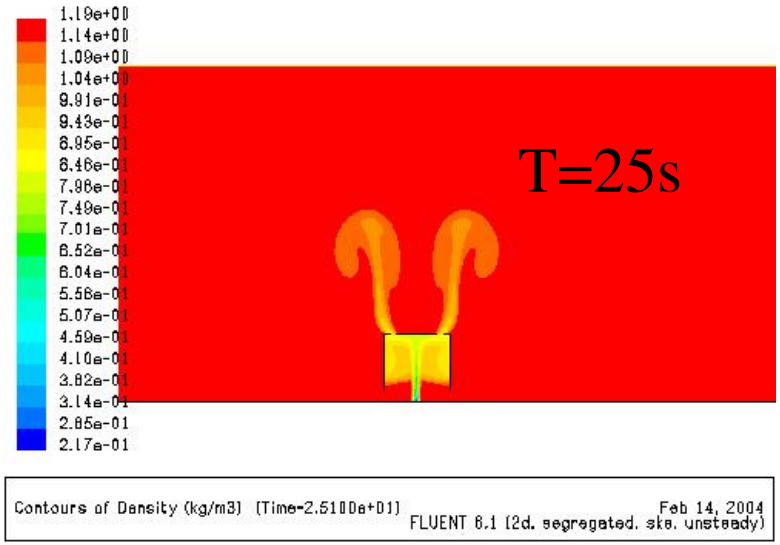


Up & Downwind Inlets: U=0 Density Contours

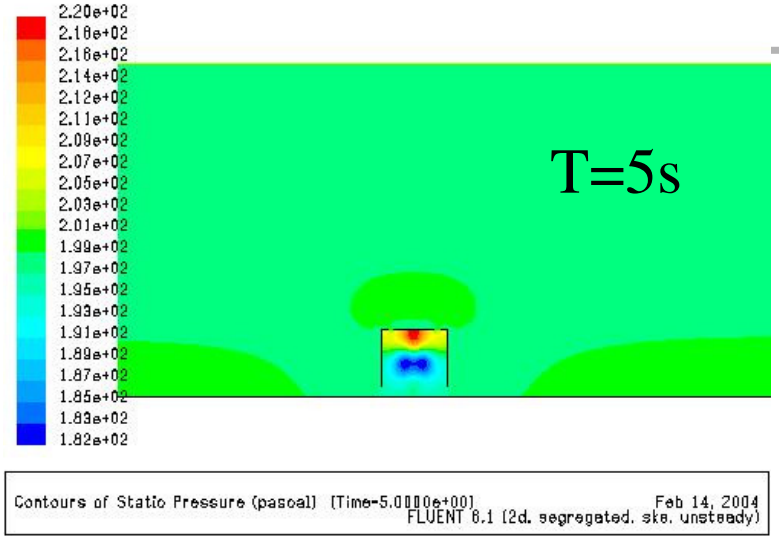


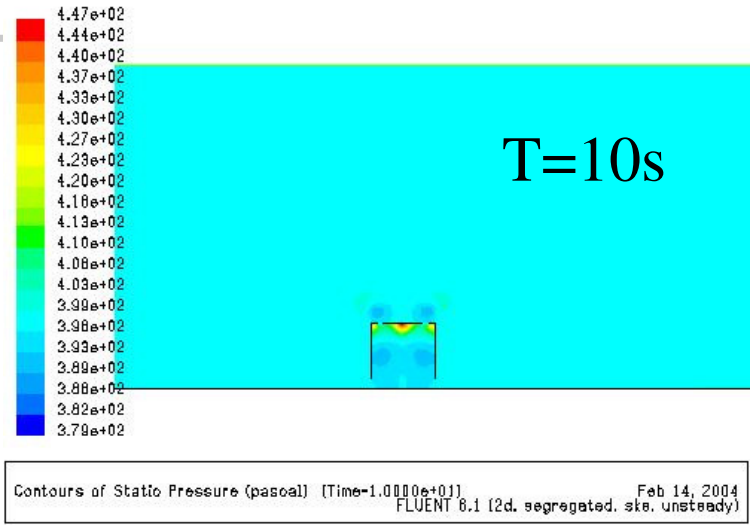


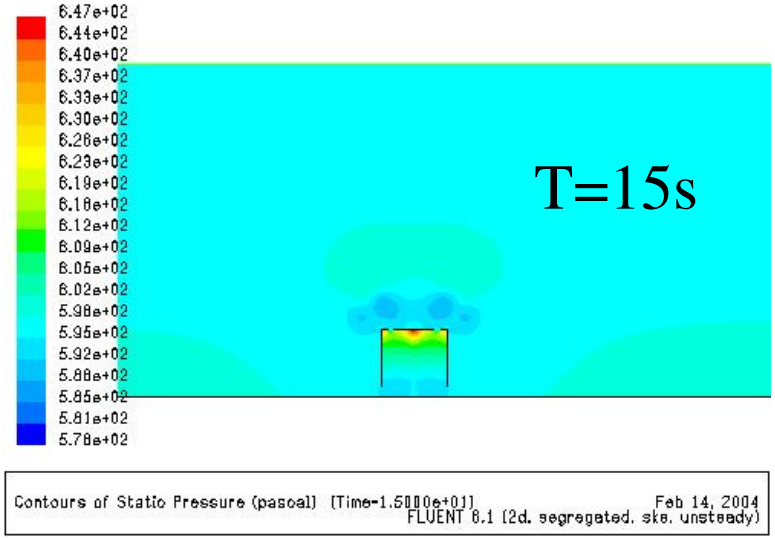


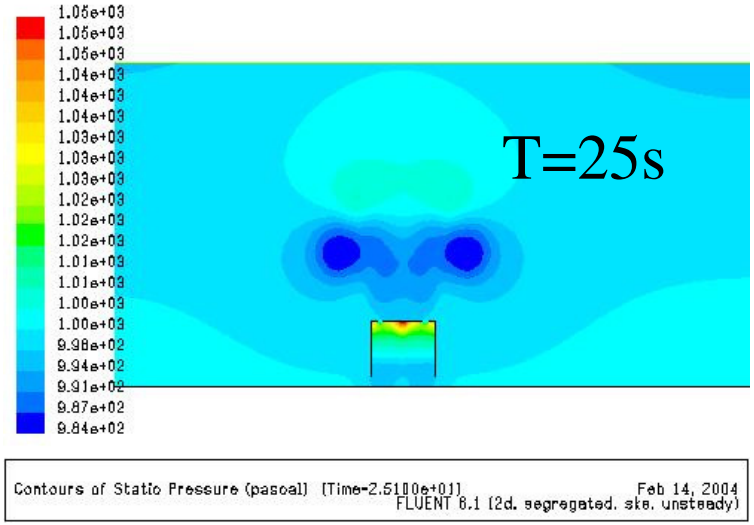


Up & Downwind Inlets: U=0
Static Pressure Contours

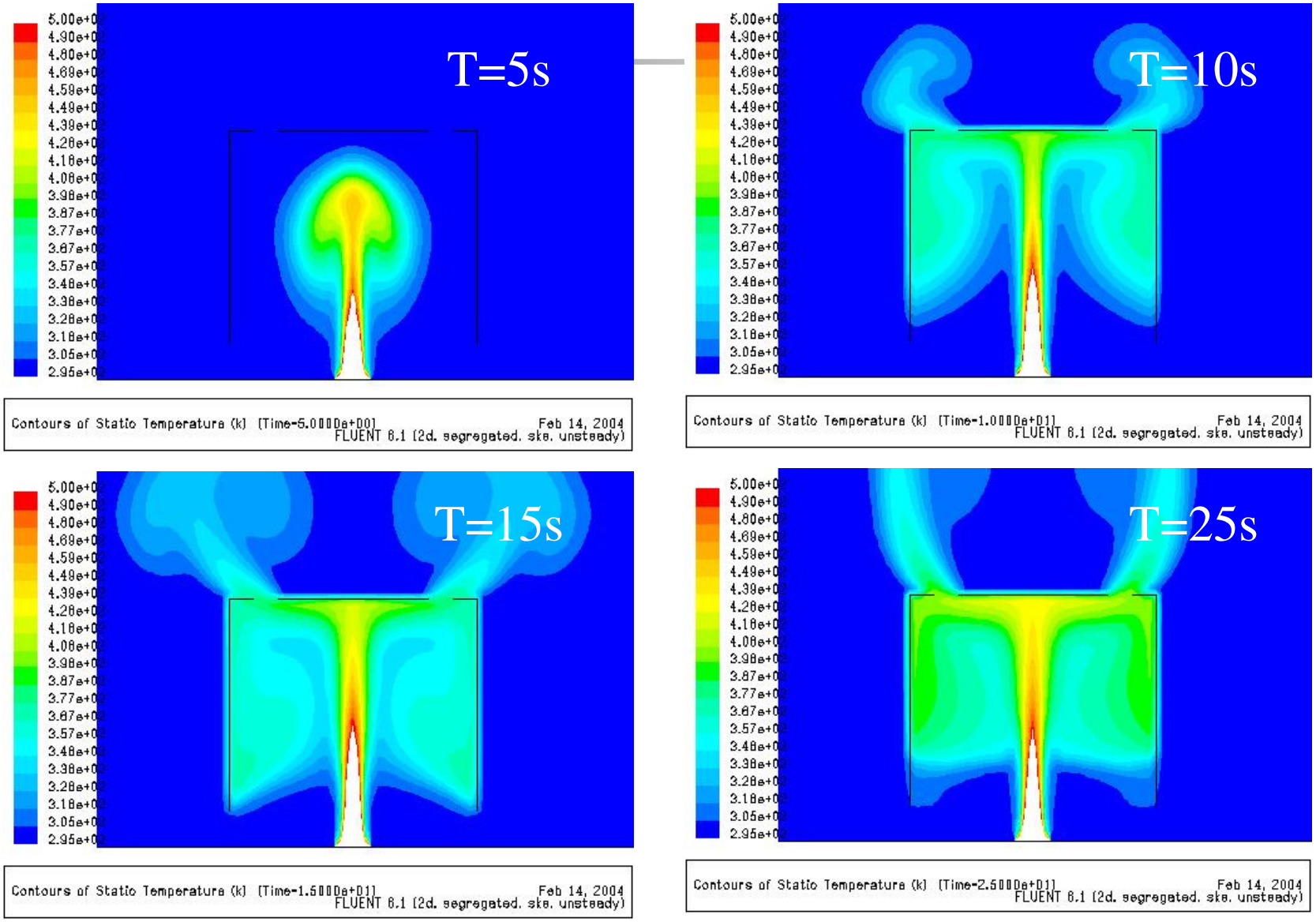




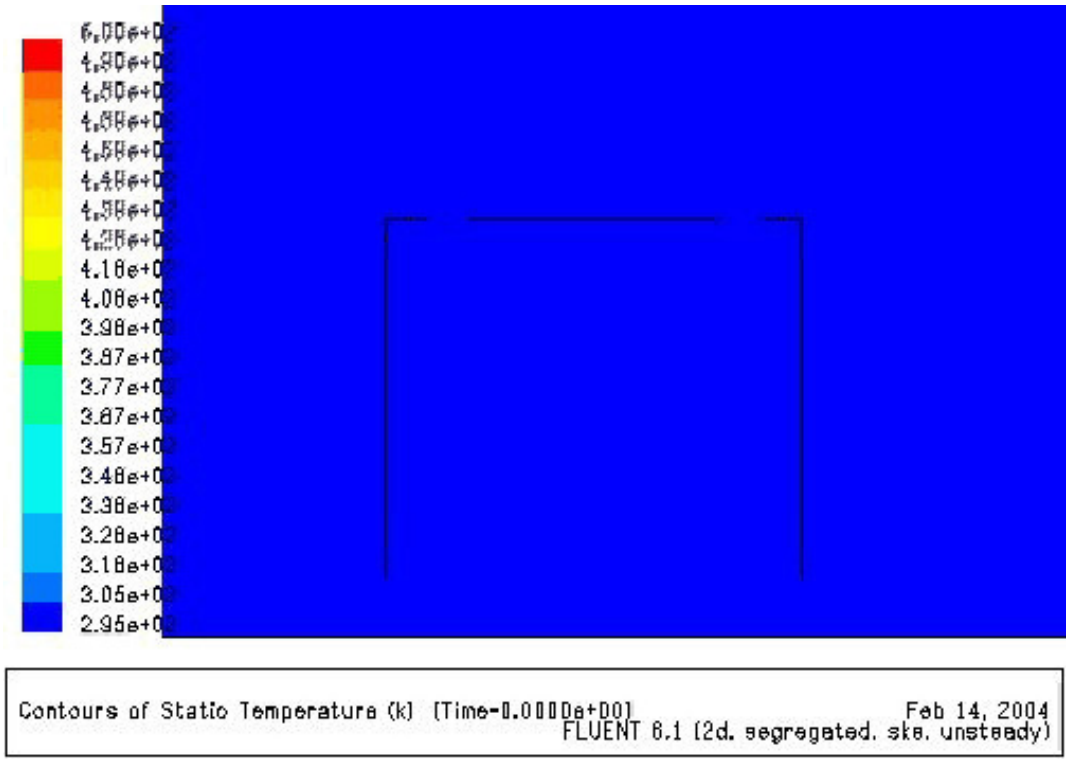




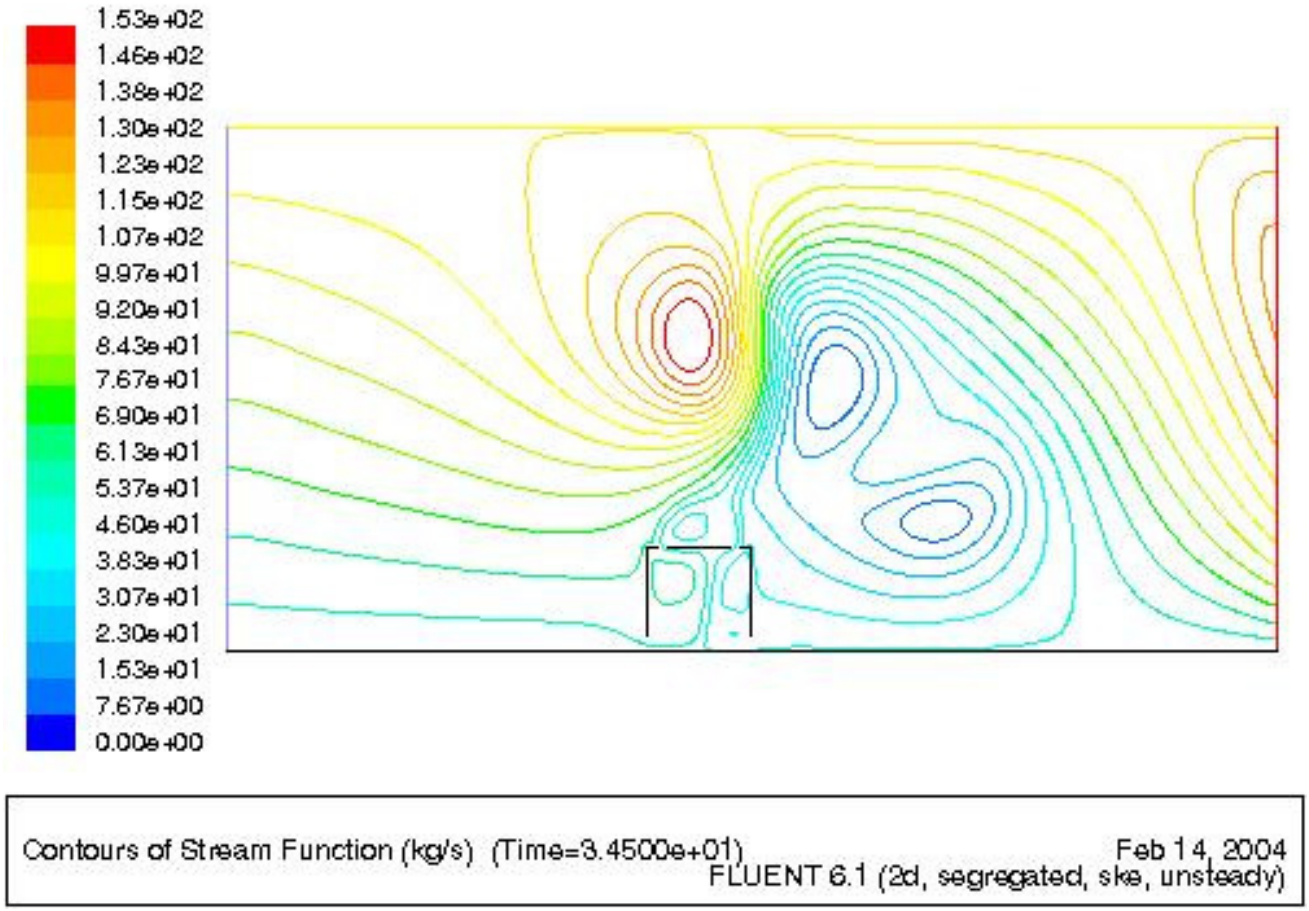
Up & Downwind Inlets: U=0 Temperature Contours



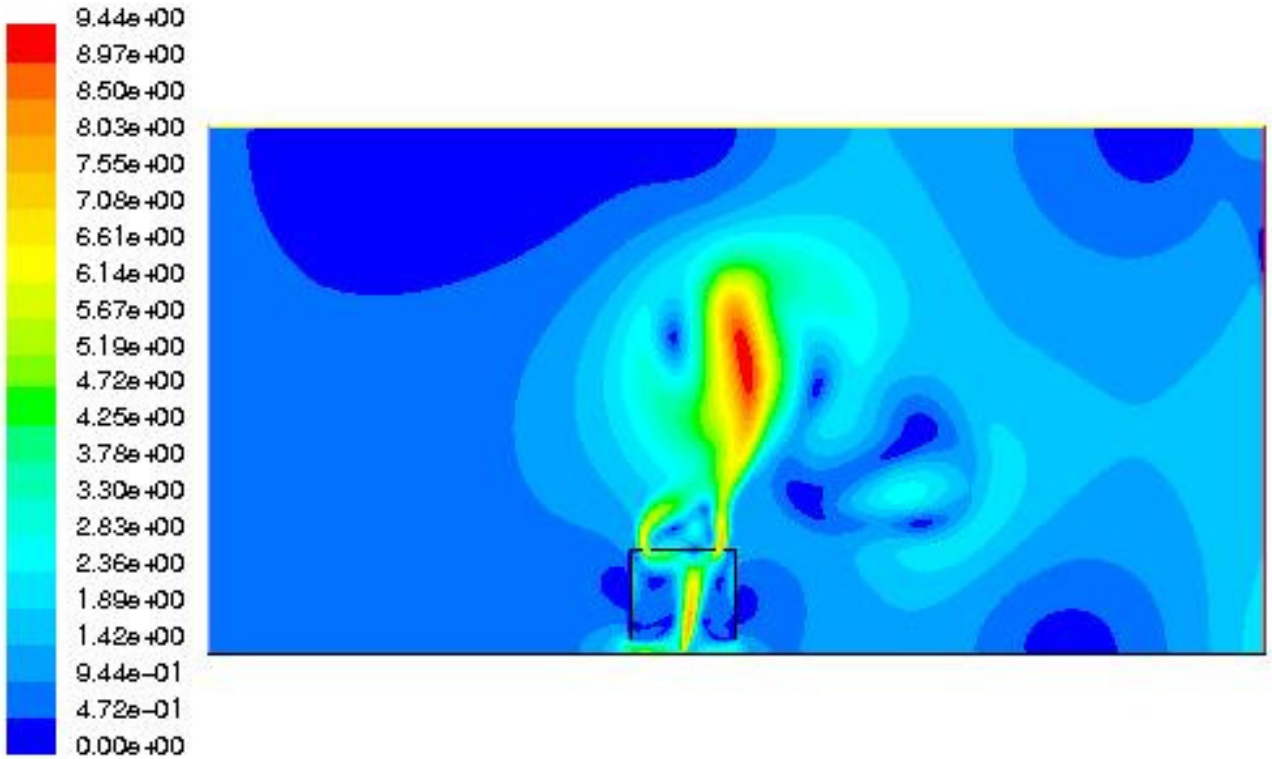
Up & Downwind Inlets: U=0 Temperature Contours Animation



Up & Downwind Inlets: U=0.5m/s Streamlines

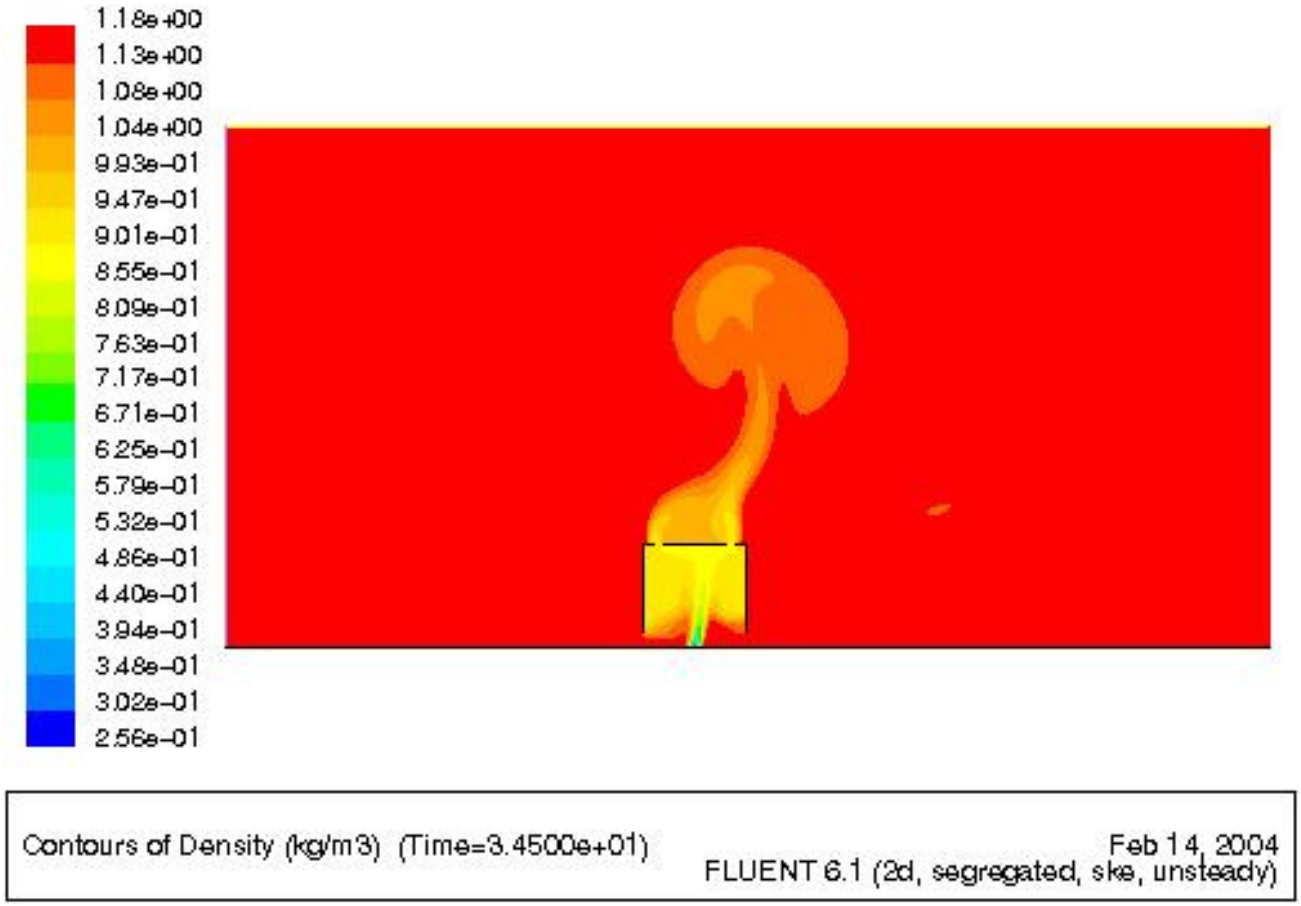


Up & Downwind Inlets: U=0.5m/s Velocity Magnitude Contours

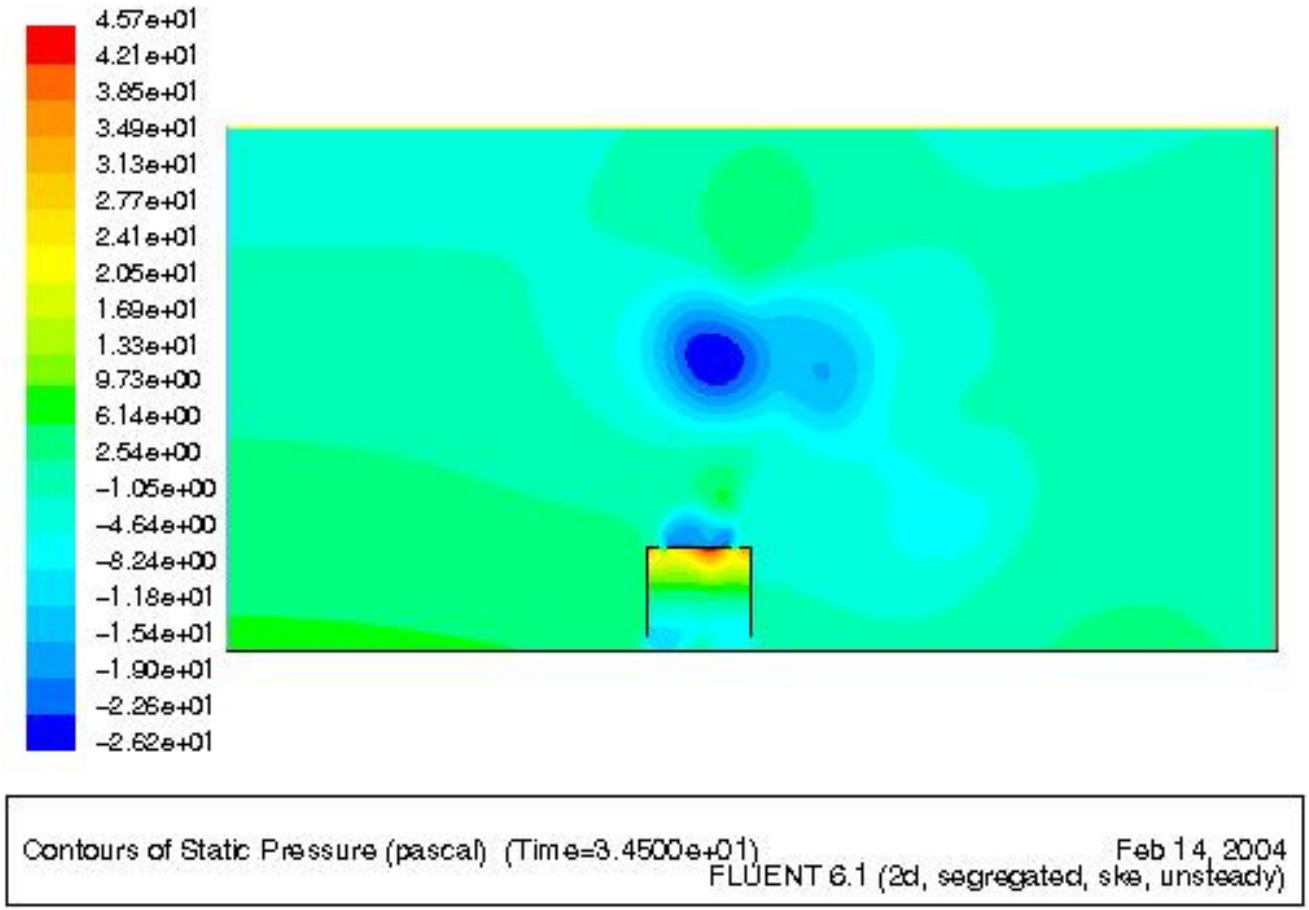


Contours of Velocity Magnitude (m/s) (Time=3.4500e+01) Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

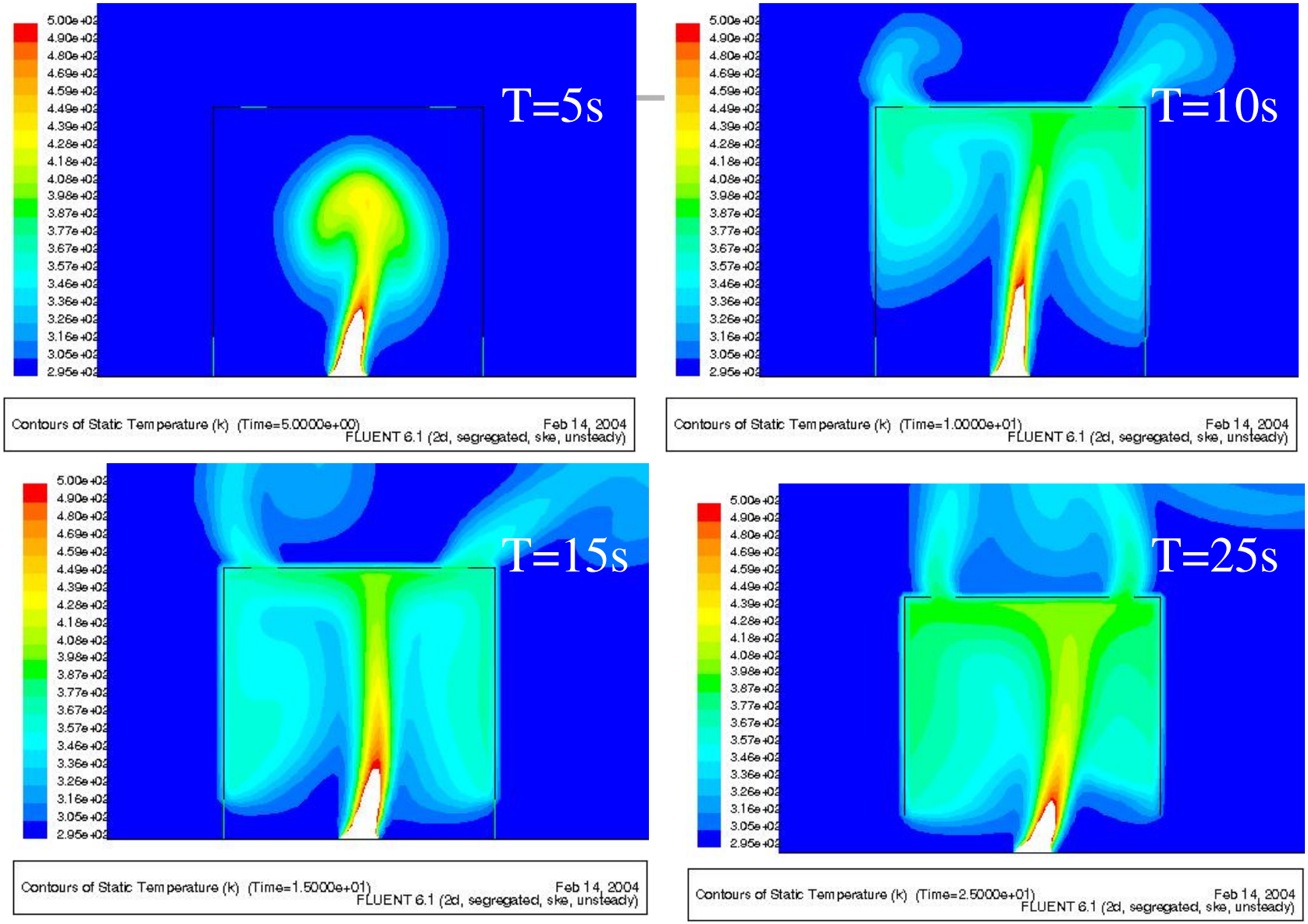
Up & Downwind Inlets: U=0.5m/s Density Contours

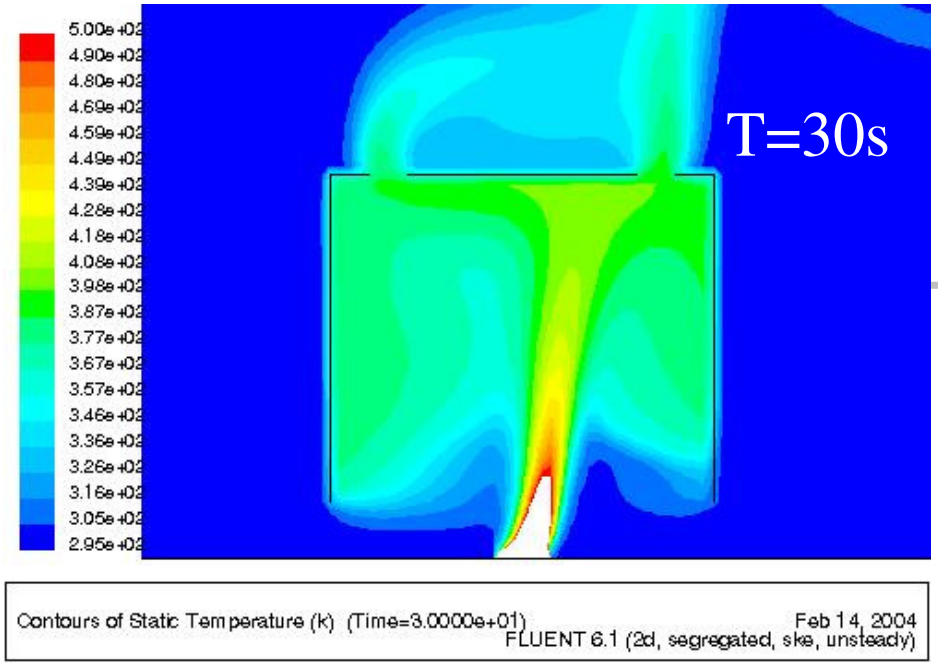


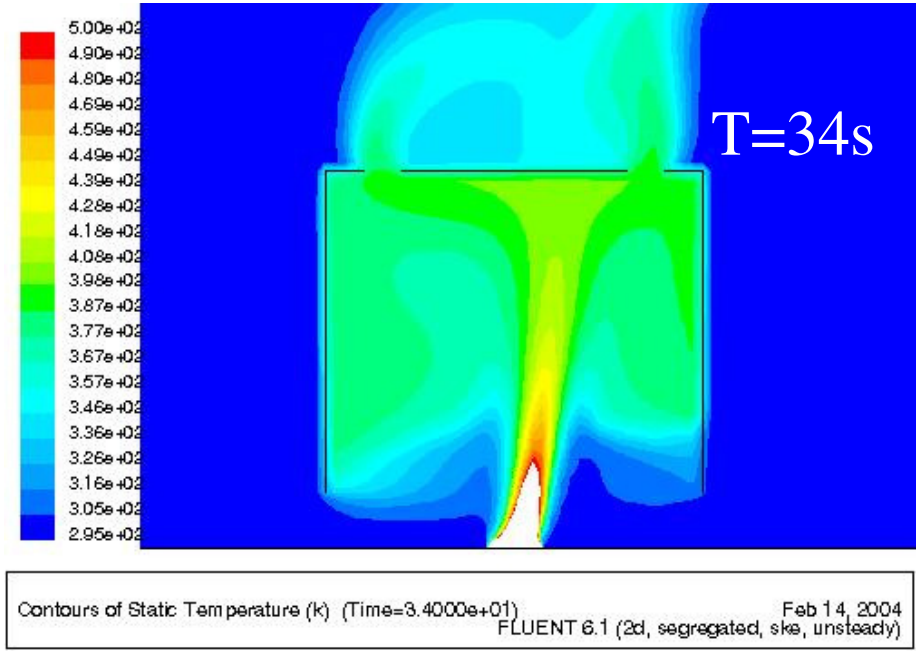
Up & Downwind Inlets: U=0.5m/s Static Pressure Contours



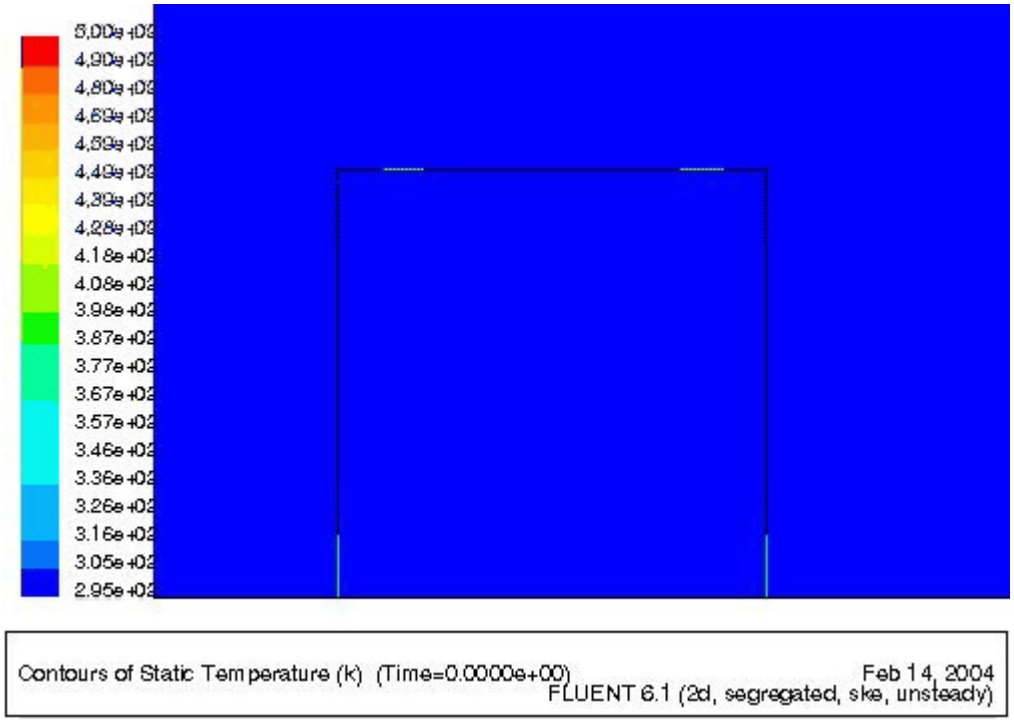
Up & Downwind Inlets: U=0.5 Temperature Contours



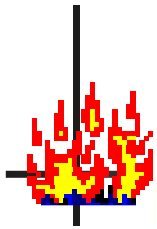

5.00e+02
4.90e+02
4.80e+02
4.69e+02
4.59e+02
4.49e+02
4.39e+02
4.28e+02
4.18e+02
4.08e+02
3.98e+02
3.87e+02
3.77e+02
3.67e+02
3.57e+02
3.46e+02
3.36e+02
3.26e+02
3.16e+02
3.05e+02
2.95e+02
T=30s
Contours of Static Temperature (k) (Time=3.0000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

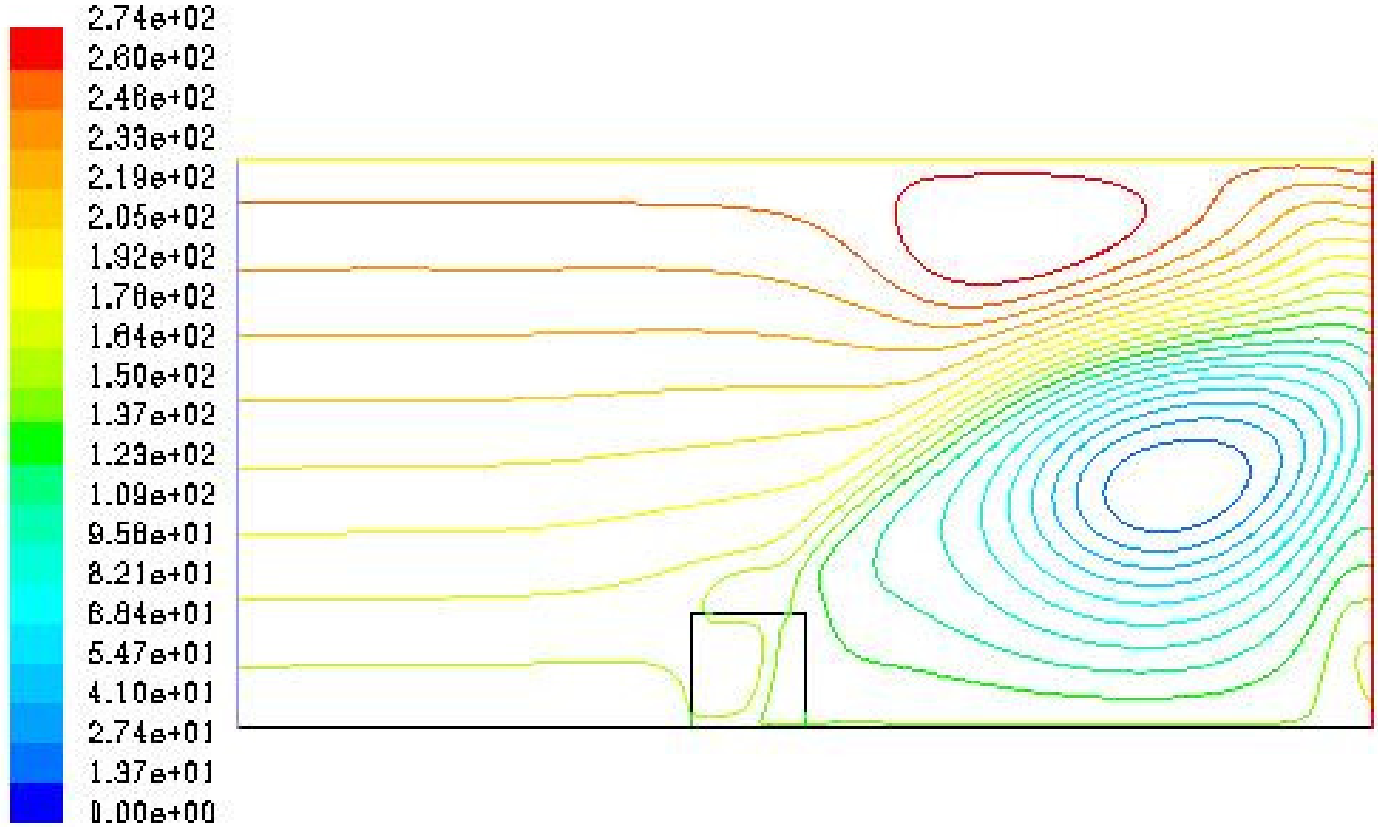

5.00e+02
4.90e+02
4.80e+02
4.69e+02
4.59e+02
4.49e+02
4.39e+02
4.28e+02
4.18e+02
4.08e+02
3.98e+02
3.87e+02
3.77e+02
3.67e+02
3.57e+02
3.46e+02
3.36e+02
3.26e+02
3.16e+02
3.05e+02
2.95e+02
T=34s
Contours of Static Temperature (k) (Time=3.4000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

Up & Downwind Inlets: U=0.5 Temperature Contours Animation



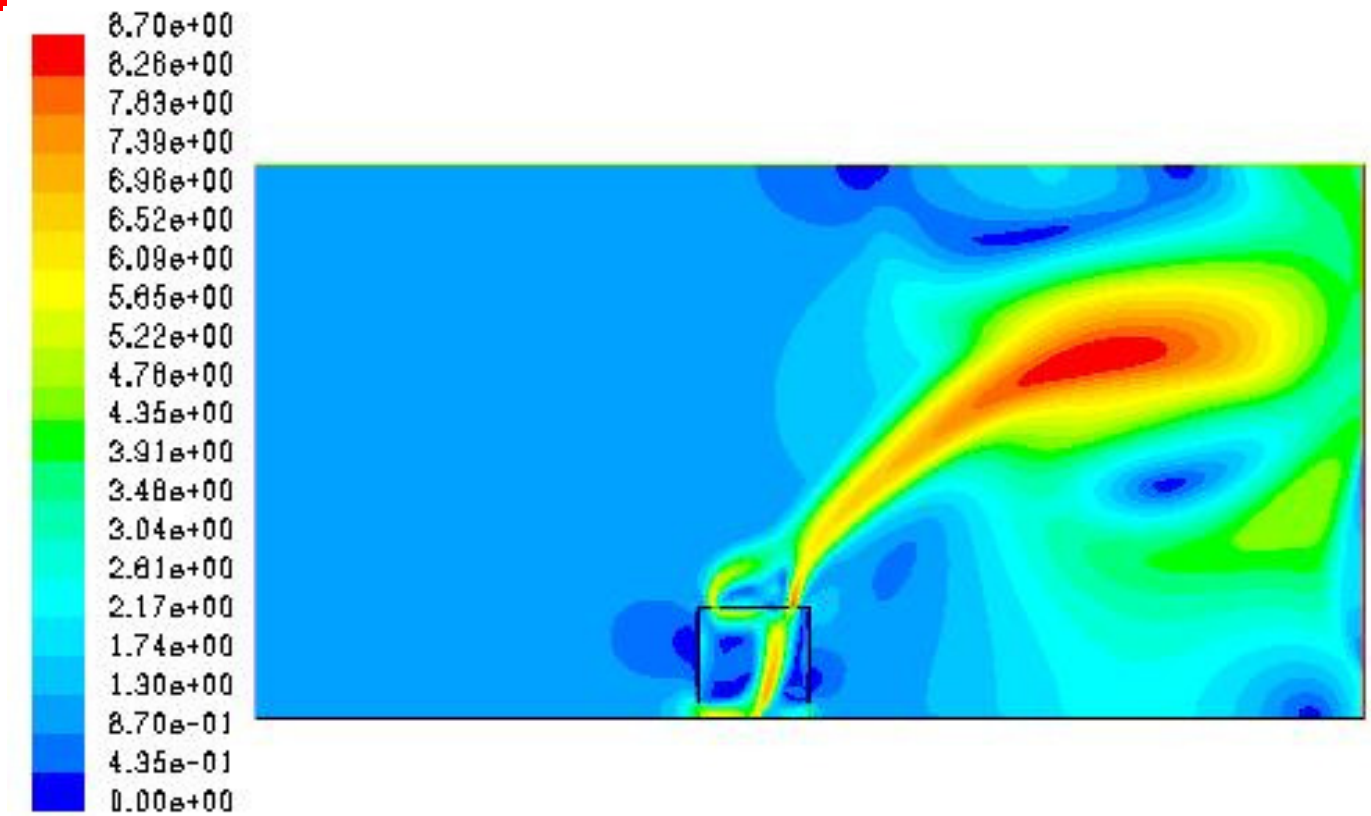
Up & Downwind Inlets: U=1m/s Streamlines





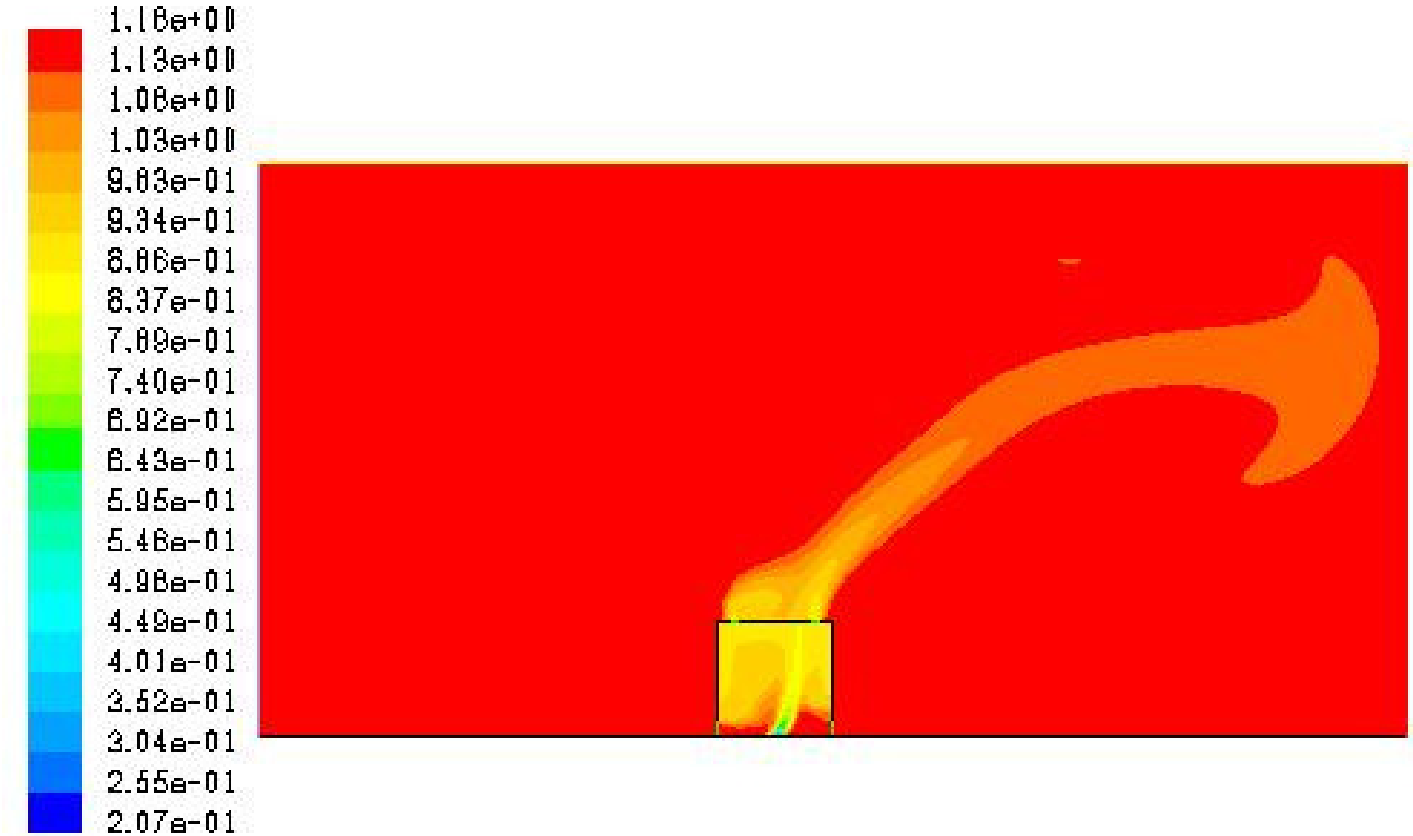
Contours of Stream Function (kg/s) (Time=5.3200e+01) Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

Up & Downwind Inlets: U=1m/s Velocity Magnitude Contours



Contours of Velocity Magnitude (m/s) (Time=5.3200e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

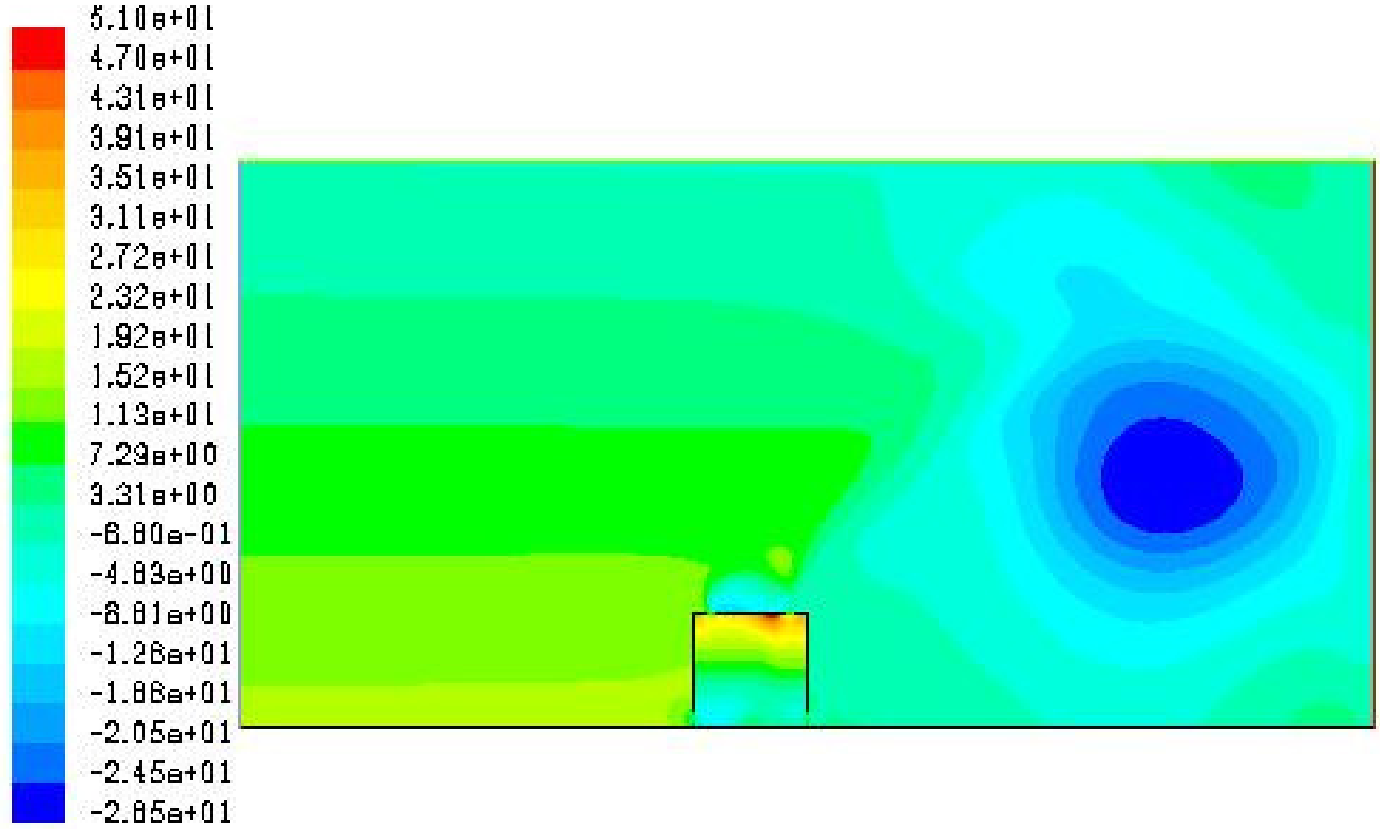
Up & Downwind Inlets: U=1m/s Density Contours



Contours of Density (kg/m3) (Time=5.3200e+01)

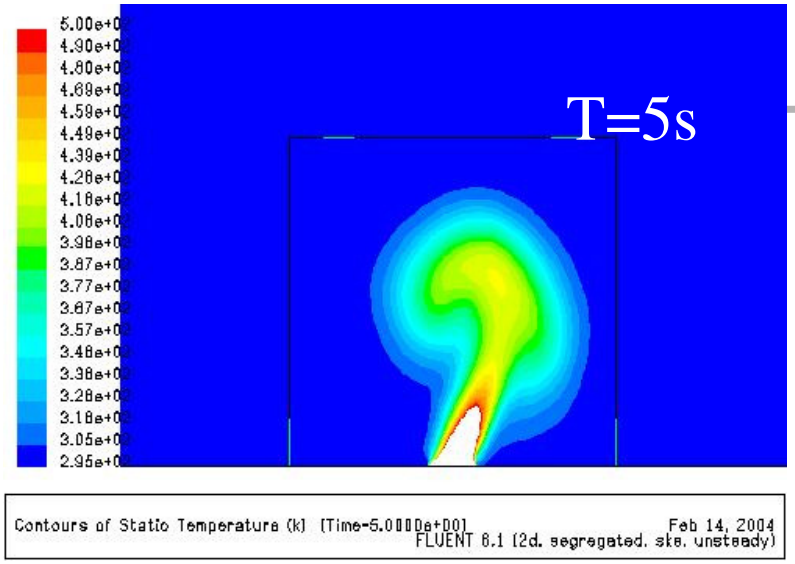
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

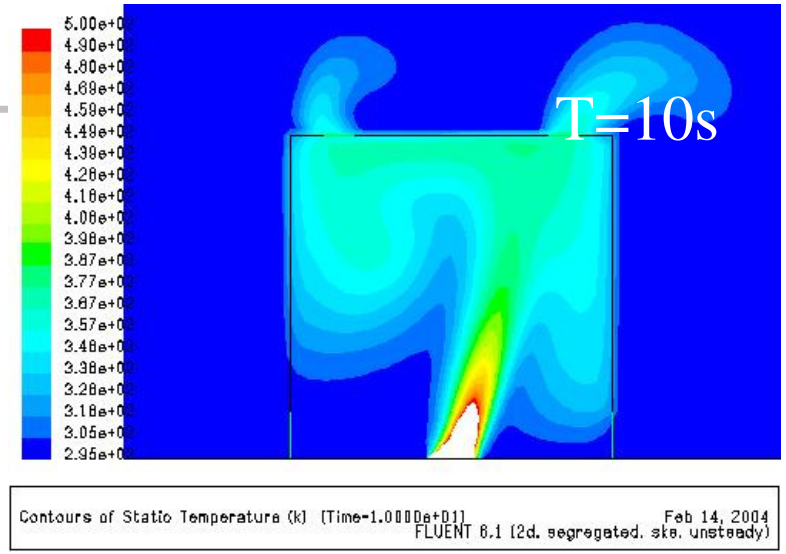
Up & Downwind Inlets: U=1m/s Static Pressure Contours

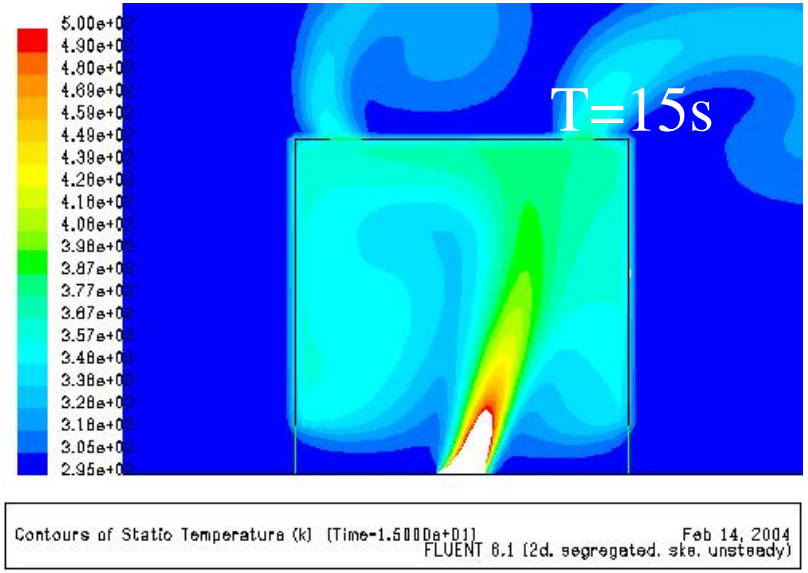


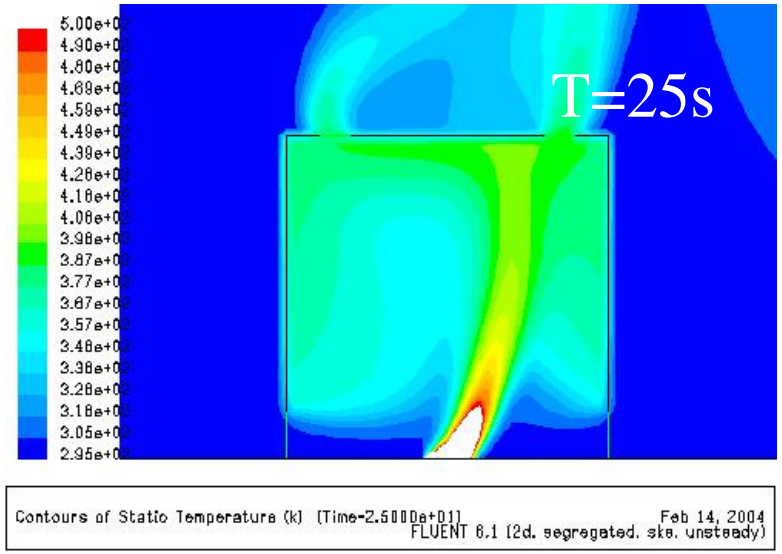
Contours of Static Pressure (pascal) (Time=5.3200e+01) Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

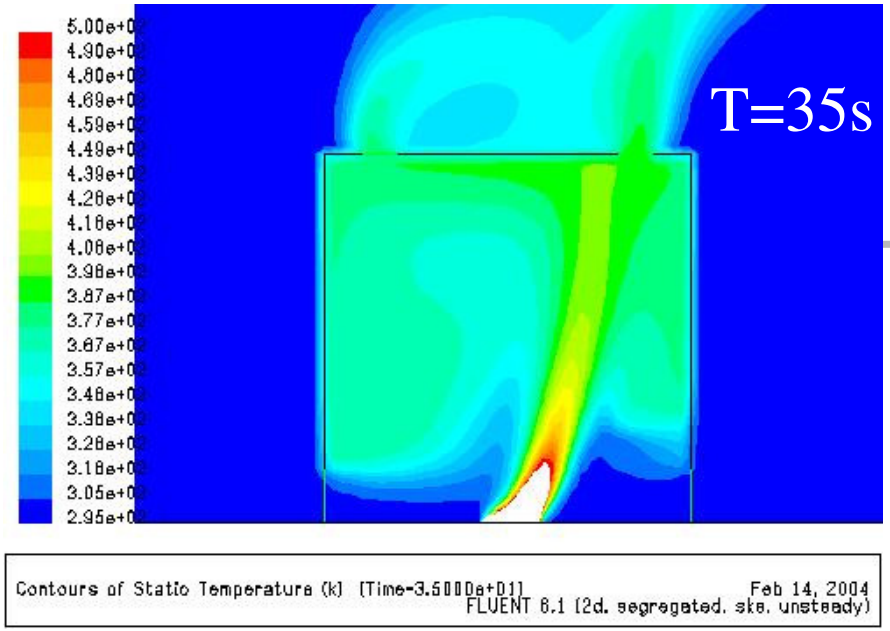
Up & Downwind Inlets: U=1 m/s Temperature Contours

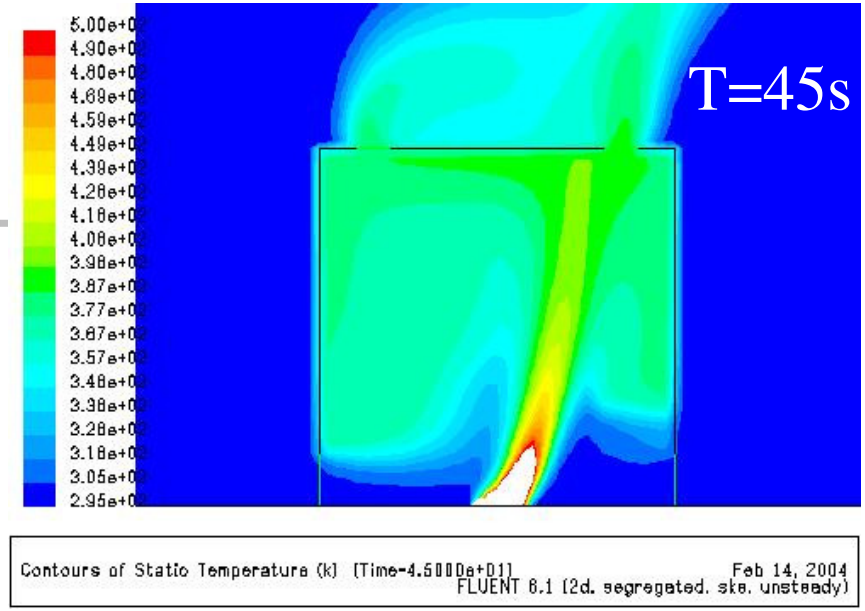


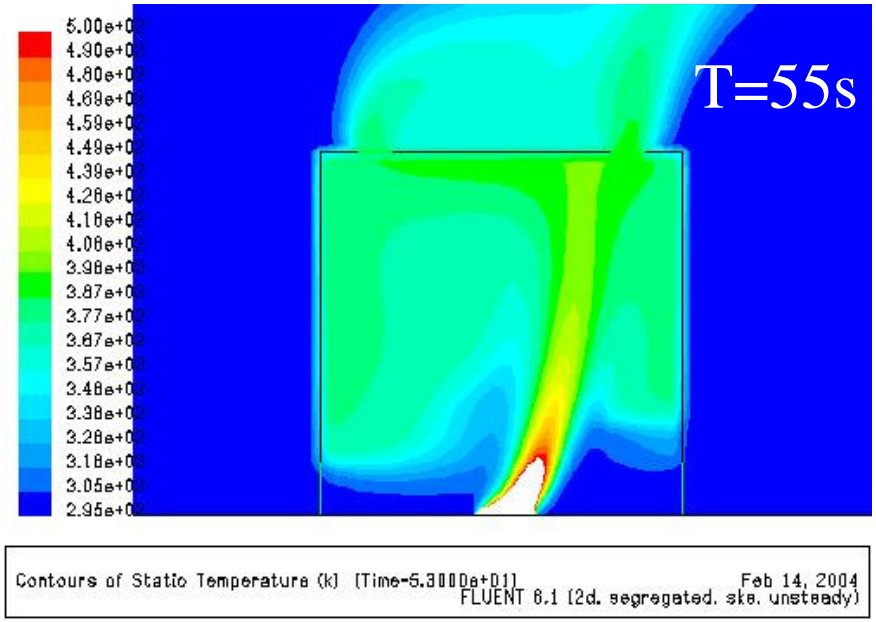







T=35s
5.00e+0
4.90e+0
4.80e+0
4.69e+0
4.59e+0
4.49e+0
4.39e+0
4.28e+0
4.18e+0
4.08e+0
3.98e+0
3.87e+0
3.77e+0
3.67e+0
3.57e+0
3.46e+0
3.36e+0
3.26e+0
3.16e+0
3.05e+0
2.95e+0
Contours of Static Temperature (k) (Time=3.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)


T=45s
5.00e+0
4.90e+0
4.80e+0
4.69e+0
4.59e+0
4.49e+0
4.39e+0
4.28e+0
4.18e+0
4.08e+0
3.98e+0
3.87e+0
3.77e+0
3.67e+0
3.57e+0
3.46e+0
3.36e+0
3.26e+0
3.16e+0
3.05e+0
2.95e+0
Contours of Static Temperature (k) (Time=4.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)


T=55s
5.00e+0
4.90e+0
4.80e+0
4.69e+0
4.59e+0
4.49e+0
4.39e+0
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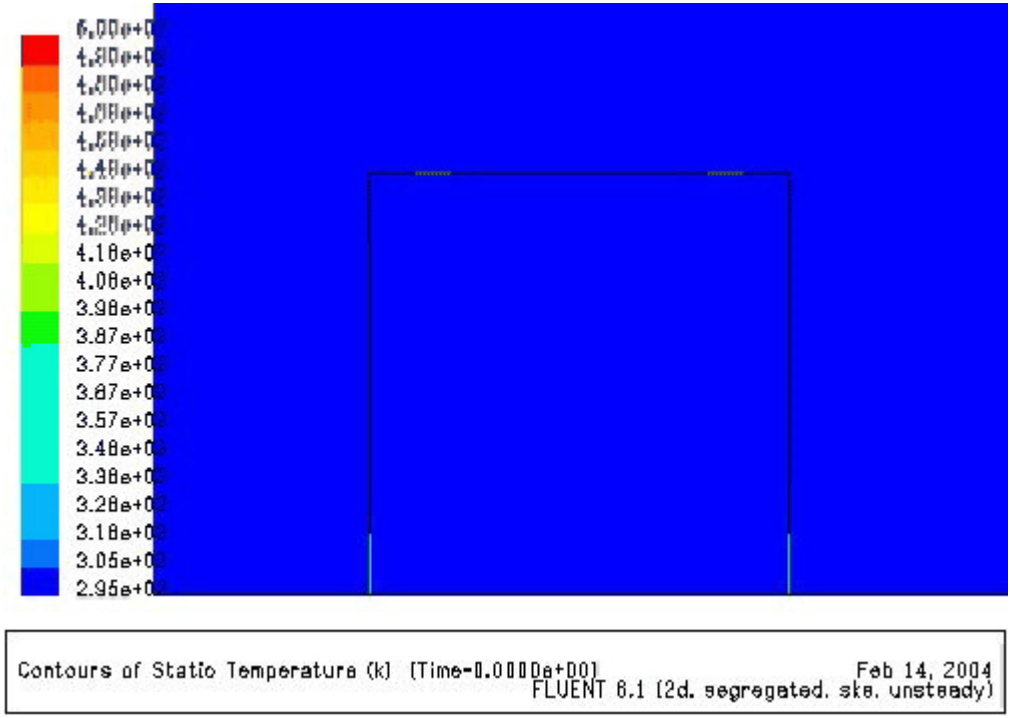
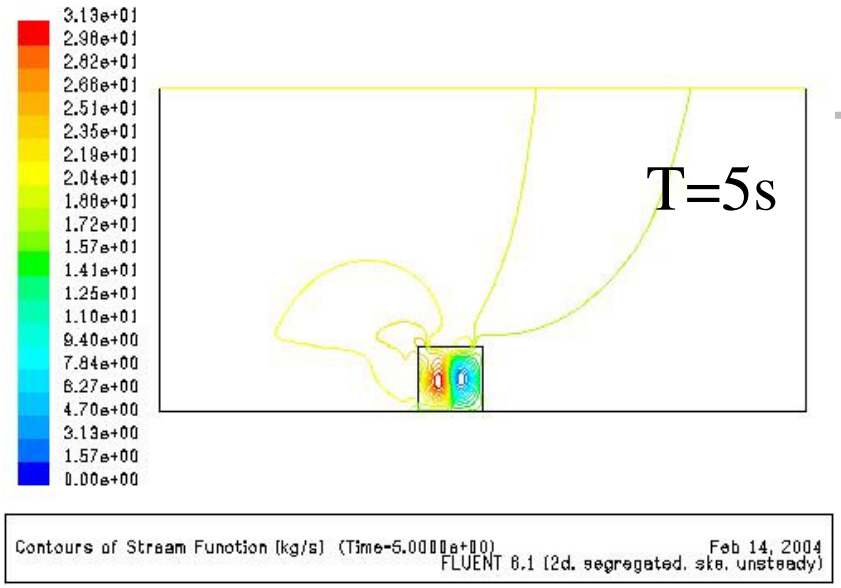
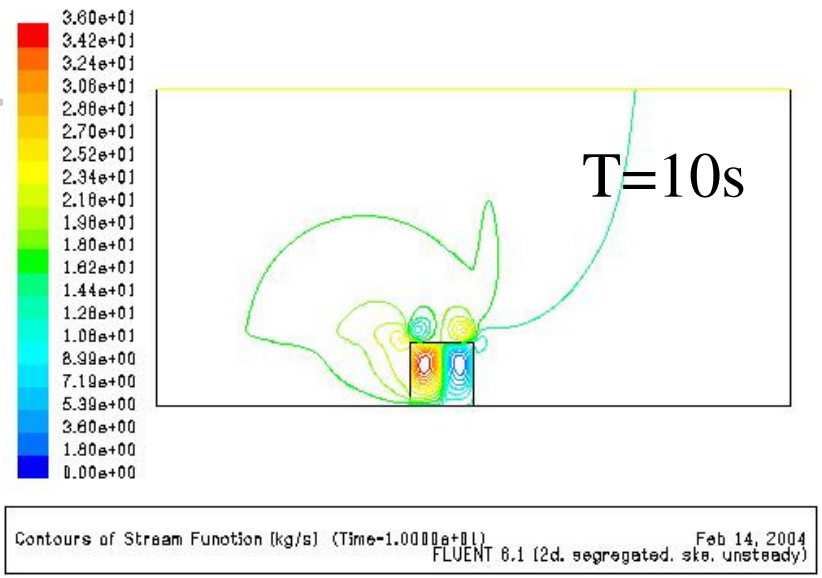
4.18e+0
4.08e+0
3.98e+0
3.87e+0
3.77e+0
3.67e+0
3.57e+0
3.46e+0
3.36e+0
3.26e+0
3.16e+0
3.05e+0
2.95e+0
Contours of Static Temperature (k) (Time=5.3000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

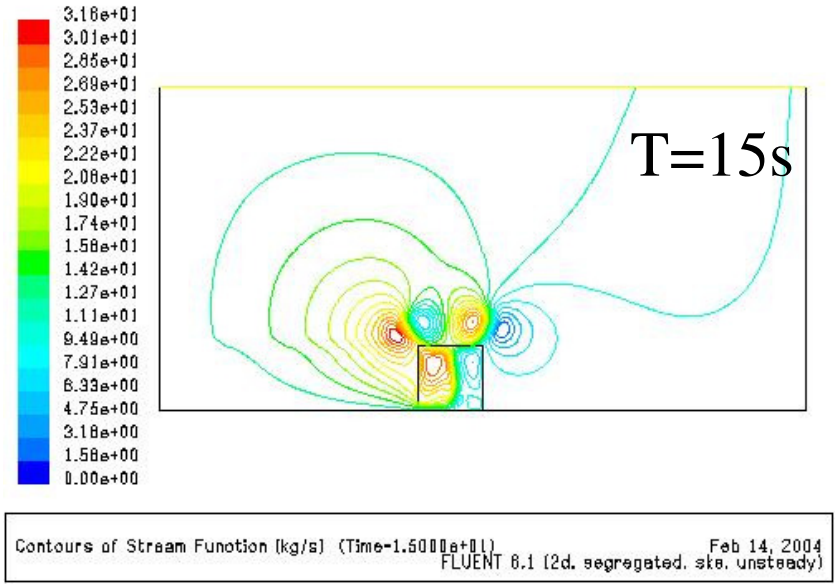
Up & Downwind Inlets: U=1.0 Temperature Contours Animation

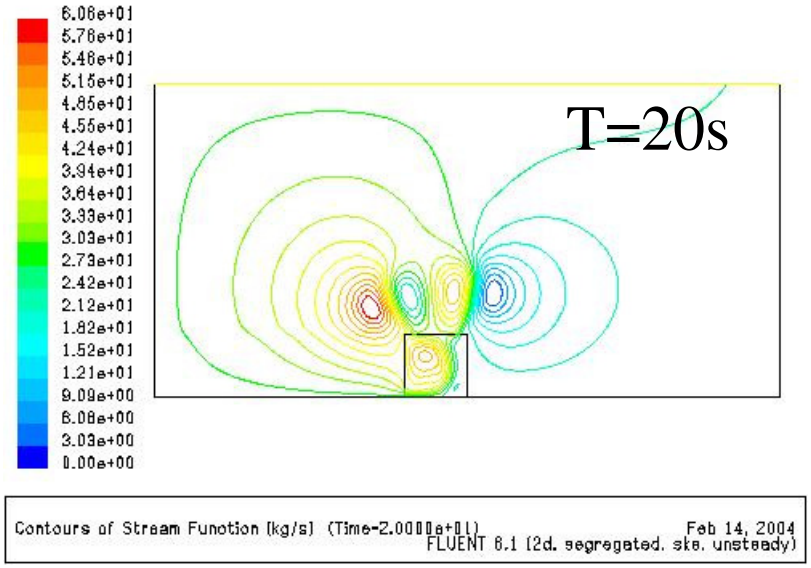


Upwind Inlets: U=0 Streamlines

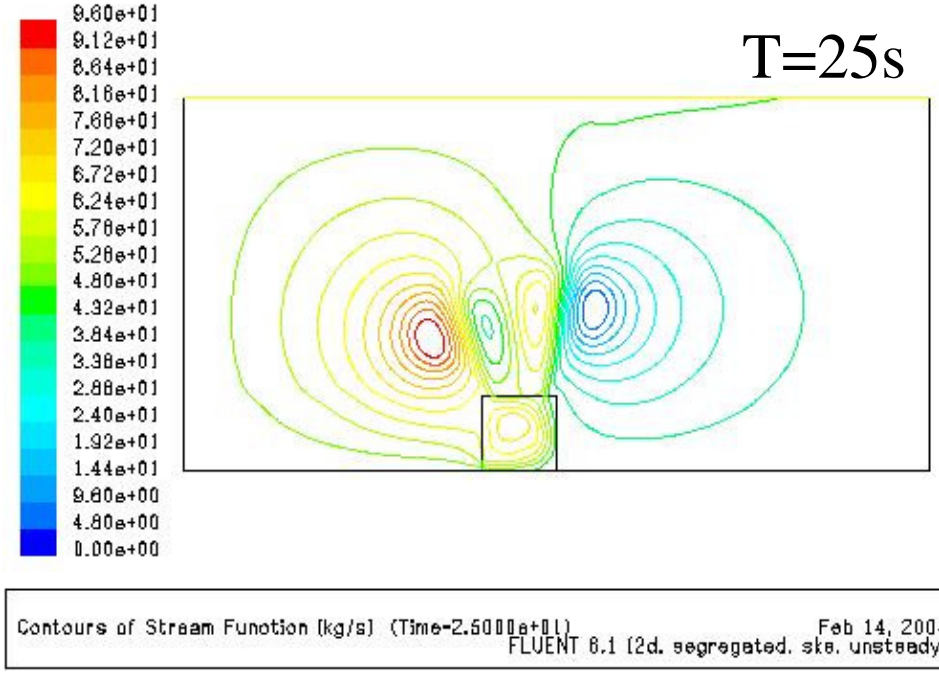




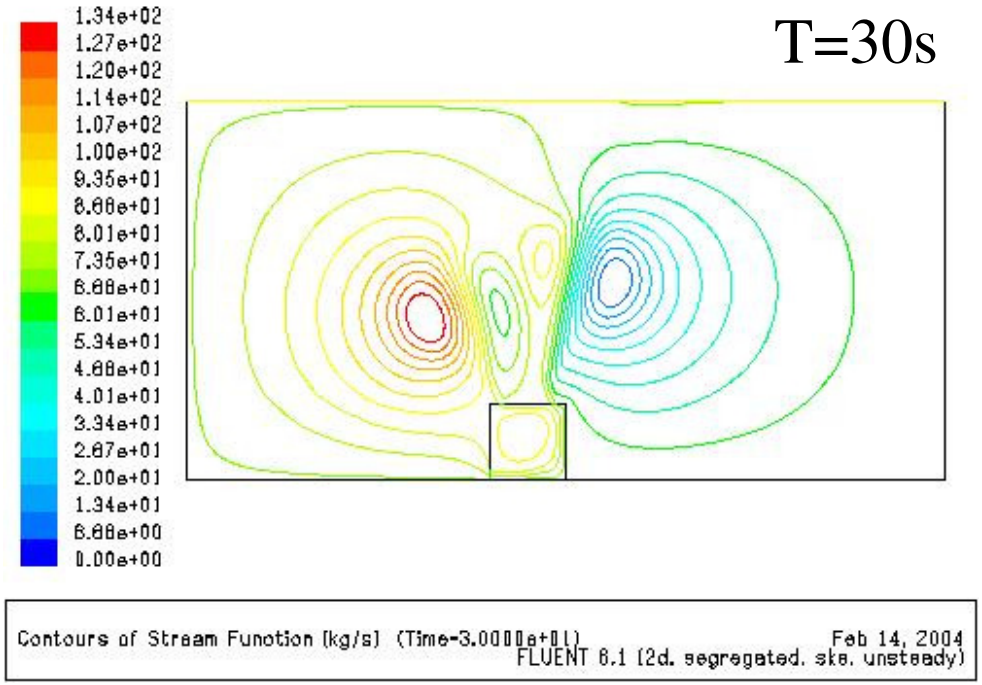




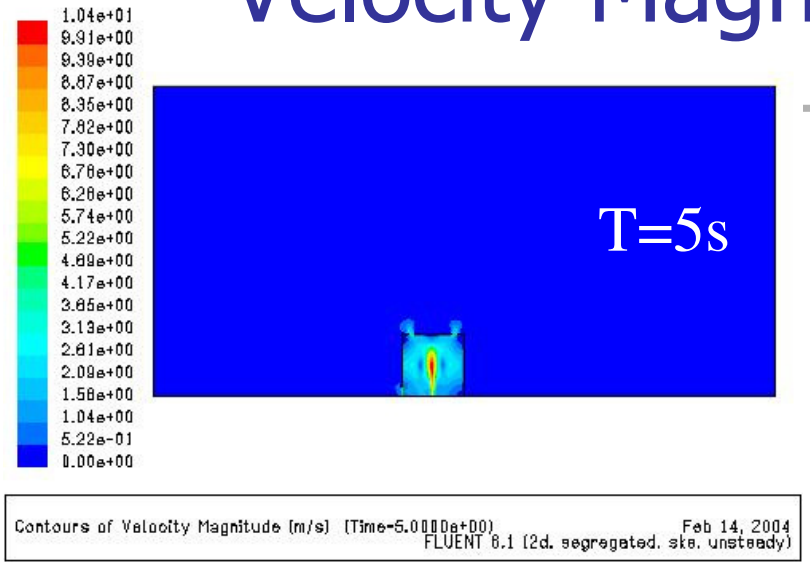
T=25s

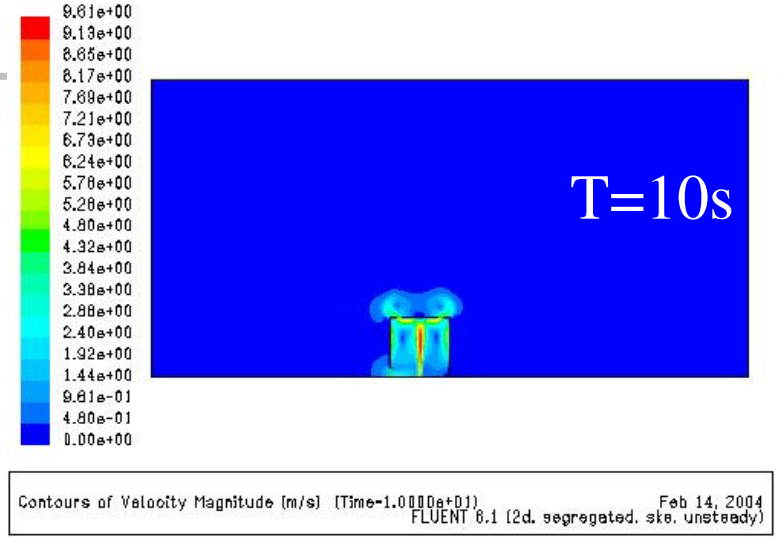

9.60e+01
9.12e+01
8.64e+01
8.16e+01
7.68e+01
7.20e+01
6.72e+01
6.24e+01
5.76e+01
5.28e+01
4.80e+01
4.32e+01
3.84e+01
3.36e+01
2.88e+01
2.40e+01
1.92e+01
1.44e+01
9.60e+00
4.80e+00
0.00e+00
Contours of Stream Function (kg/s) (Time=2.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

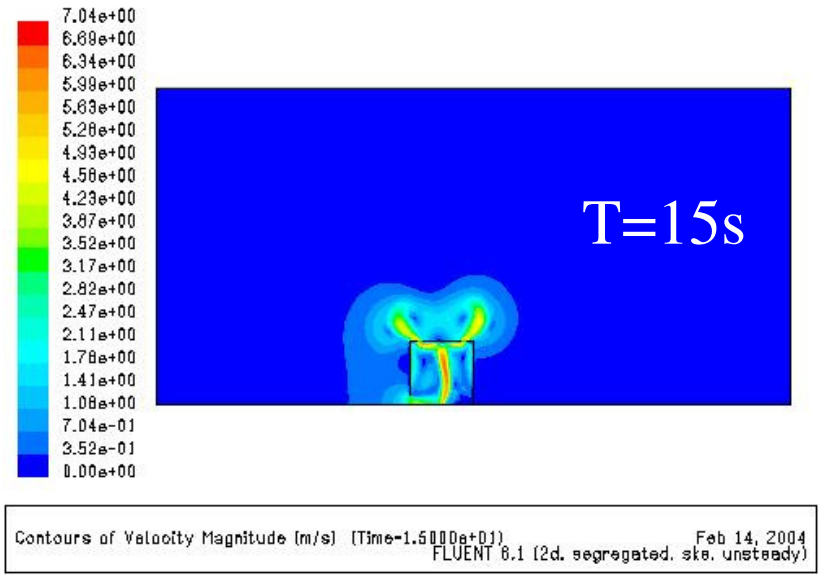
T=30s

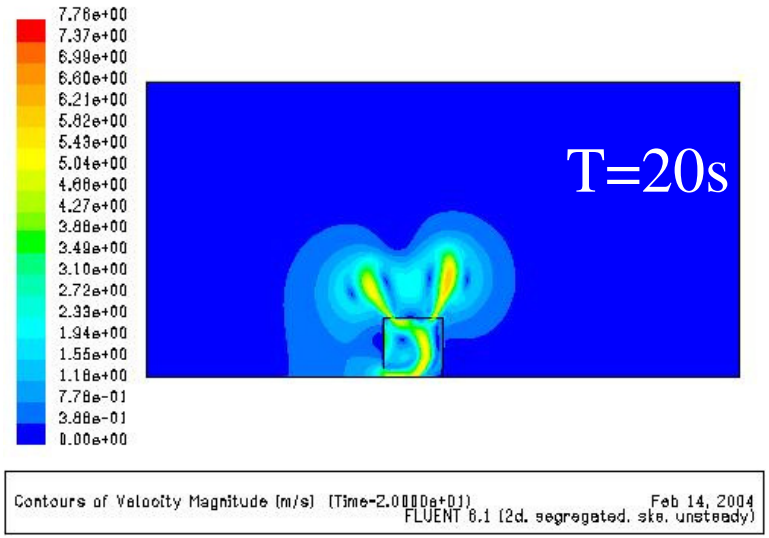

1.34e+02
1.27e+02
1.20e+02
1.14e+02
1.07e+02
1.00e+02
9.35e+01
8.68e+01
8.01e+01
7.35e+01
6.68e+01
6.01e+01
5.34e+01
4.68e+01
4.01e+01
3.34e+01
2.67e+01
2.00e+01
1.34e+01
6.68e+00
0.00e+00
Contours of Stream Function (kg/s) (Time=3.0000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

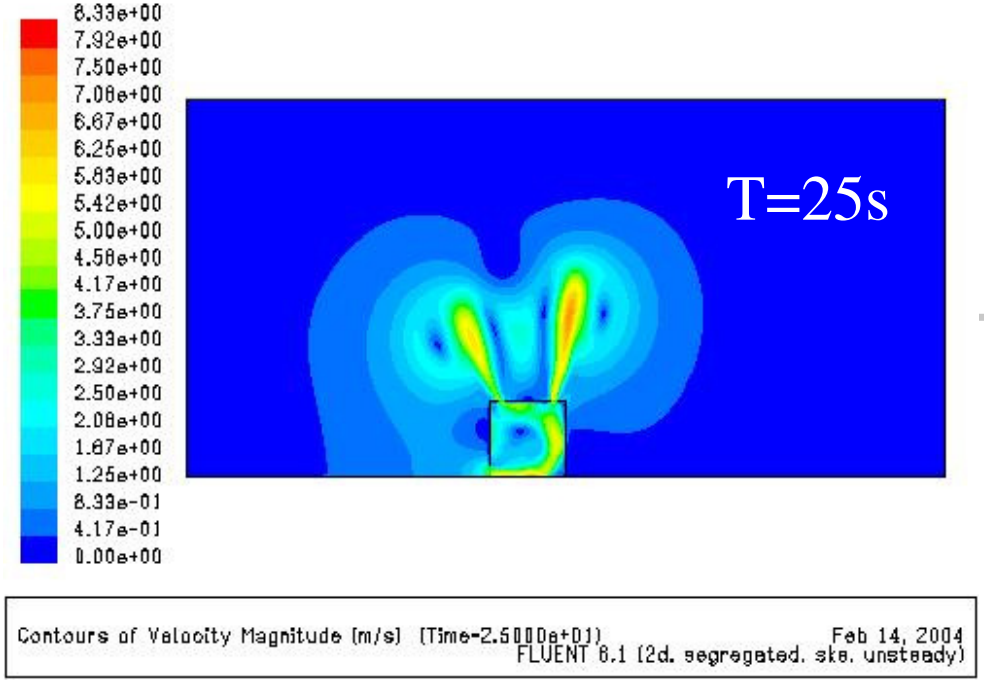
Upwind Inlets: U=0
Velocity Magnitude Contours

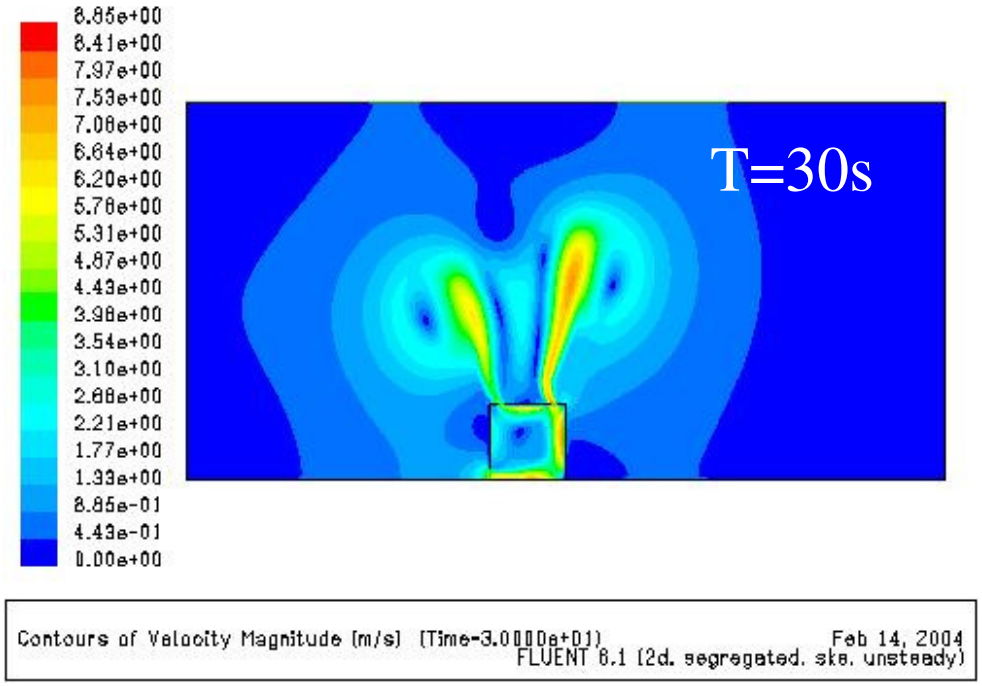




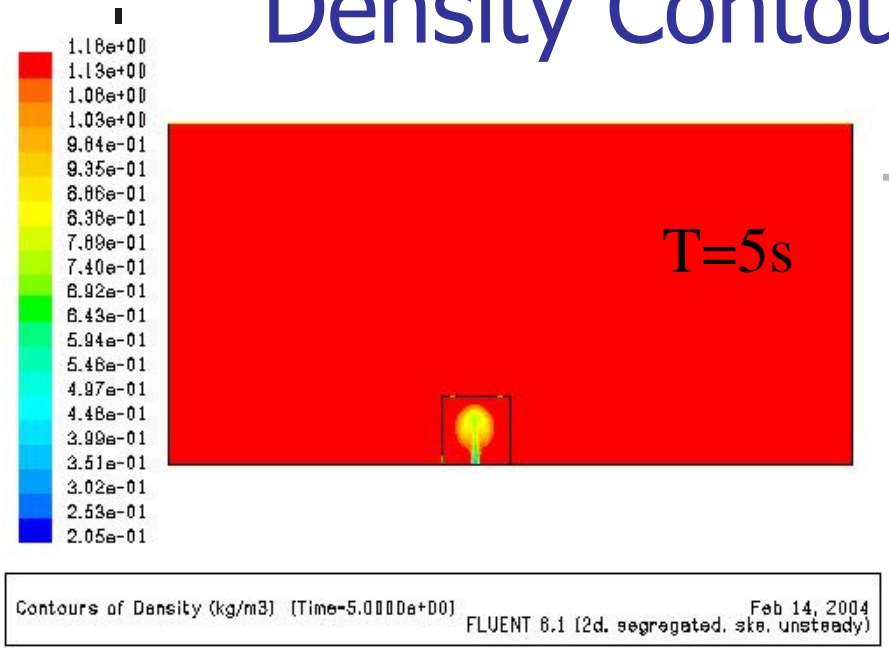


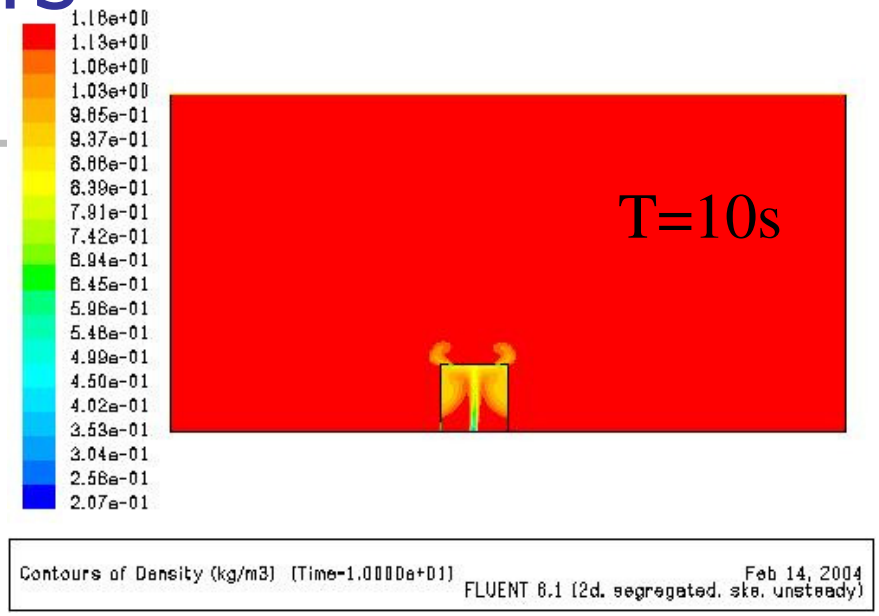


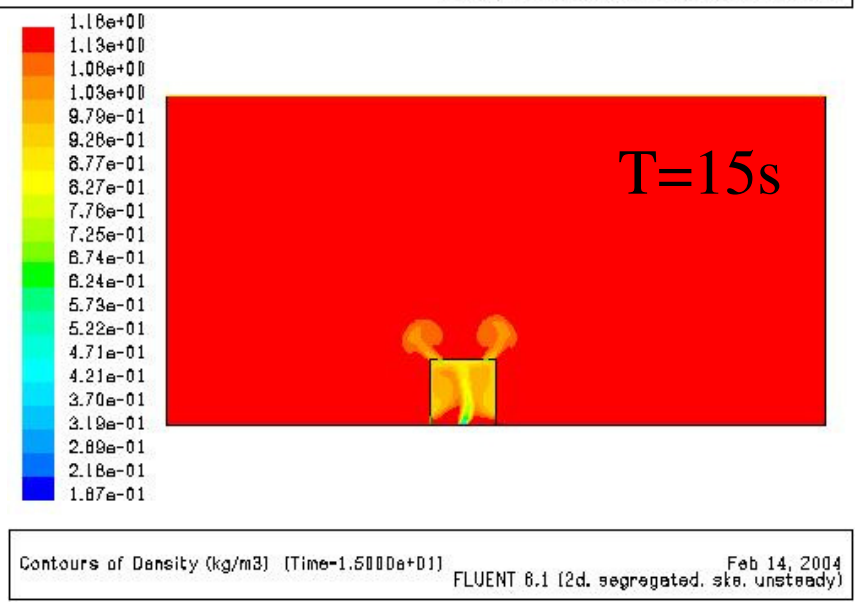

8.33e+00
7.92e+00
7.50e+00
7.08e+00
6.67e+00
6.25e+00
5.83e+00
5.42e+00
5.00e+00
4.58e+00
4.17e+00
3.75e+00
3.33e+00
2.92e+00
2.50e+00
2.08e+00
1.67e+00
1.25e+00
8.33e-01
4.17e-01
0.00e+00
T=25s
Contours of Velocity Magnitude (m/s) (Time=2.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

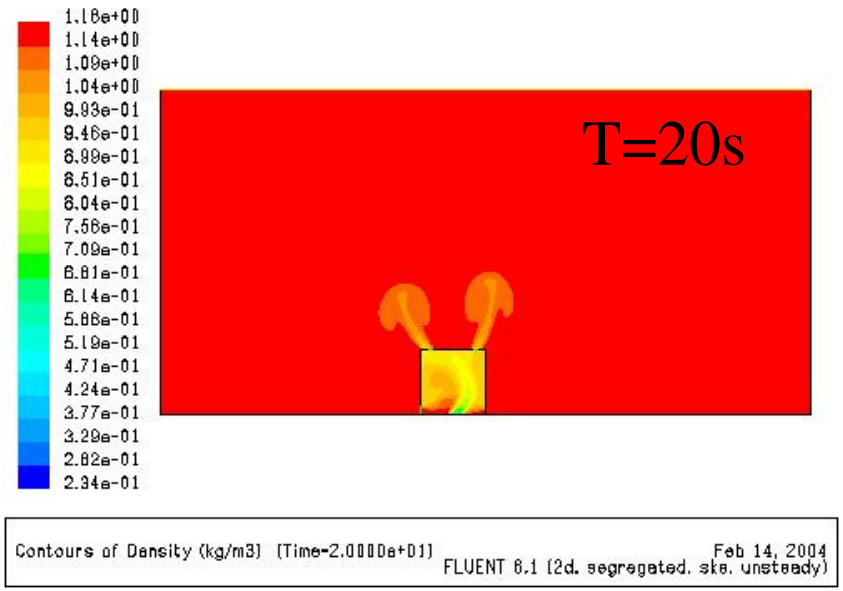

8.85e+00
8.41e+00
7.97e+00
7.53e+00
7.08e+00
6.64e+00
6.20e+00
5.76e+00
5.31e+00
4.87e+00
4.43e+00
3.98e+00
3.54e+00
3.10e+00
2.66e+00
2.21e+00
1.77e+00
1.33e+00
8.85e-01
4.43e-01
0.00e+00
T=30s
Contours of Velocity Magnitude (m/s) (Time=3.0000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

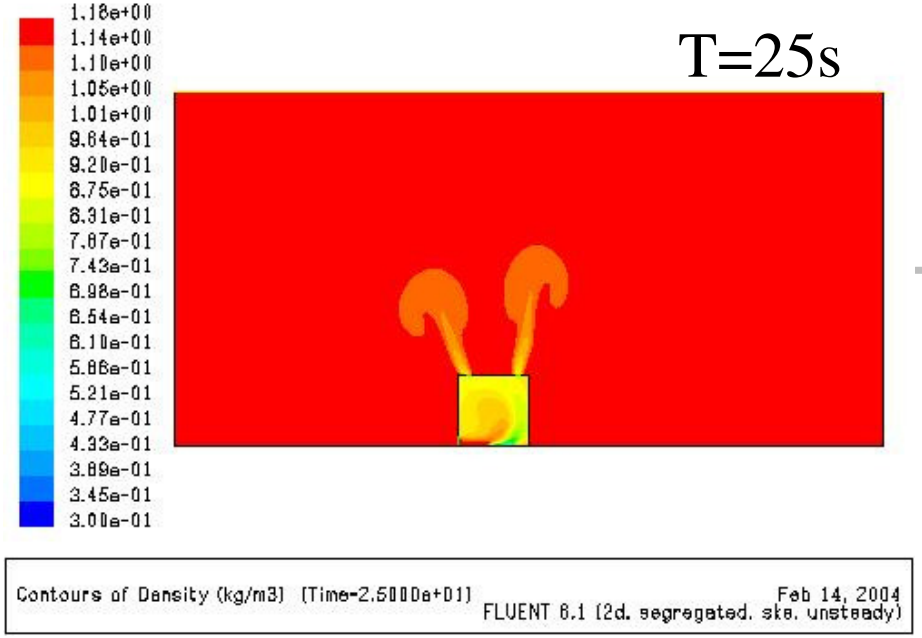
Upwind Inlets: U=0
Density Contours

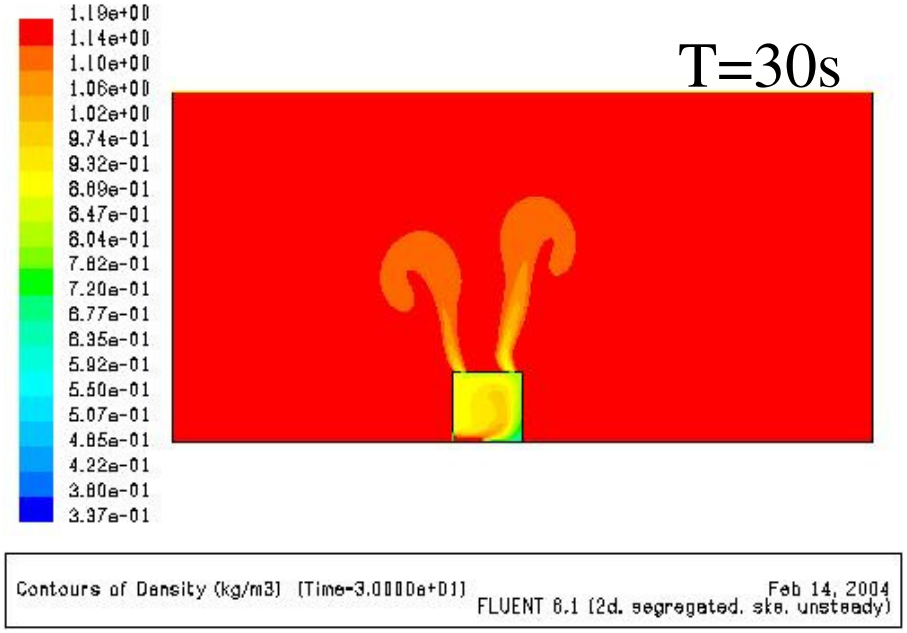




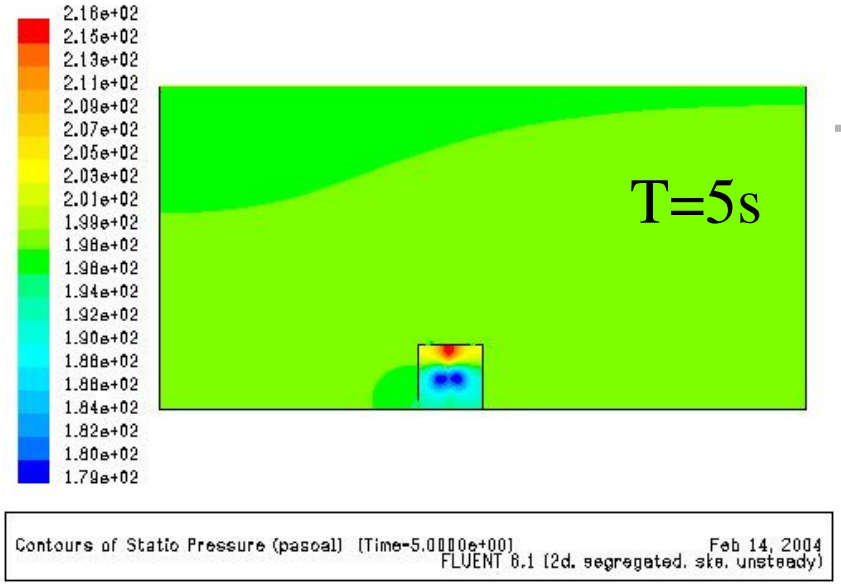


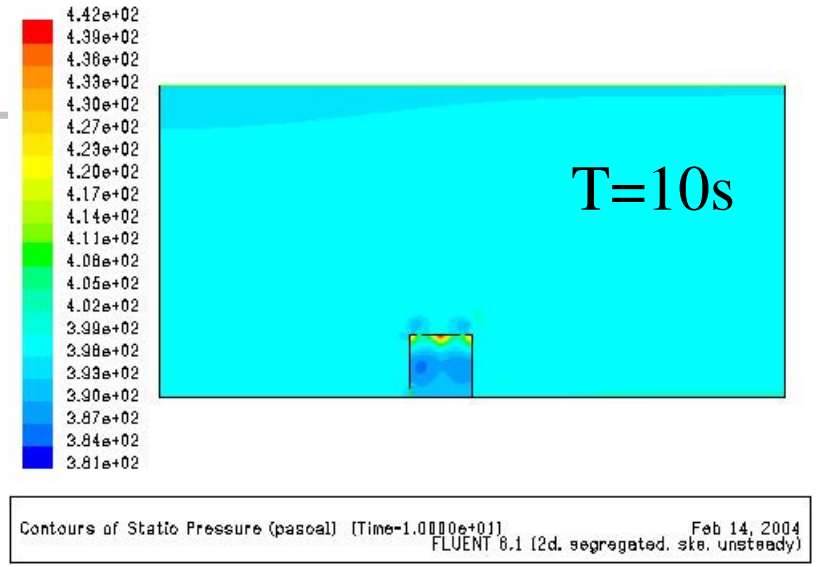


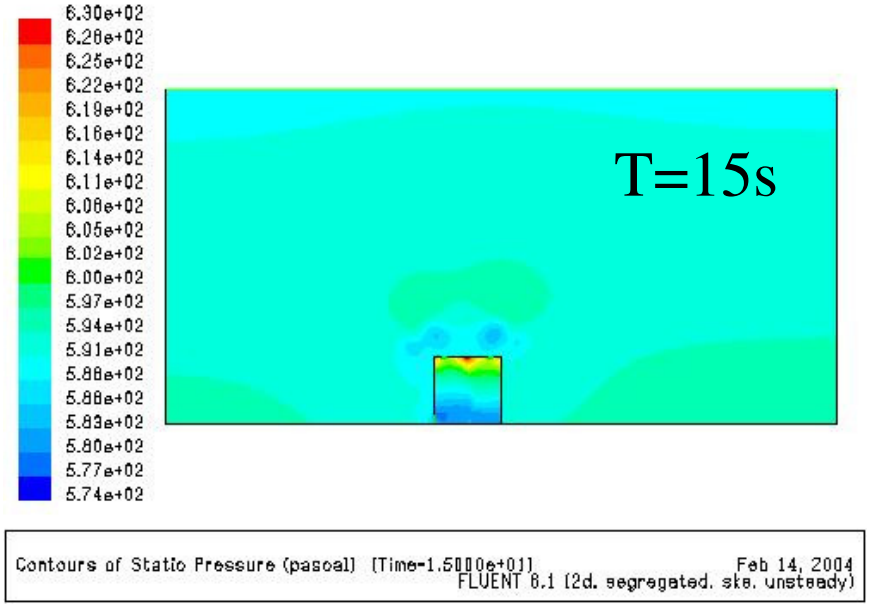

T=25s
1.18e+00
1.14e+00
1.10e+00
1.05e+00
1.01e+00
9.64e-01
9.20e-01
8.75e-01
8.31e-01
7.87e-01
7.43e-01
6.98e-01
6.54e-01
6.10e-01
5.66e-01
5.21e-01
4.77e-01
4.33e-01
3.89e-01
3.45e-01
3.00e-01
Contours of Density (kg/m3) (Time=2.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

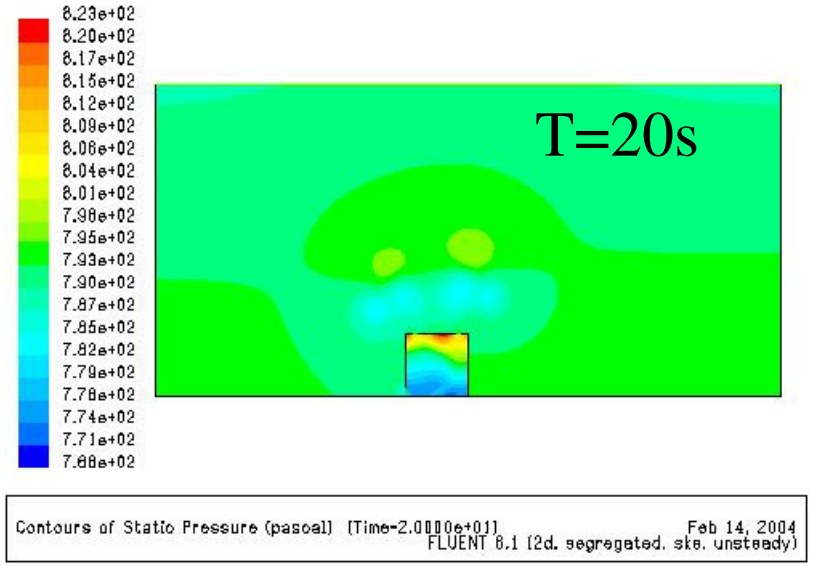

T=30s
1.19e+00
1.14e+00
1.10e+00
1.06e+00
1.02e+00
9.74e-01
9.32e-01
8.89e-01
8.47e-01
8.04e-01
7.62e-01
7.20e-01
6.77e-01
6.35e-01
5.92e-01
5.50e-01
5.07e-01
4.65e-01
4.22e-01
3.80e-01
3.37e-01
Contours of Density (kg/m3) (Time=3.0000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

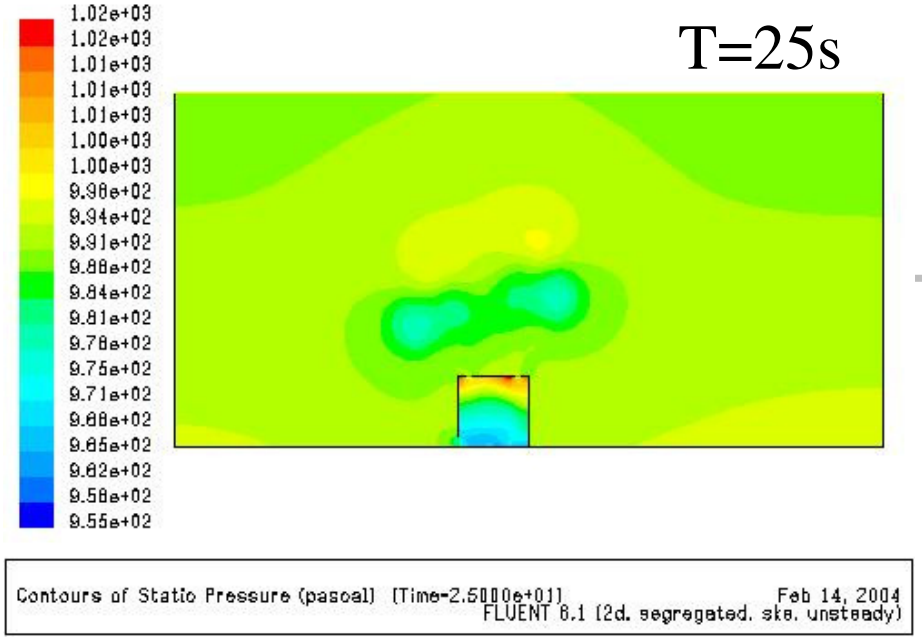
Upwind Inlets: U=0
Static Pressure Contours

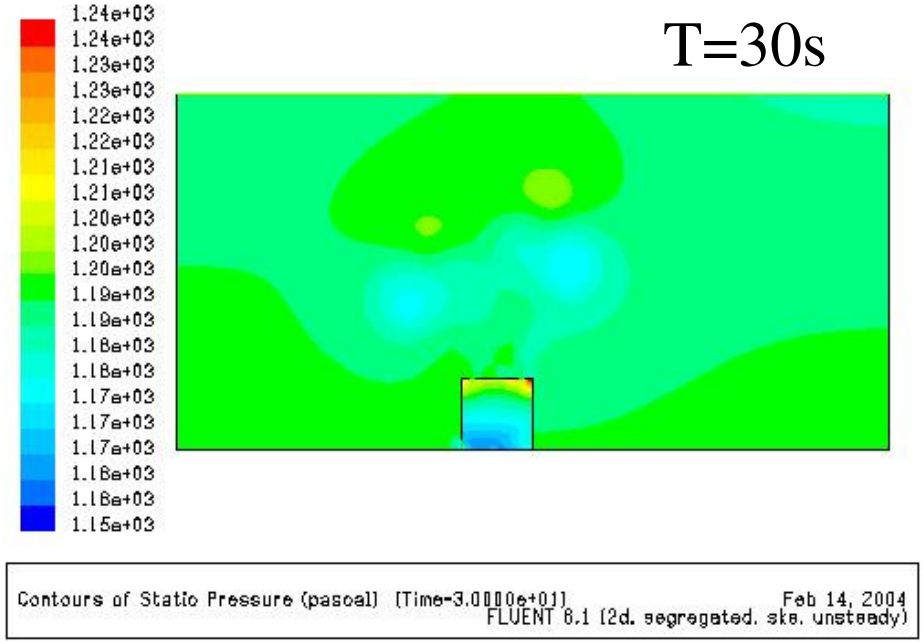




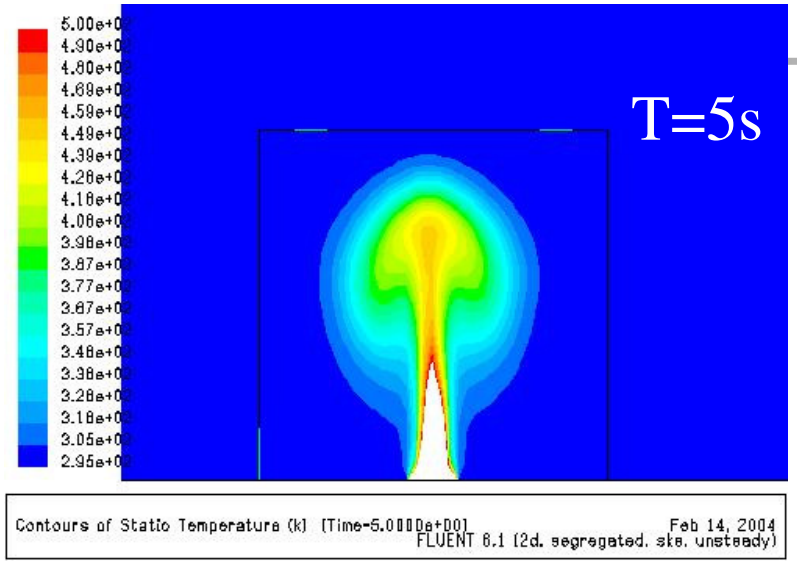


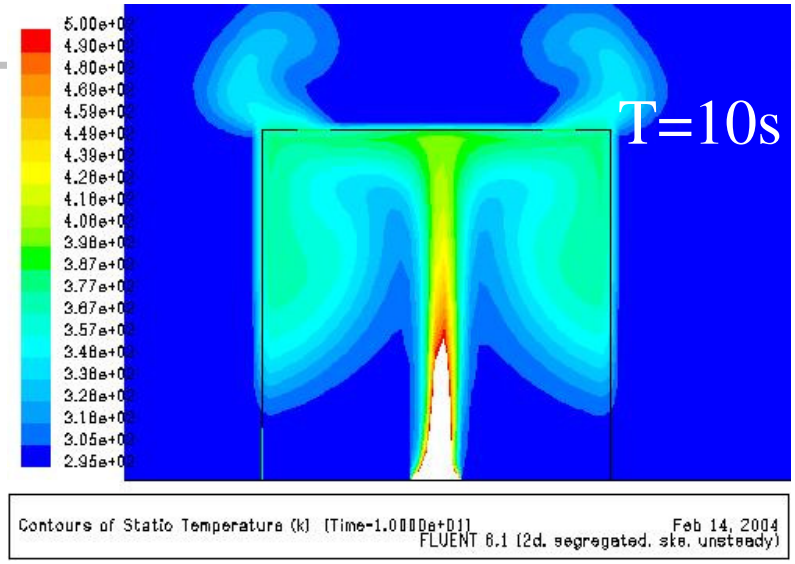


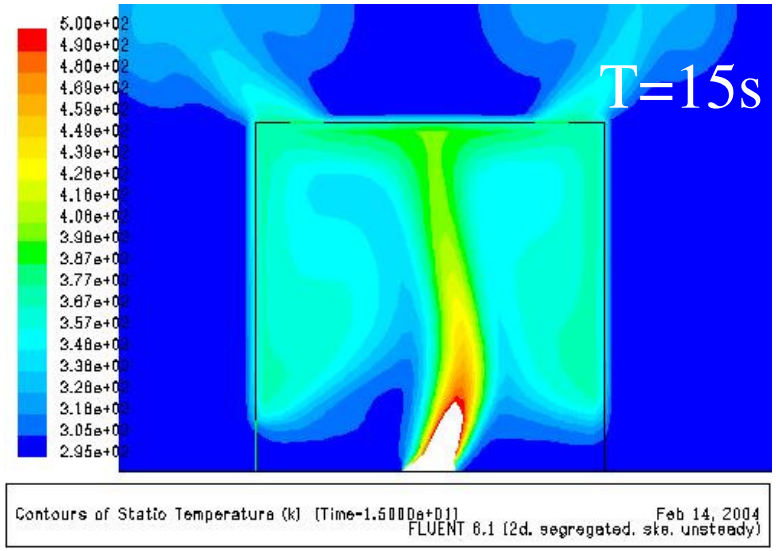

T=25s
1.02e+03
1.02e+03
1.01e+03
1.01e+03
1.01e+03
1.00e+03
1.00e+03
9.98e+02
9.94e+02
9.91e+02
9.88e+02
9.84e+02
9.81e+02
9.78e+02
9.75e+02
9.71e+02
9.68e+02
9.65e+02
9.62e+02
9.58e+02
9.55e+02
Contours of Static Pressure (pascal) (Time=2.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

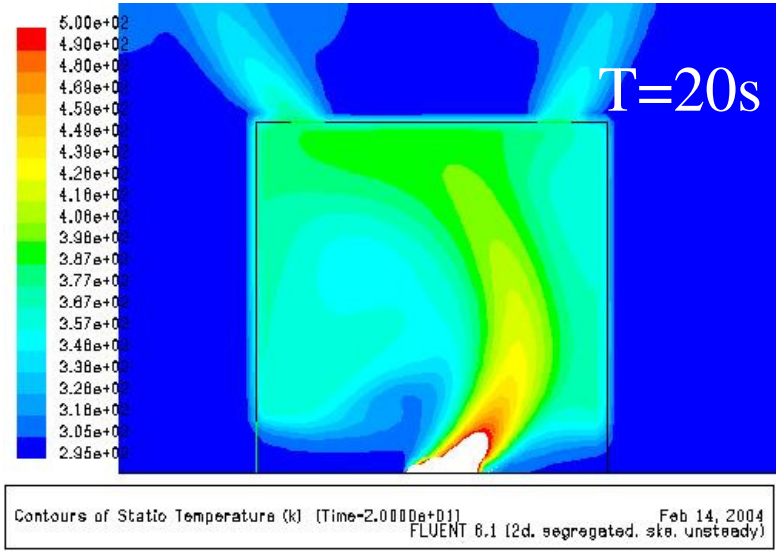

T=30s
1.24e+03
1.24e+03
1.23e+03
1.23e+03
1.22e+03
1.22e+03
1.21e+03
1.21e+03
1.20e+03
1.20e+03
1.20e+03
1.19e+03
1.19e+03
1.18e+03
1.18e+03
1.17e+03
1.17e+03
1.17e+03
1.16e+03
1.16e+03
1.15e+03
Contours of Static Pressure (pascal) (Time=3.0000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

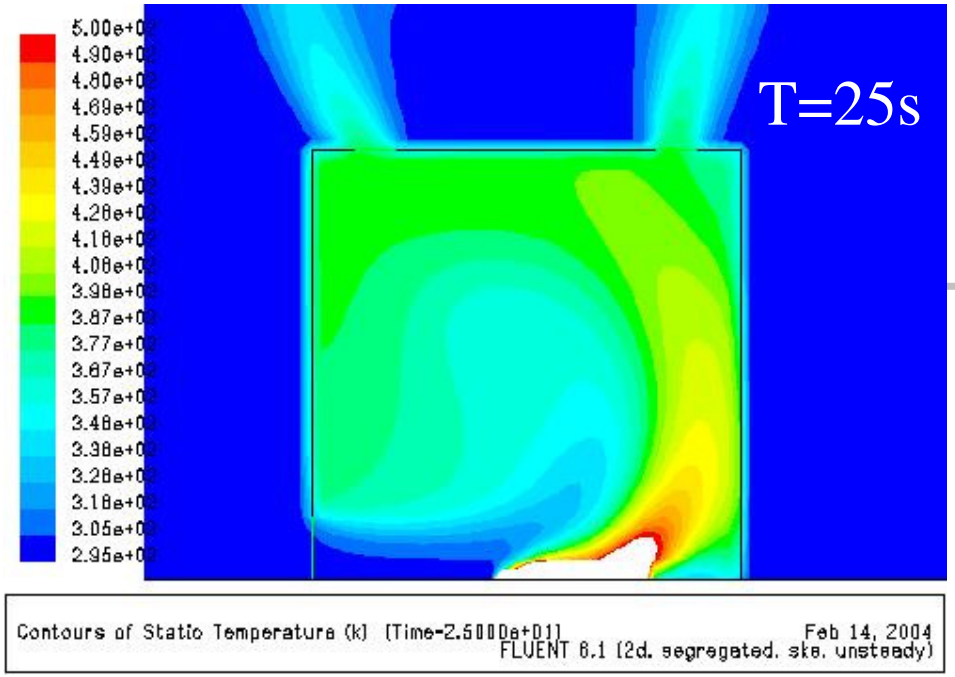
Upwind Inlets: U=0
Temperature Contours

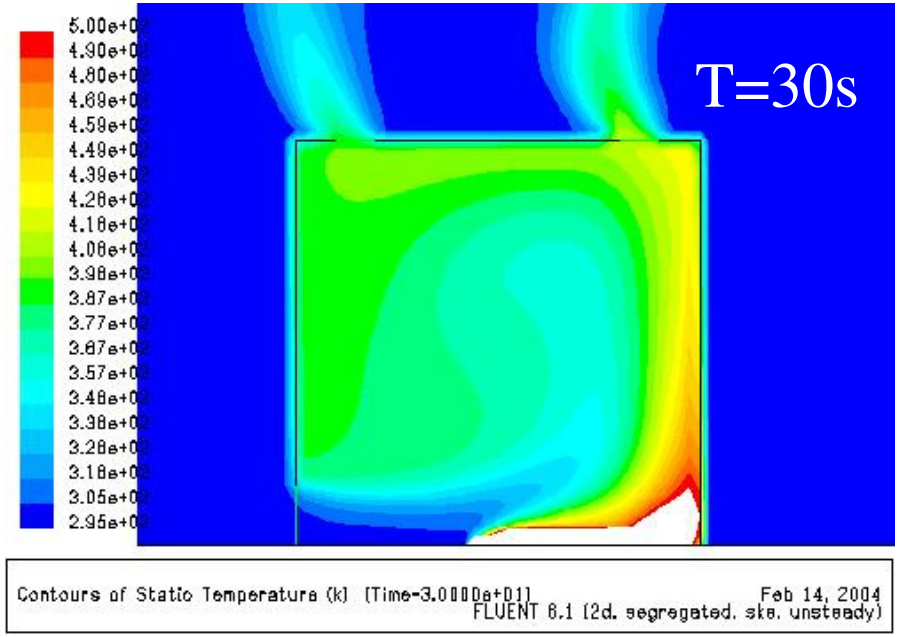









T=25s
5.00e+0
4.90e+0
4.80e+0
4.69e+0
4.59e+0
4.49e+0
4.39e+0
4.28e+0
4.18e+0
4.08e+0
3.98e+0
3.87e+0
3.77e+0
3.67e+0
3.57e+0
3.46e+0
3.36e+0
3.26e+0
3.16e+0
3.05e+0
2.95e+0
Contours of Static Temperature (k) (Time=2.5000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)


T=30s
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4.90e+0
4.80e+0
4.69e+0
4.59e+0
4.49e+0
4.39e+0
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4.18e+0
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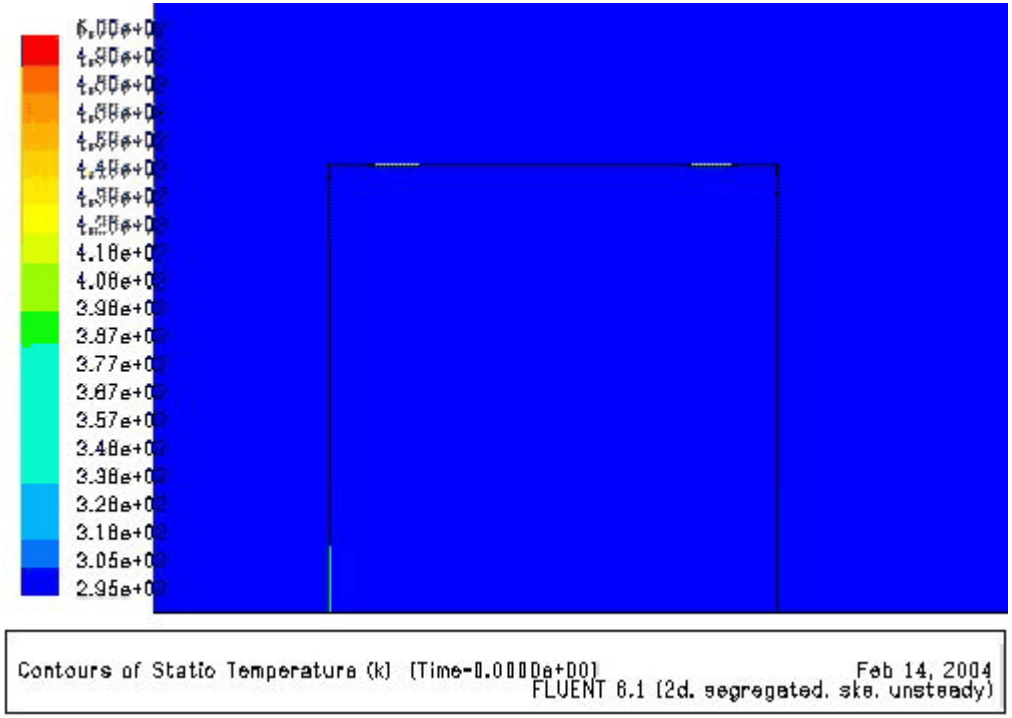
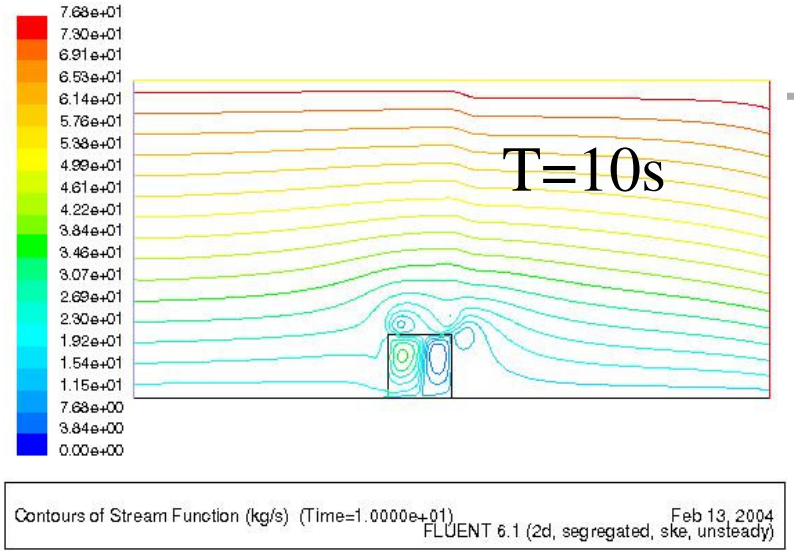
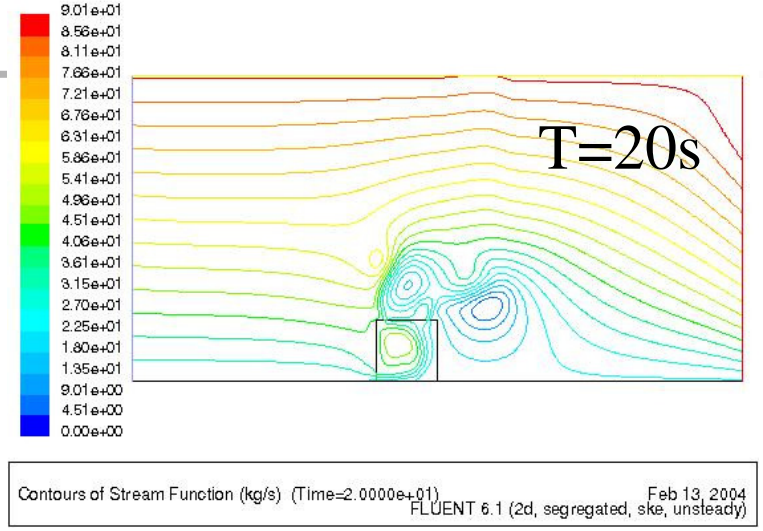
3.98e+0
3.87e+0
3.77e+0
3.67e+0
3.57e+0
3.46e+0
3.36e+0
3.26e+0
3.16e+0
3.05e+0
2.95e+0
Contours of Static Temperature (k) (Time=3.0000e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

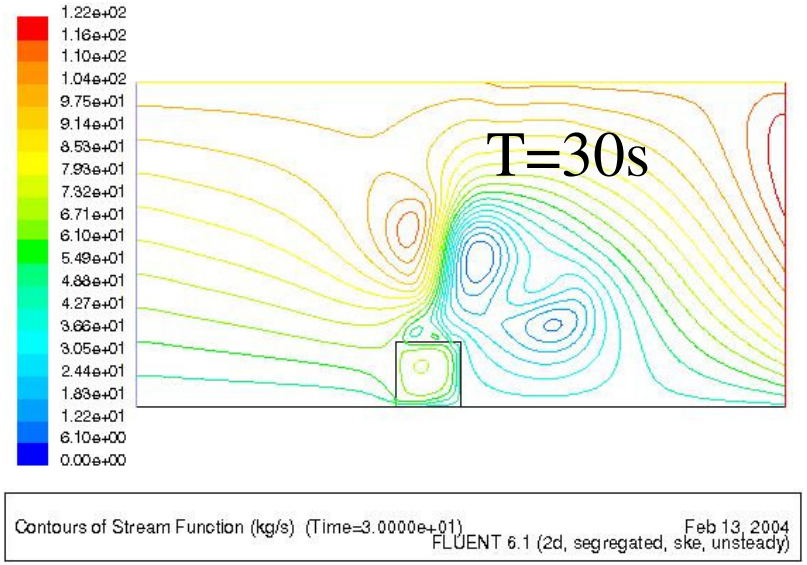
Upwind Inlets: U=0
Temperature Contours Animation

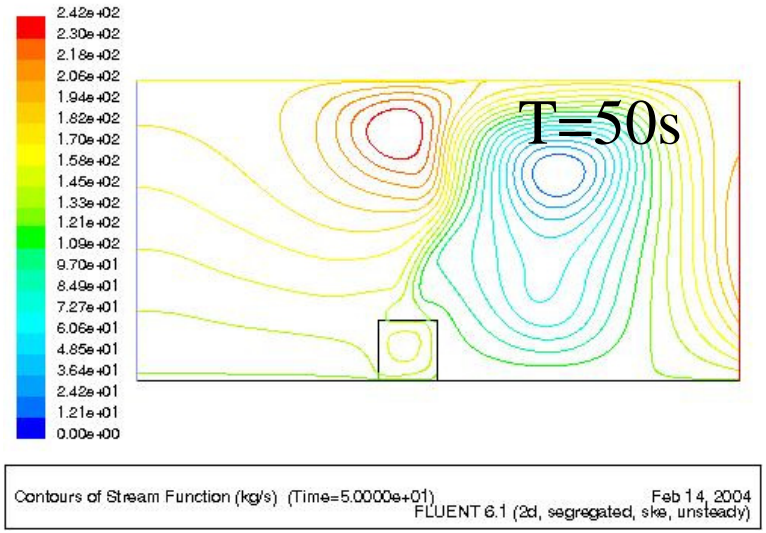


Upwind Inlets: U=0.5m/s Streamlines

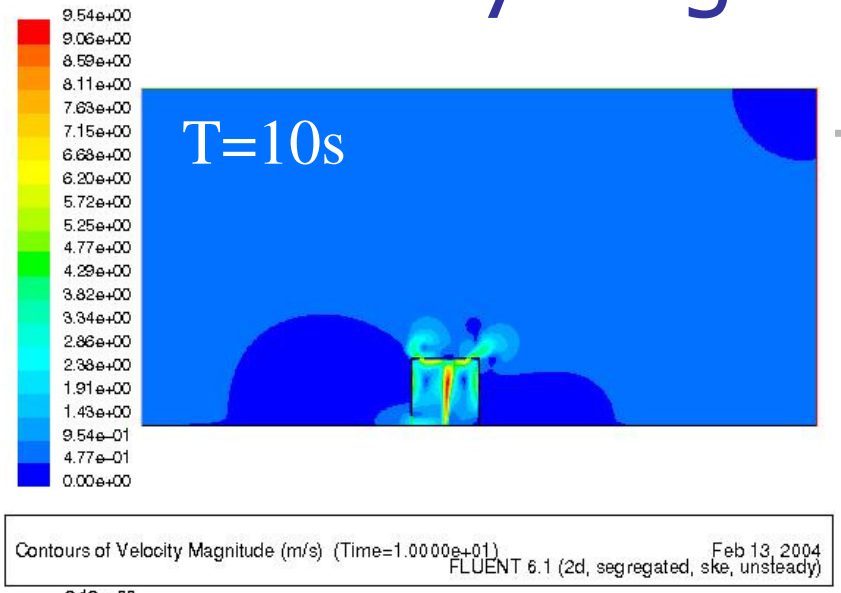


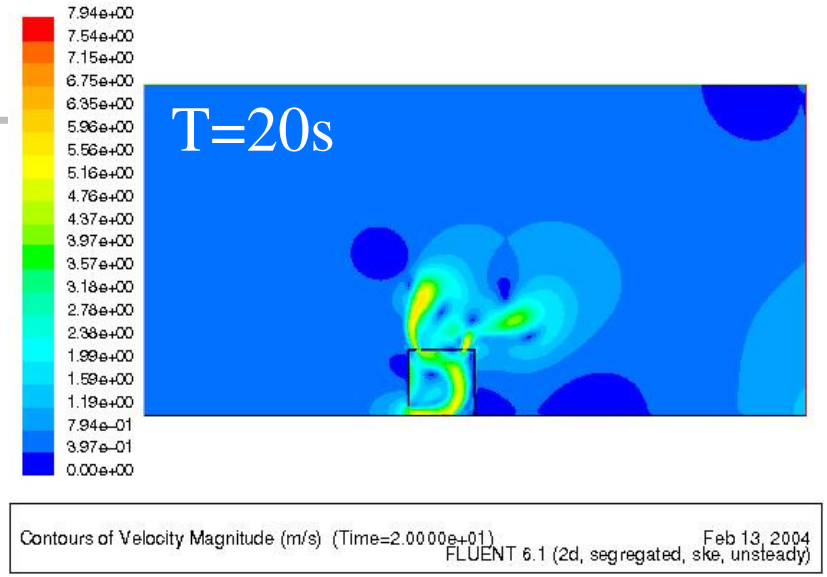


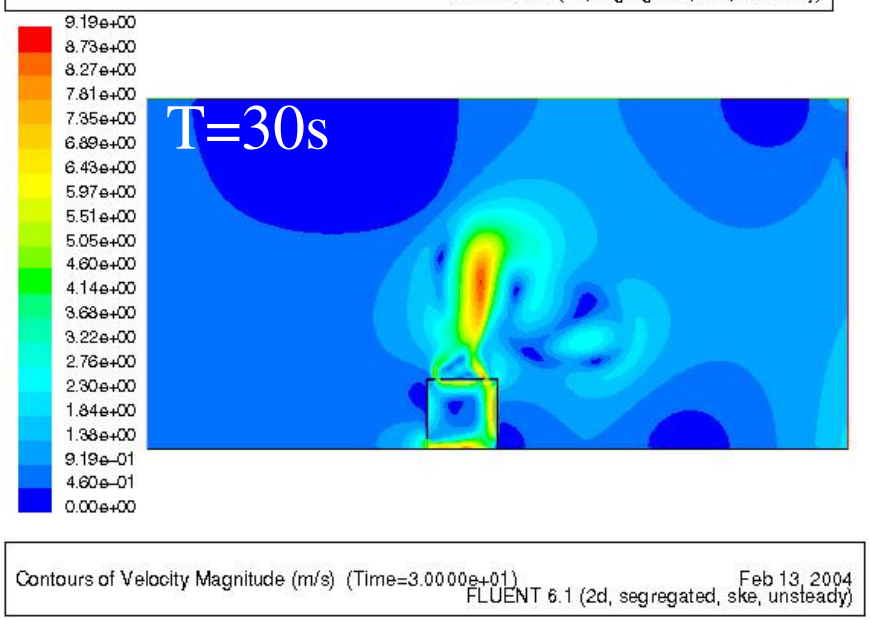


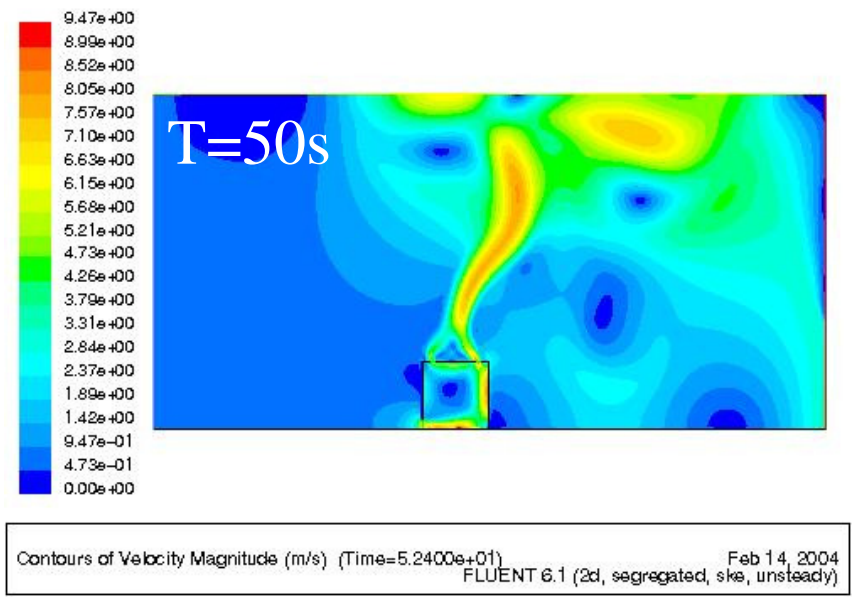


Upwind Inlets: U=0.5m/s Velocity Magnitude Contours

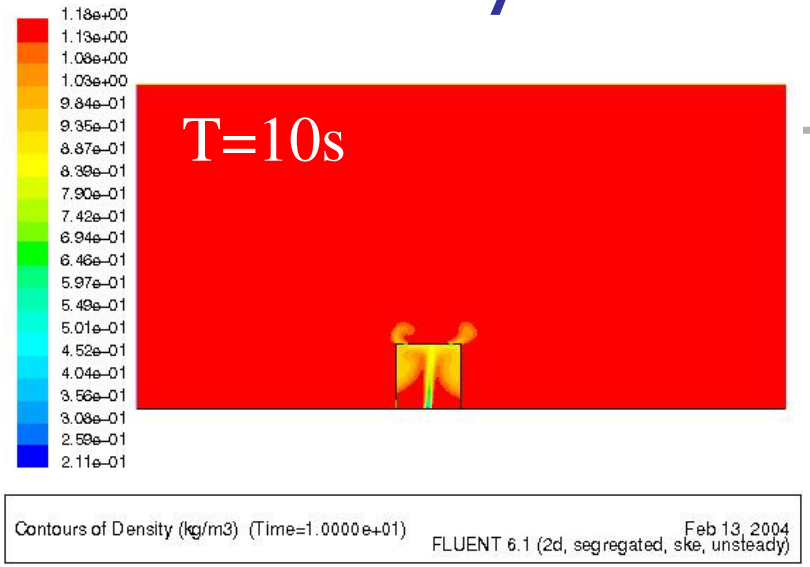


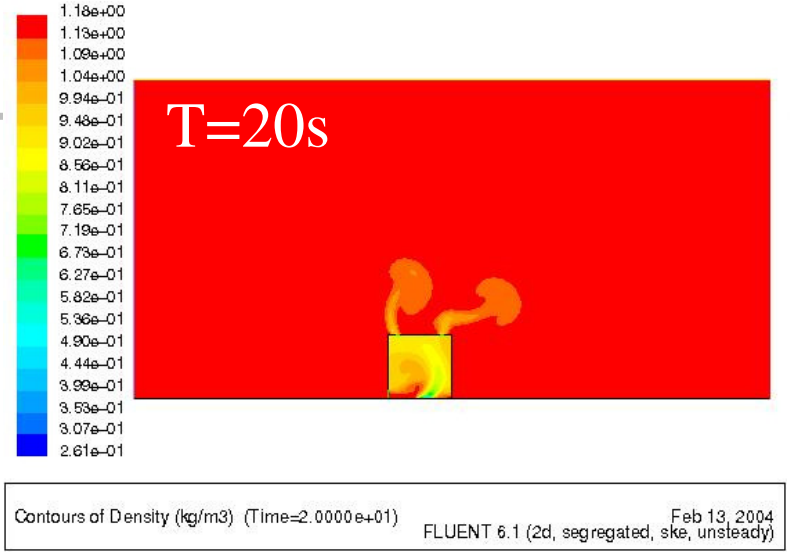


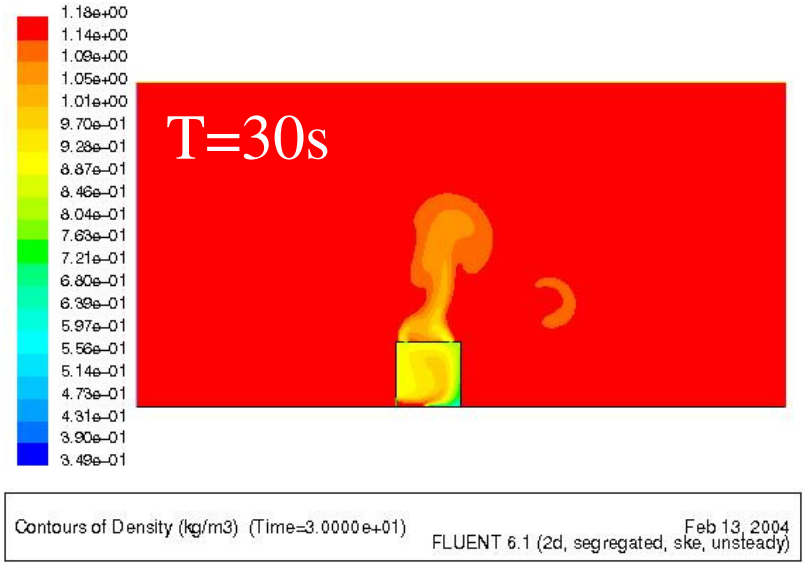


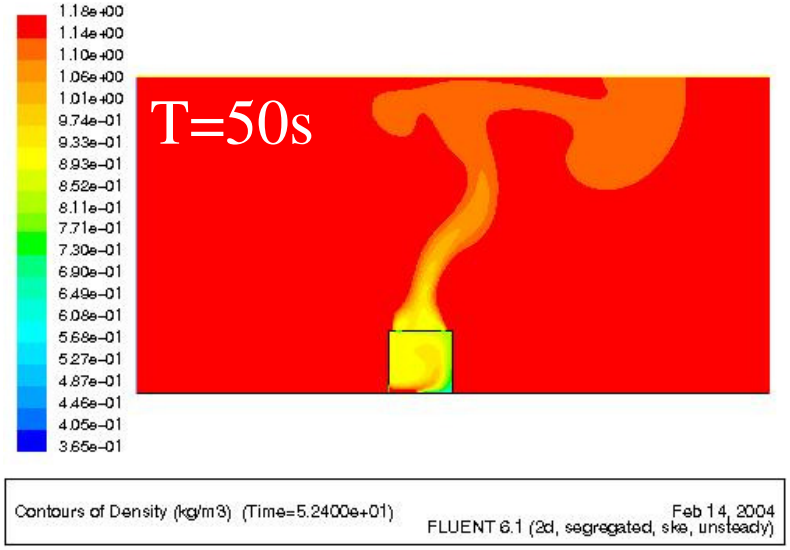


Upwind Inlets: U=0.5m/s Density Contours

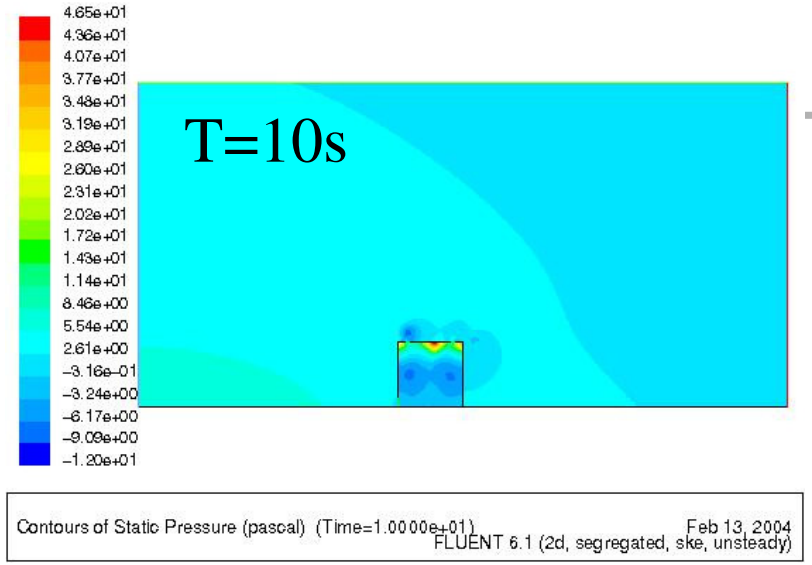


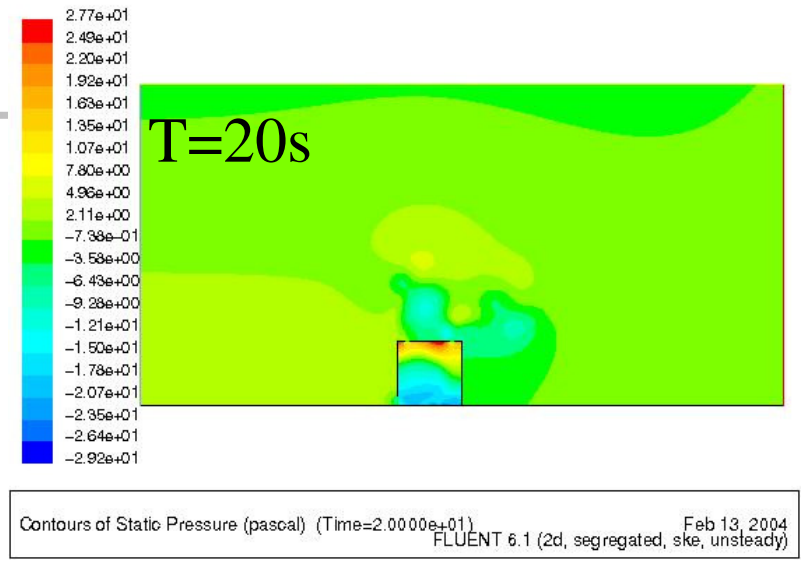


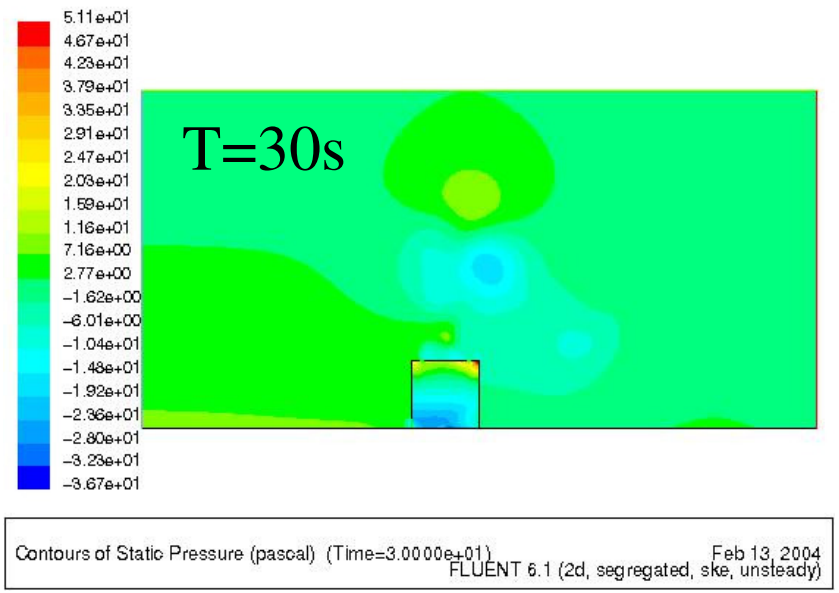


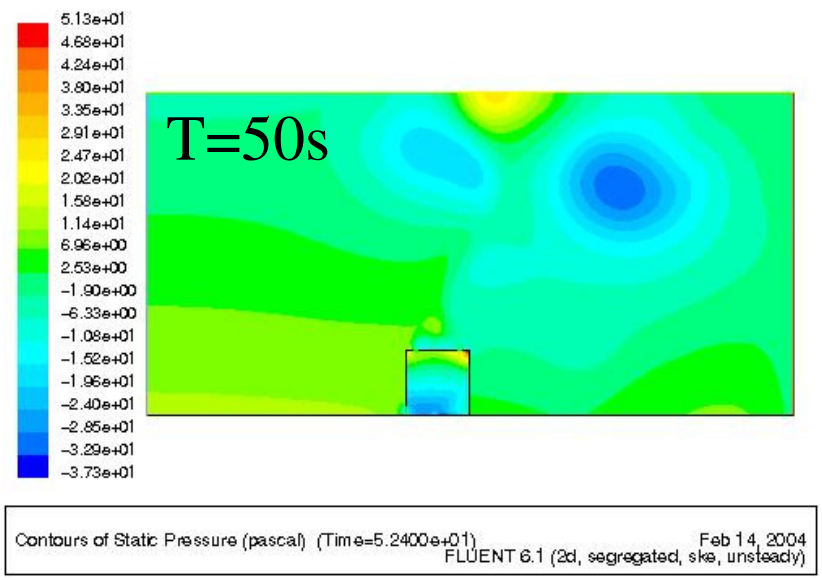


Upwind Inlets: U=0.5m/s
Static Pressure Contours

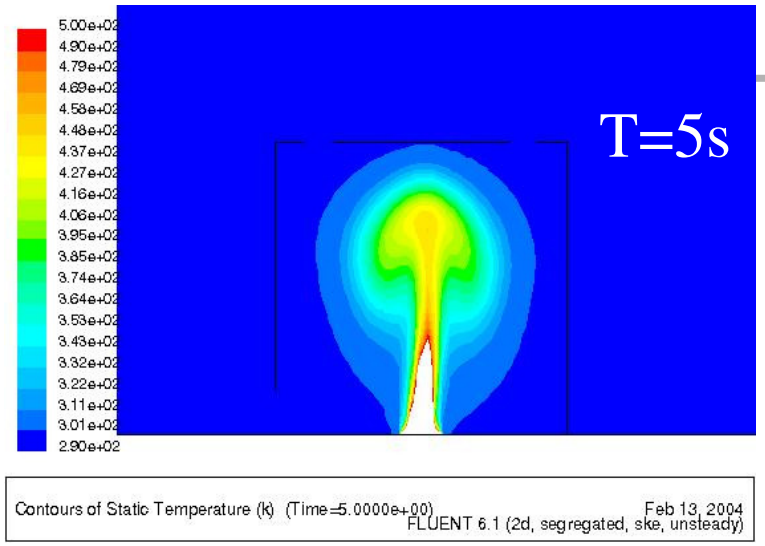


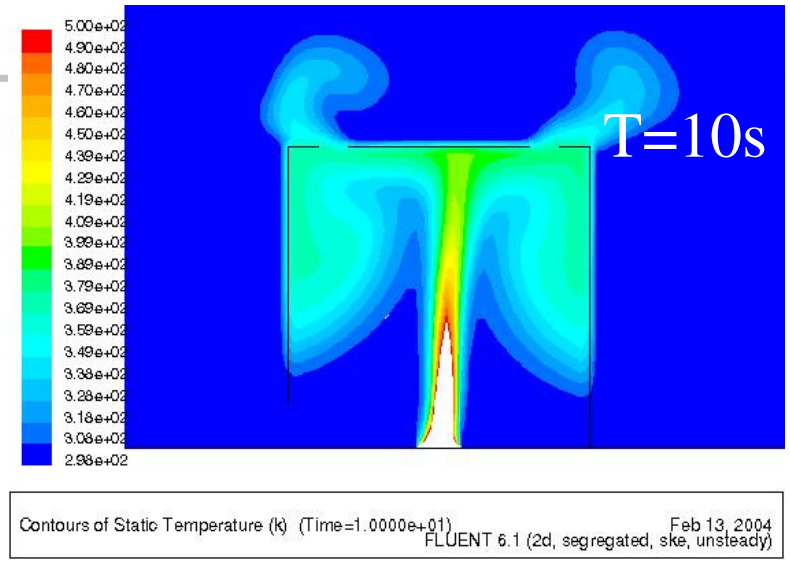


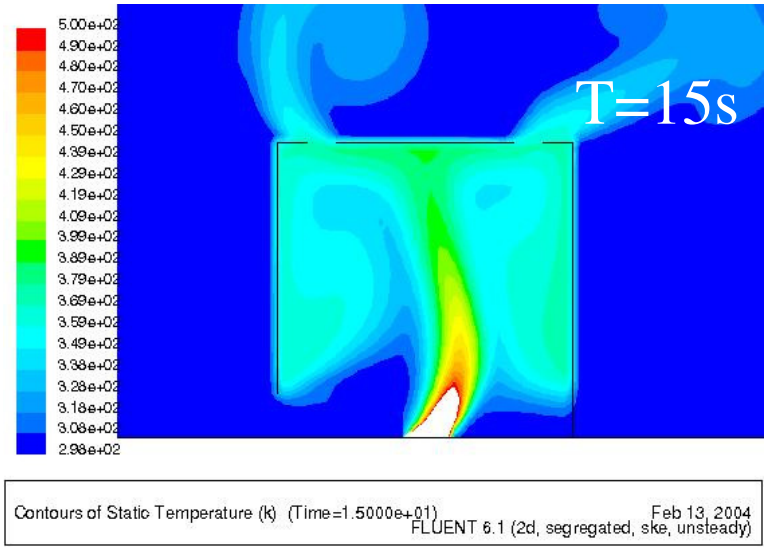


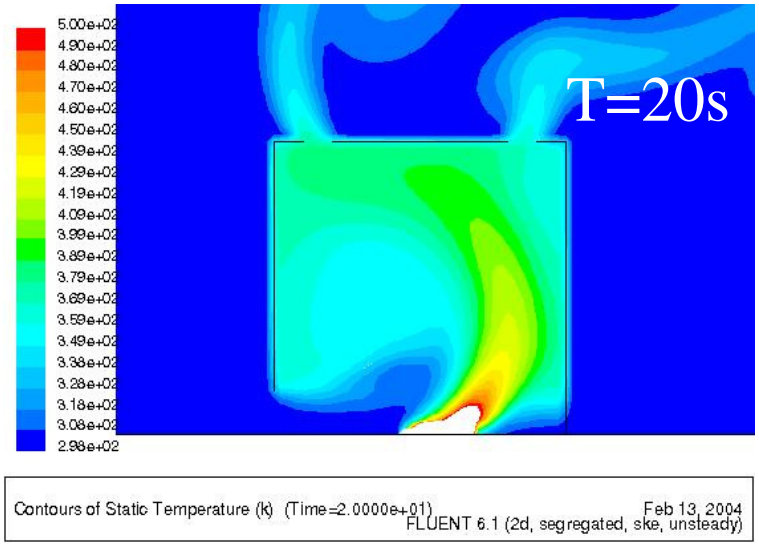


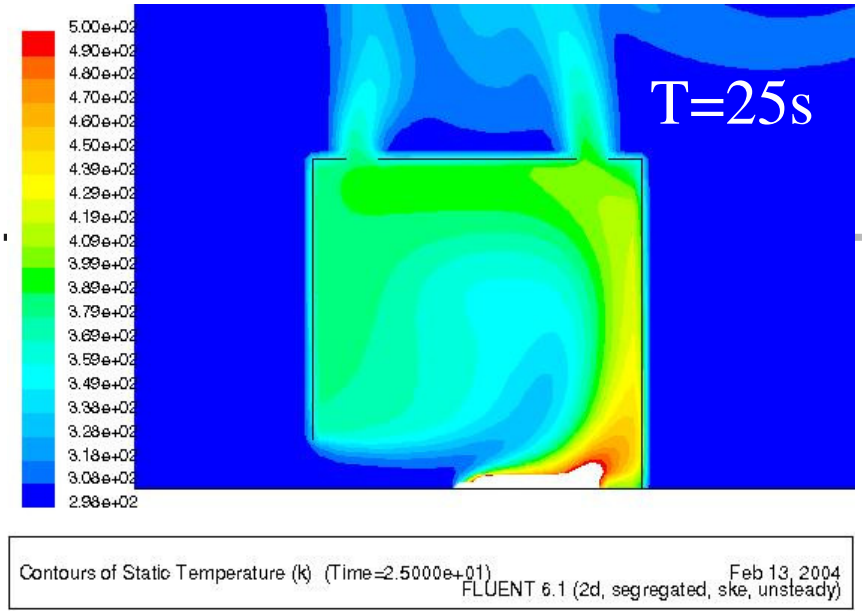
Upwind Inlets: U=0.5m/s Temperature Contours

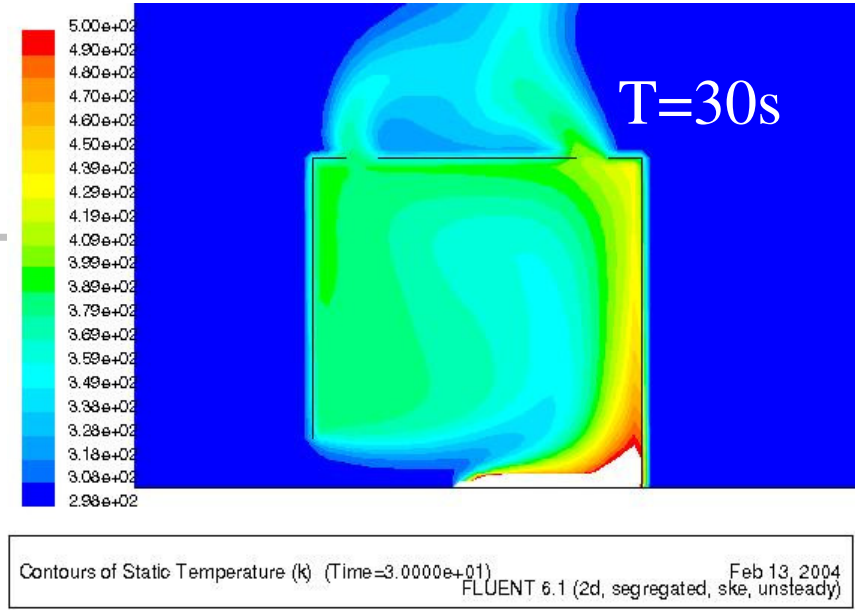


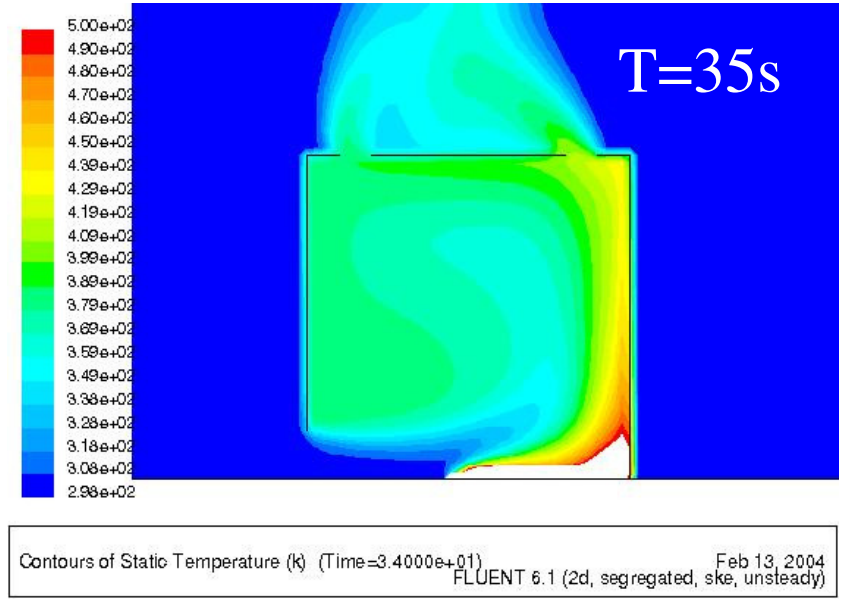







T=25s
5.00e+02
4.90e+02
4.80e+02
4.70e+02
4.60e+02
4.50e+02
4.39e+02
4.29e+02
4.19e+02
4.09e+02
3.99e+02
3.89e+02
3.79e+02
3.69e+02
3.59e+02
3.49e+02
3.38e+02
3.28e+02
3.18e+02
3.08e+02
2.98e+02
Contours of Static Temperature (k) (Time=2.5000e+01)
Feb 13, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)


T=30s
5.00e+02
4.90e+02
4.80e+02
4.70e+02
4.60e+02
4.50e+02
4.39e+02
4.29e+02
4.19e+02
4.09e+02
3.99e+02
3.89e+02
3.79e+02
3.69e+02
3.59e+02
3.49e+02
3.38e+02
3.28e+02
3.18e+02
3.08e+02
2.98e+02
Contours of Static Temperature (k) (Time=3.0000e+01)
Feb 13, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)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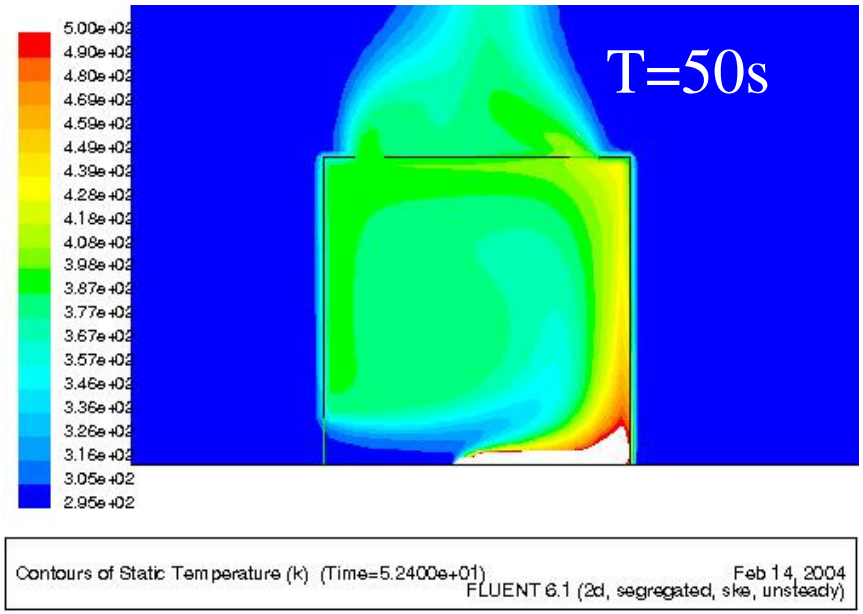
4.90e+02
4.80e+02
4.70e+02
4.60e+02
4.50e+02
4.39e+02
4.29e+02
4.19e+02
4.09e+02
3.99e+02
3.89e+02
3.79e+02
3.69e+02
3.59e+02
3.49e+02
3.38e+02
3.28e+02
3.18e+02
3.08e+02
2.98e+02
Contours of Static Temperature (k) (Time=3.4000e+01)
Feb 13, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)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4.80e+02
4.69e+02
4.59e+02
4.49e+02
4.39e+02
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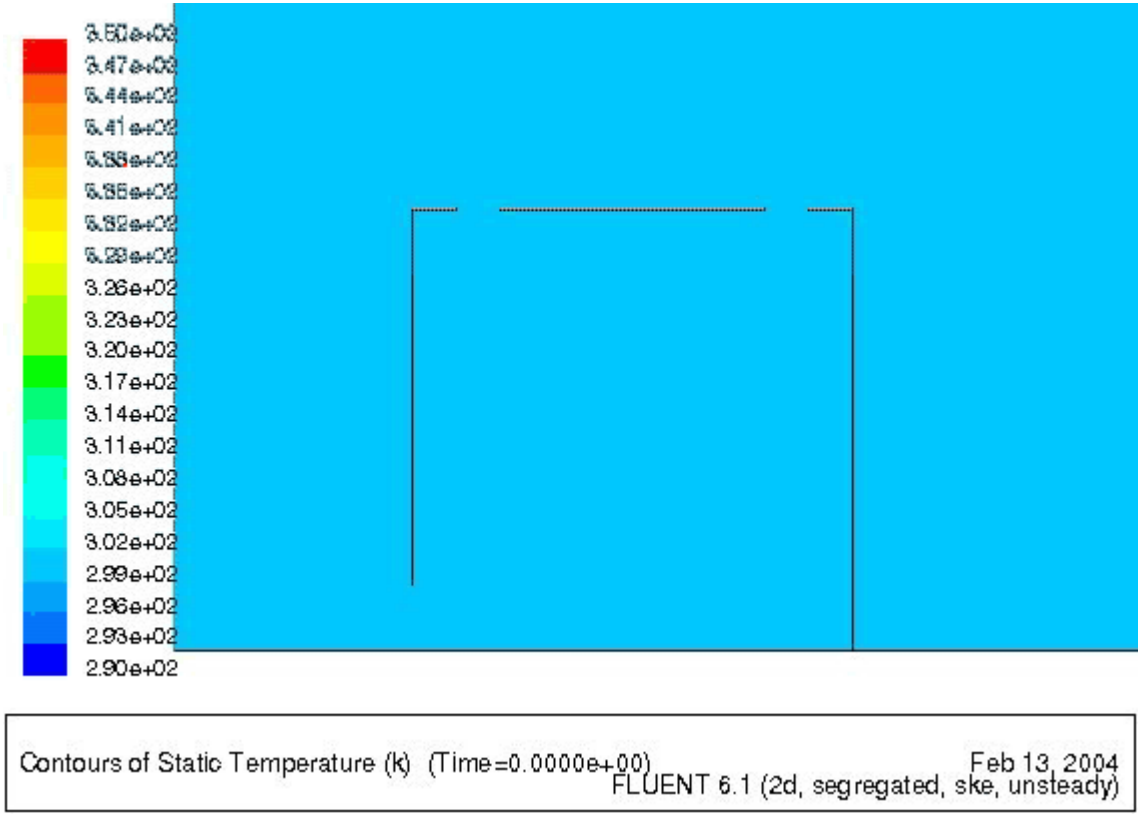
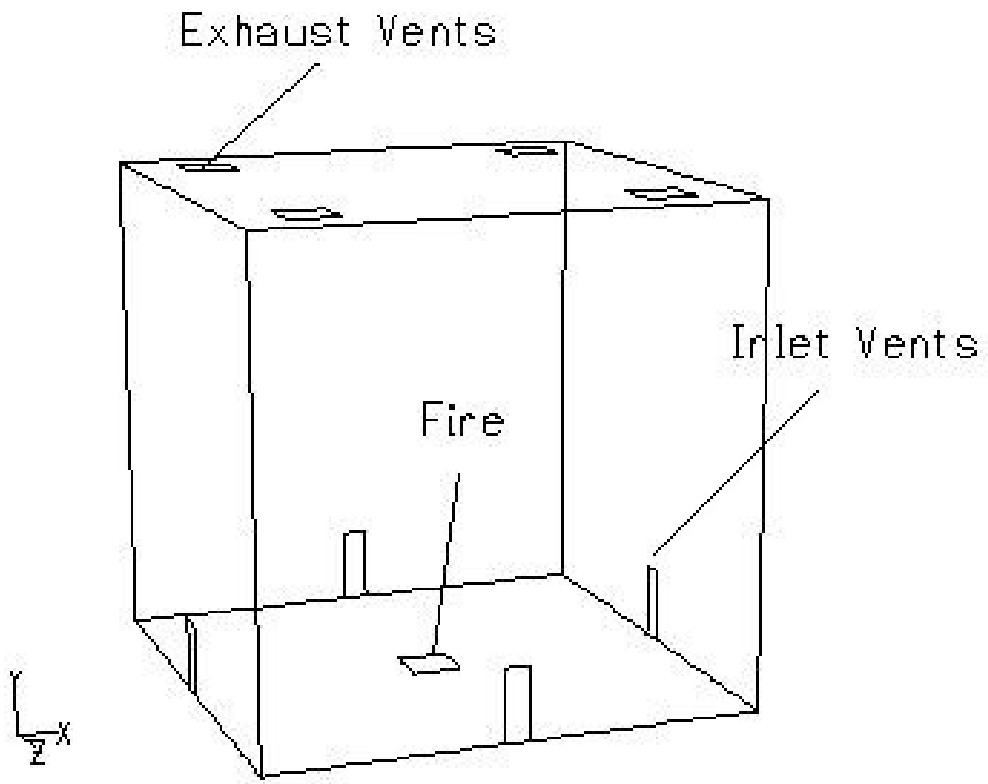
4.18e+02
4.08e+02
3.98e+02
3.87e+02
3.77e+02
3.67e+02
3.57e+02
3.46e+02
3.36e+02
3.26e+02
3.16e+02
3.05e+02
2.95e+02
Contours of Static Temperature (k) (Time=5.2400e+01)
Feb 14, 2004
FLUENT 6.1 (2d, segregated, ske, unsteady)

Upwind Inlets: U=0.5 m/s Temperature Contours Animation

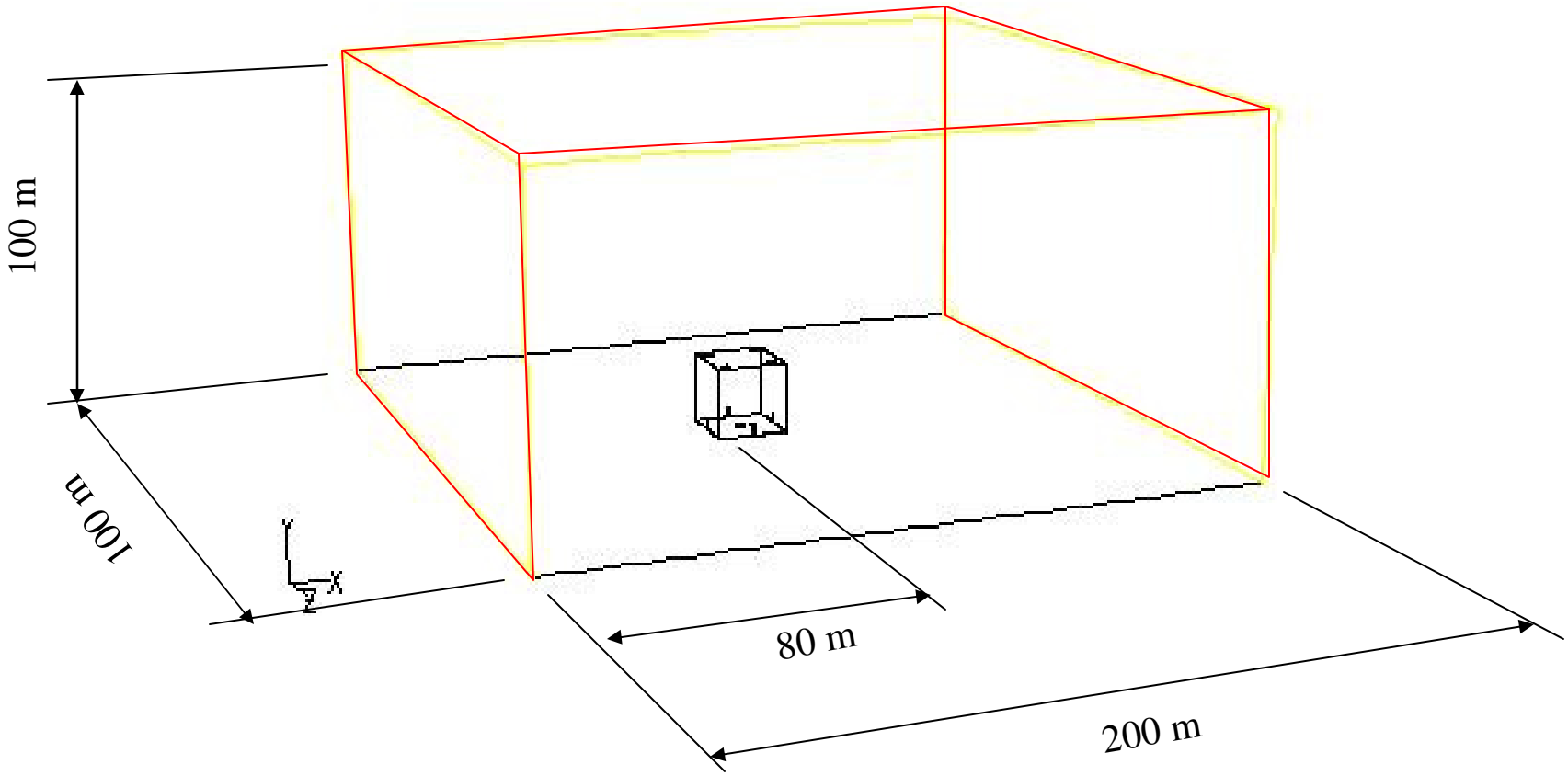


Three Dimensional Atrium

- Bldg Size = 20 x 20 m, Inlets = 1 x 3 m, Exhausts = 2 x 2 m

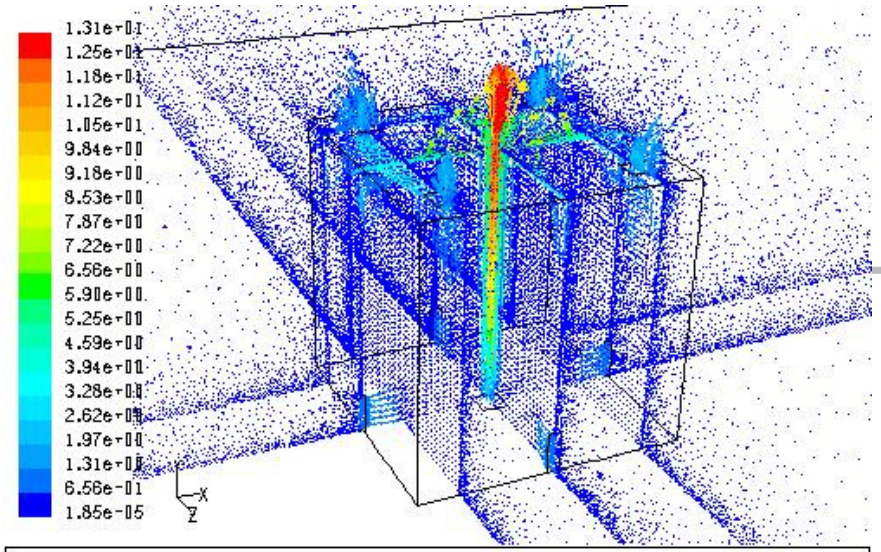


Three Dimensional Atrium



Computational Details 3-d

- Fluent 6
- Large eddy simulation (LES) turbulence model
- Second order accuracy
- Uniform flow inlet, U = 0 & 2.0 m/s
- Grid: Hexagonal 442,000 cells
- Time step = 0.1 sec
- Fire strength = 2,500,000 W (2.5 MW)


1.31e+01
1.25e+01
1.18e+01
1.12e+01
1.05e+01
9.84e+00
9.18e+00
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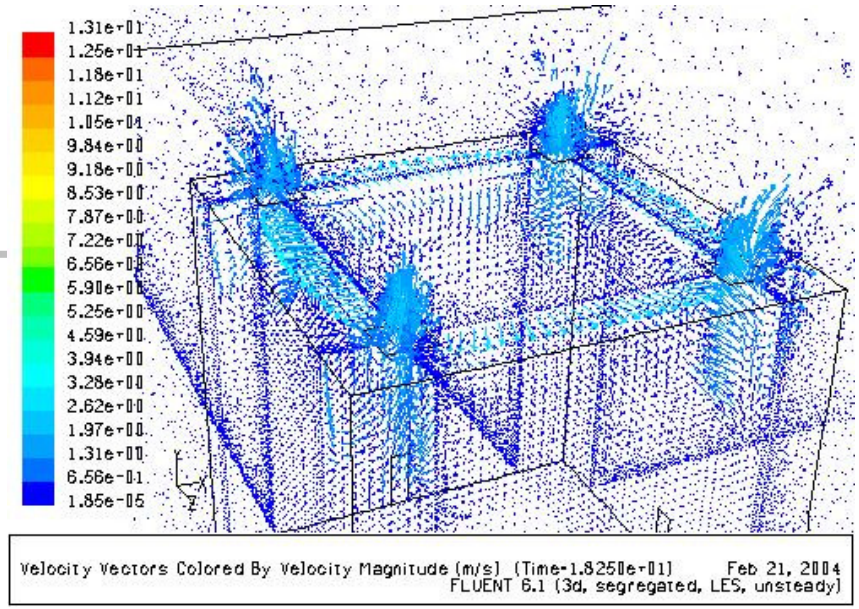
7.87e+00
7.22e+00
6.56e+00
5.90e+00
5.25e+00
4.59e+00
3.94e+00
3.28e+00
2.62e+00
1.97e+00
1.31e+00
6.56e-01
1.85e-05
X
Z
Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=1.8250e+01) Feb 21, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)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1.12e+01
1.05e+01
9.84e+00
9.18e+00
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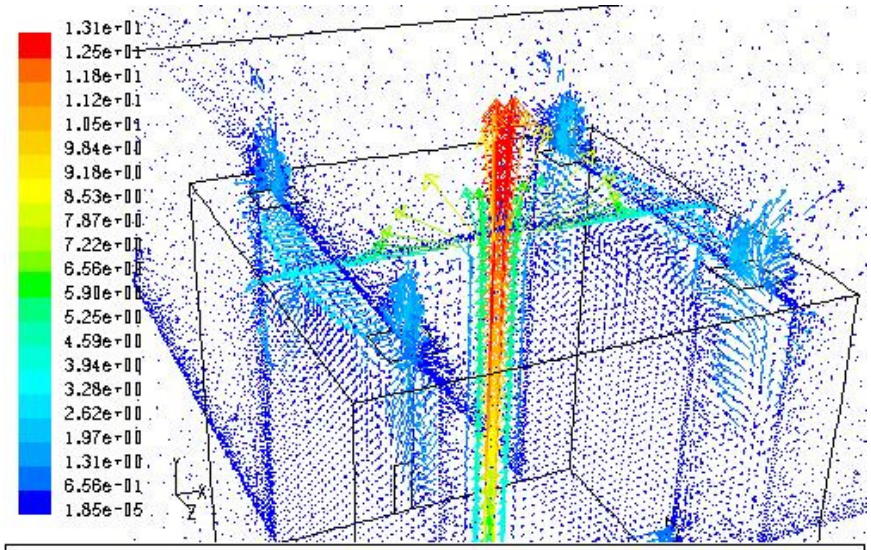
7.87e+00
7.22e+00
6.56e+00
5.90e+00
5.25e+00
4.59e+00
3.94e+00
3.28e+00
2.62e+00
1.97e+00
1.31e+00
6.56e-01
1.85e-05
Y
Z
Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=1.8250e+01) Feb 21, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)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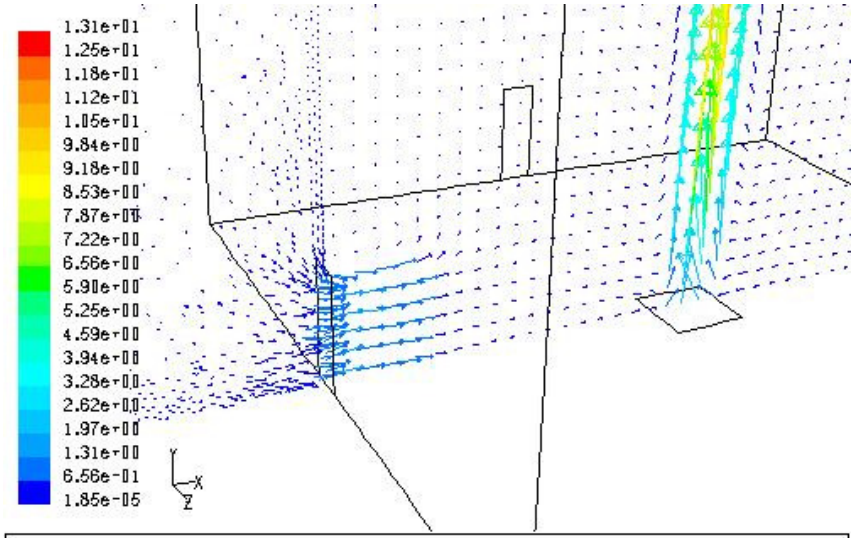
7.22e+00
6.56e+00
5.90e+00
5.25e+00
4.59e+00
3.94e+00
3.28e+00
2.62e+00
1.97e+00
1.31e+00
6.56e-01
1.85e-05
X
Z
Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=1.8250e+01) Feb 21, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)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1.25e+01
1.18e+01
1.12e+01
1.05e+01
9.84e+00
9.18e+00
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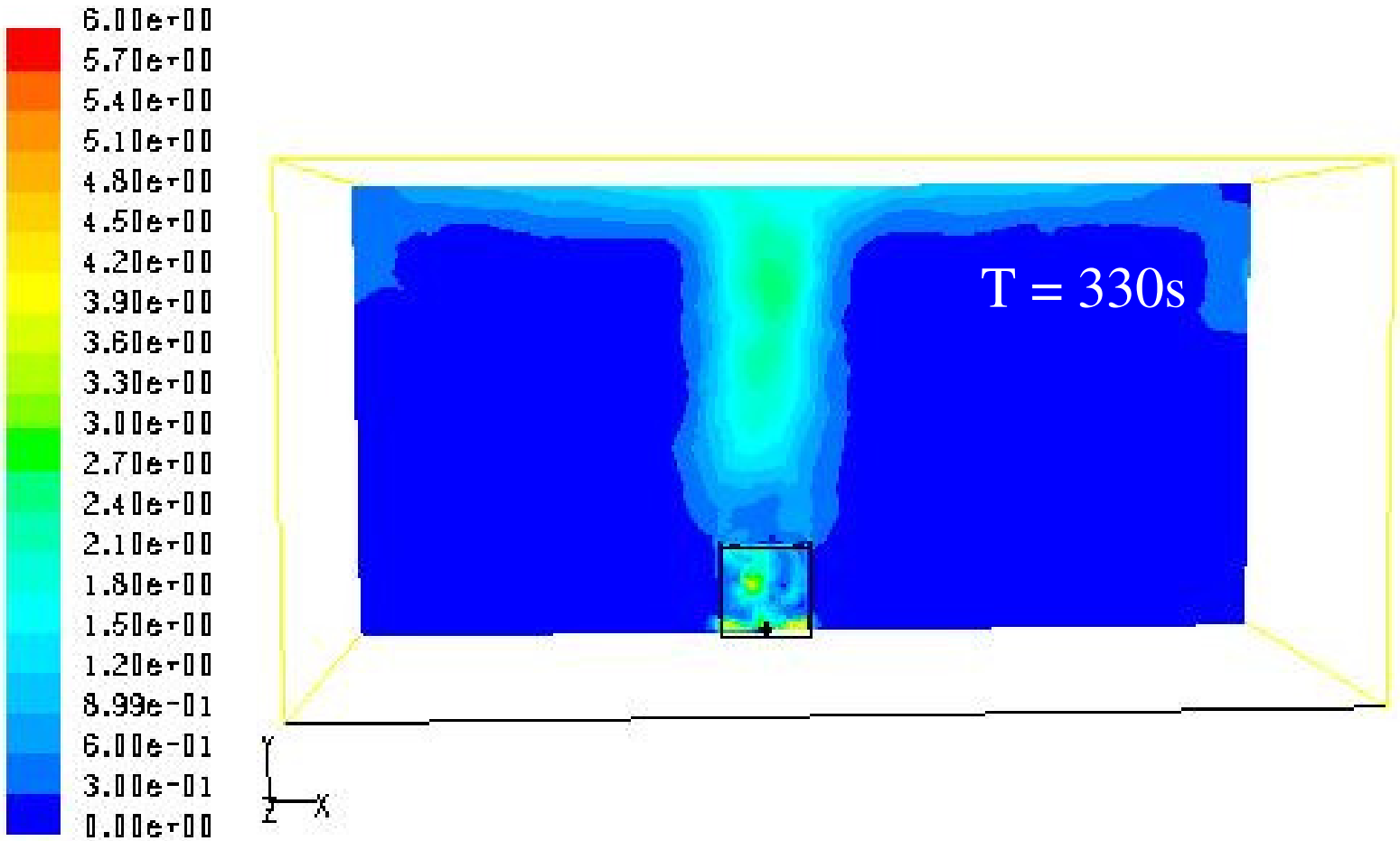
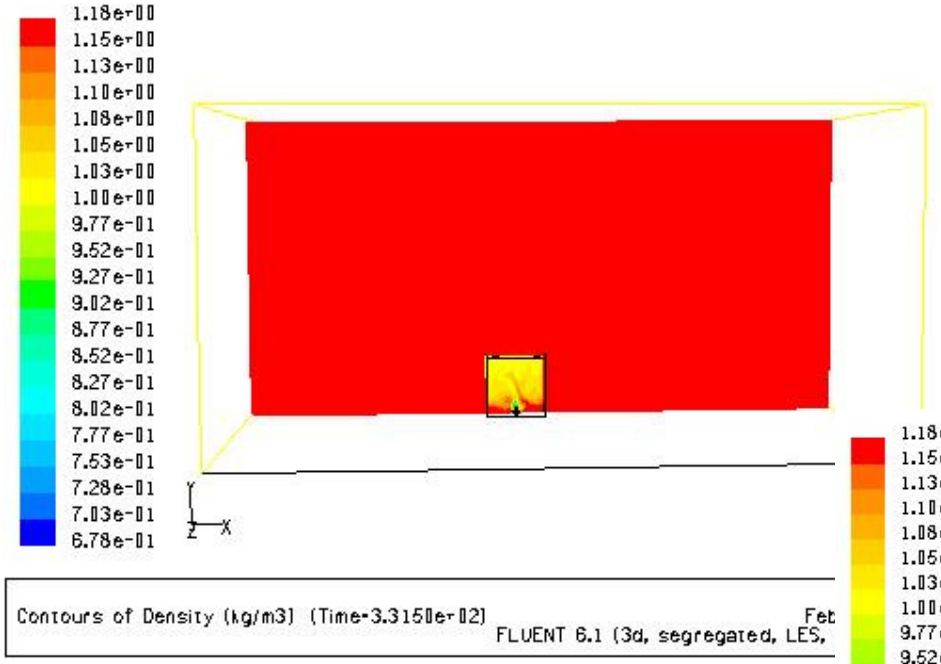
7.87e+00
7.22e+00
6.56e+00
5.90e+00
5.25e+00
4.59e+00
3.94e+00
3.28e+00
2.62e+00
1.97e+00
1.31e+00
6.56e-01
1.85e-05
Y
X
Z
Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=1.8250e+01) Feb 21, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)

3-d Cube: LES, U = 0 m/s
Velocity Magnitude 3-d

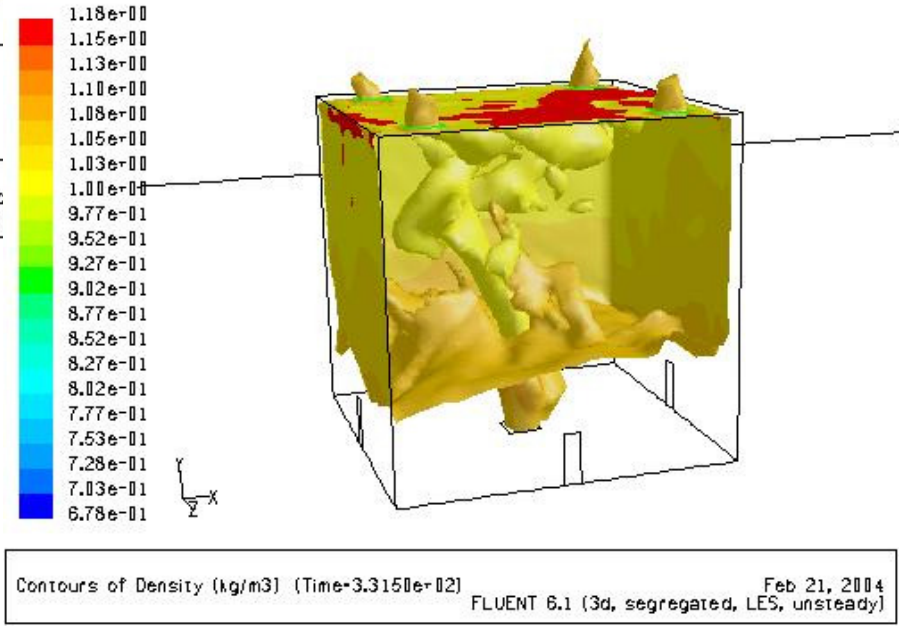


Contours of Velocity Magnitude (m/s) (Time=3.3150e+02) Feb 21, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)

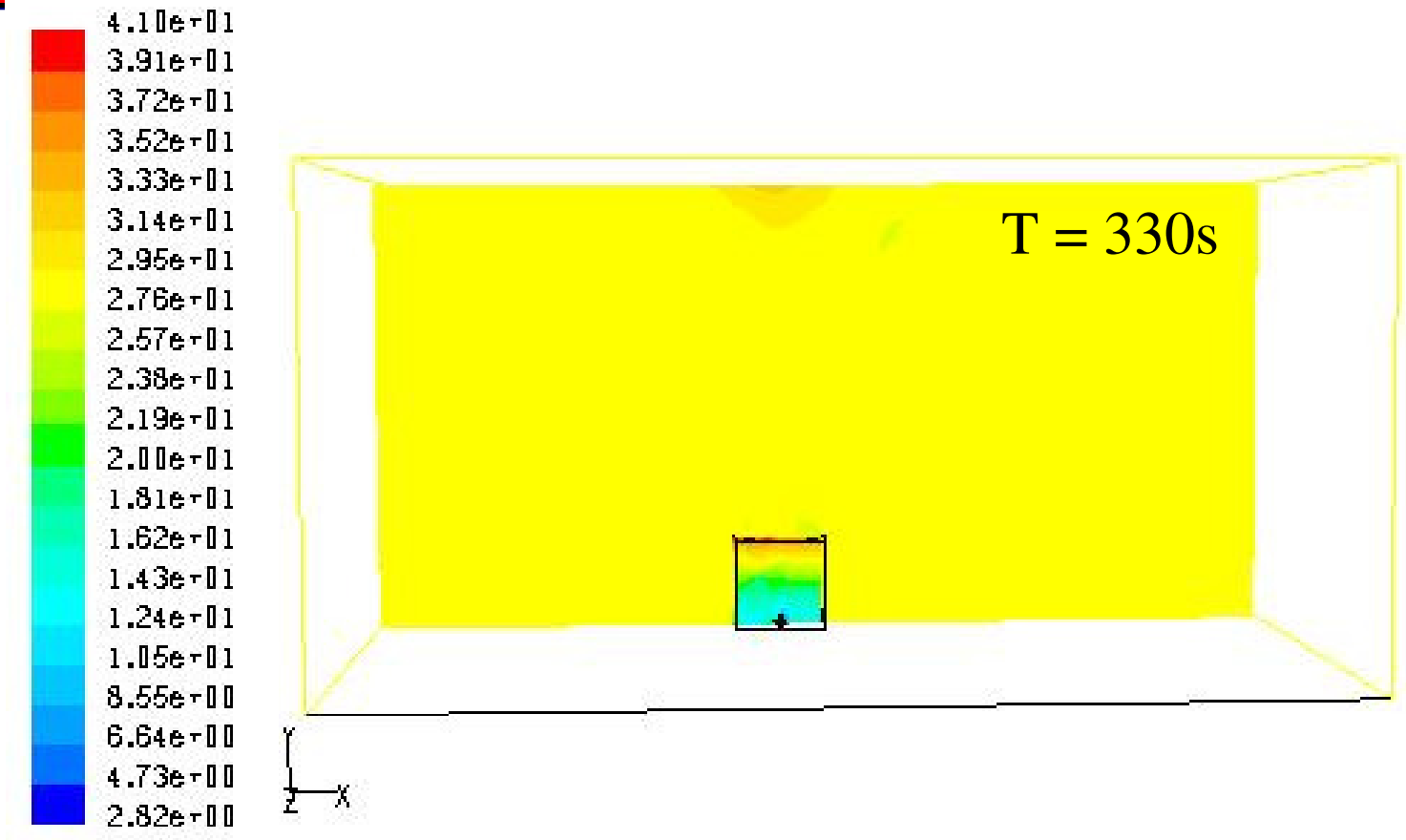
3-d Cube: LES, U = 0 m/s
Density Contours



T = 330s

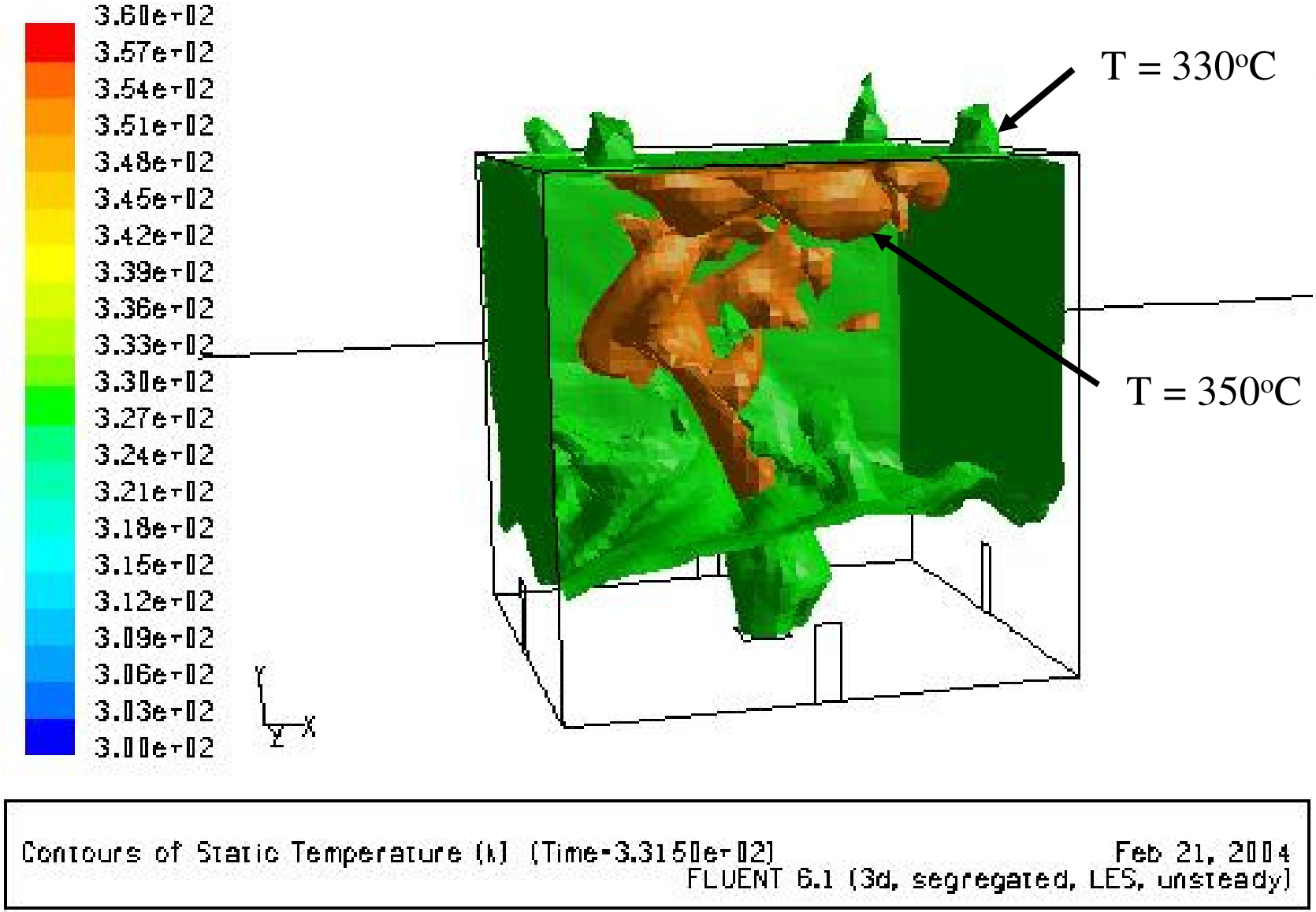


3-d Cube: LES, U = 0 m/s
Static Pressure Contours

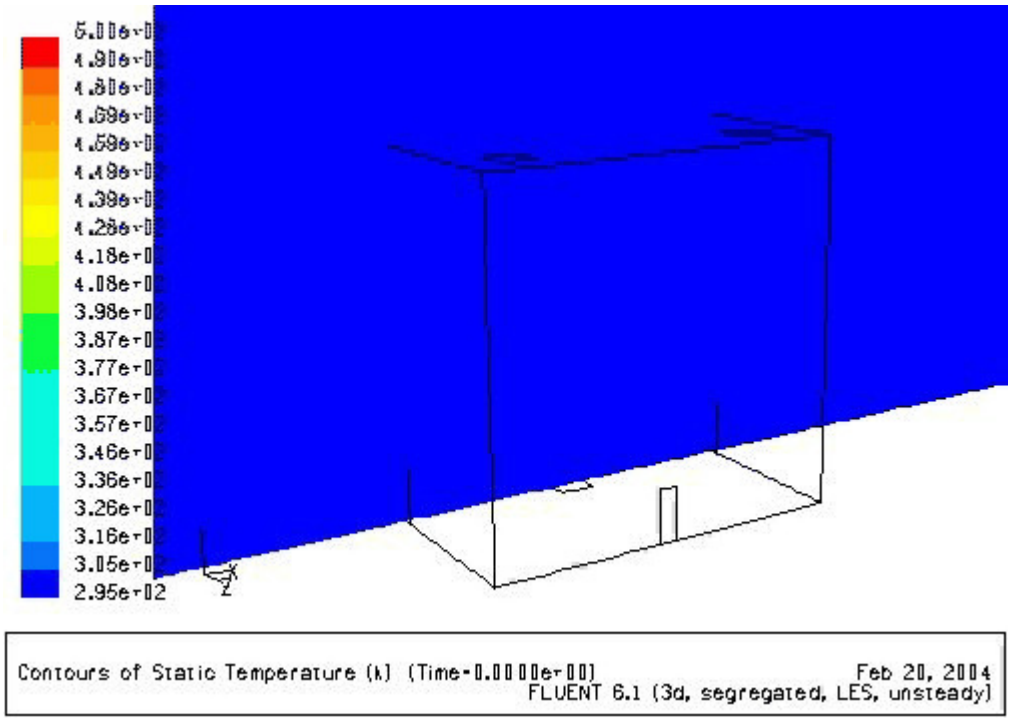


Contours of Static Pressure (pascal) (Time=3.3150e+02) Feb 21, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)

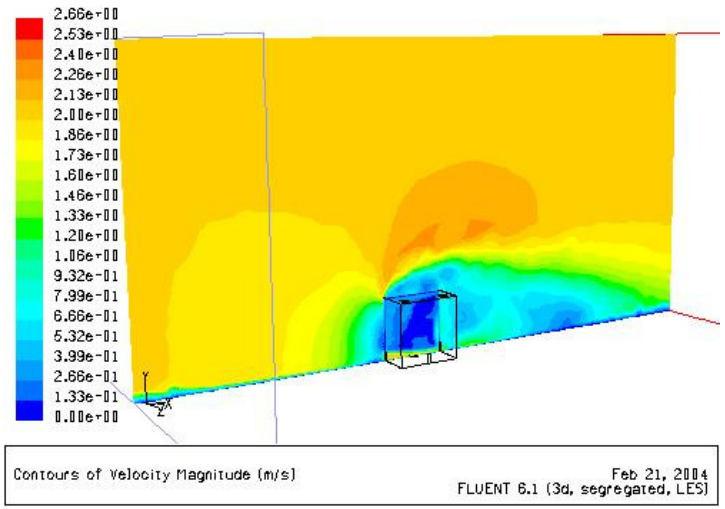
3-d Cube: LES, U = 0 m/s
Temperature Contours



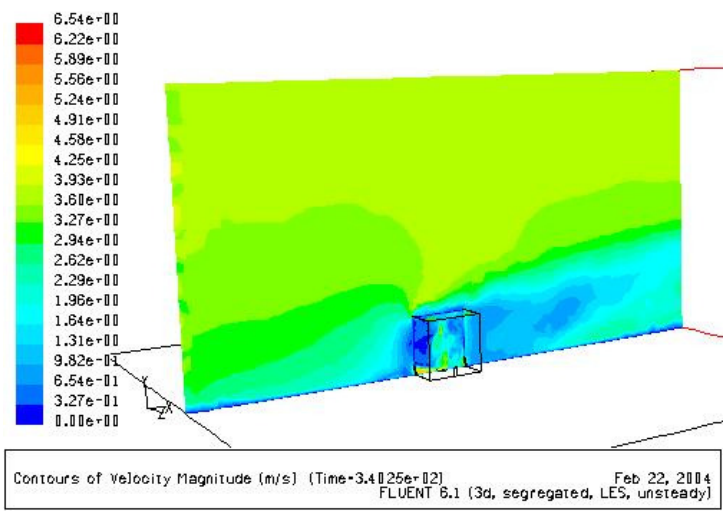
3-d Cube: LES, U = 0 m/s Temperature Contours Animation

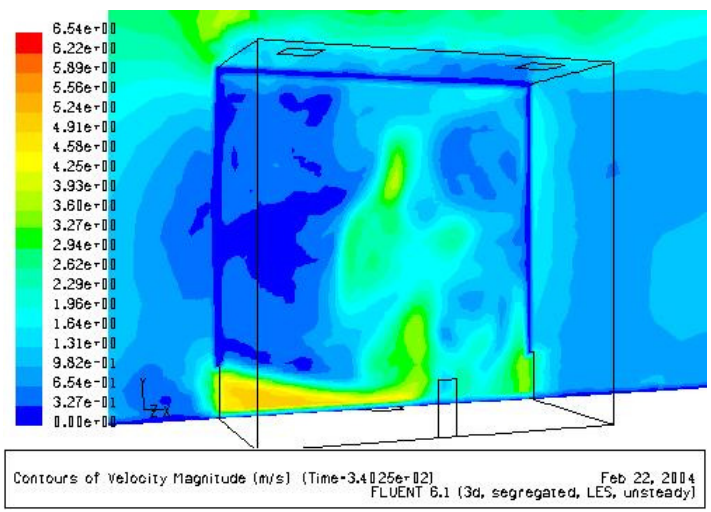


3-d Cube: LES, U = 2 m/s Velocity Magnitude



Before fire starts

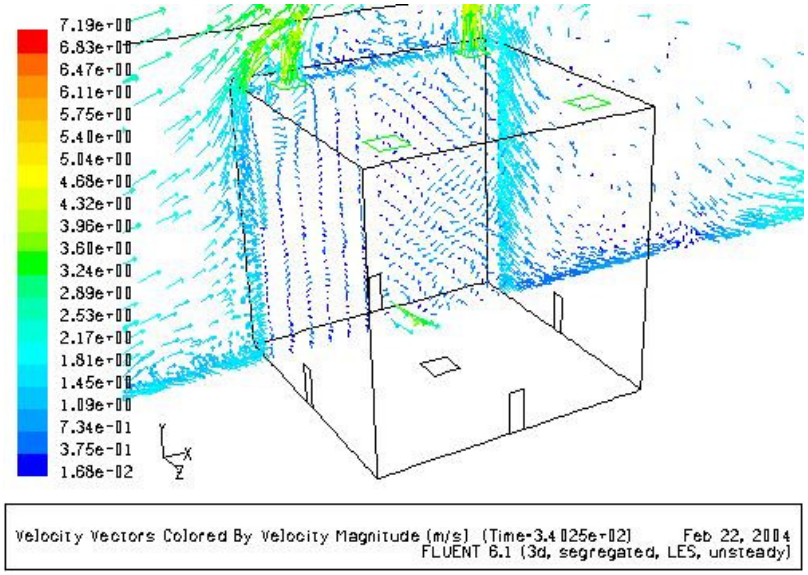


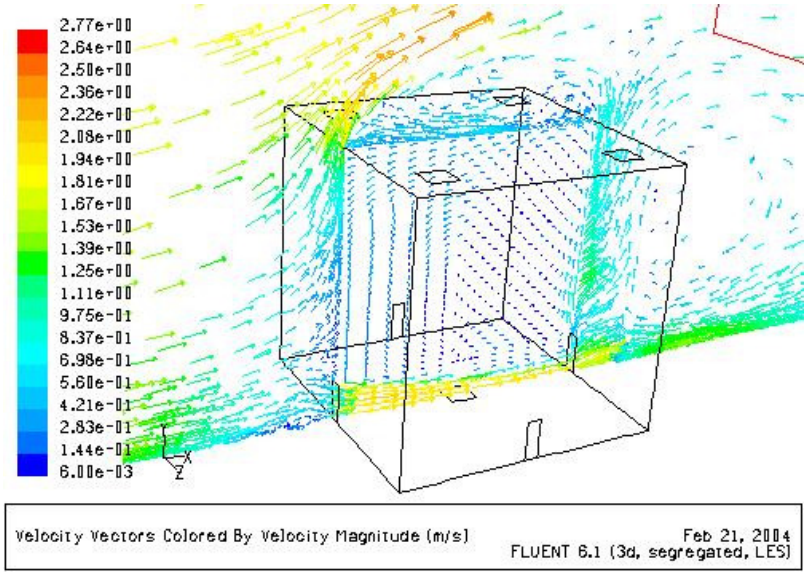


t = 330 s after fire starts

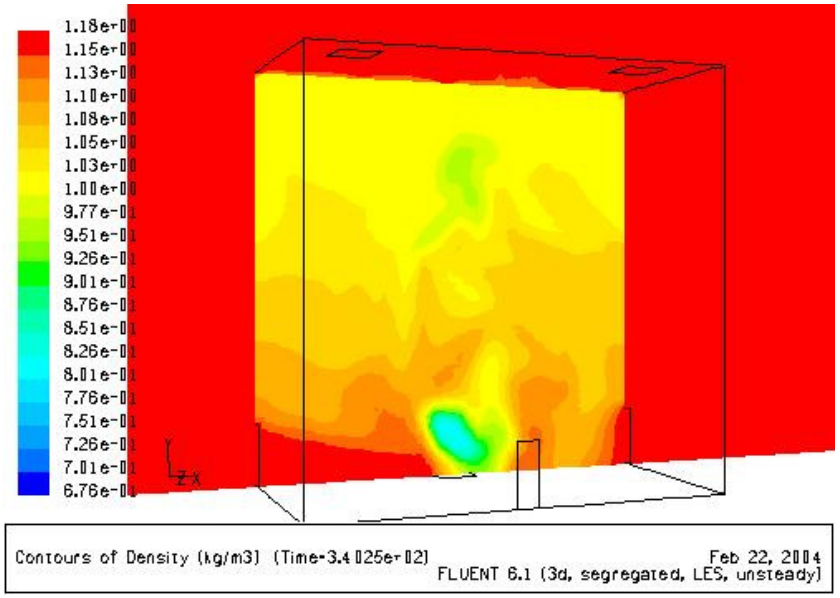
3-d Cube: LES, U = 2 m/s Velocity Magnitude

Before fire starts

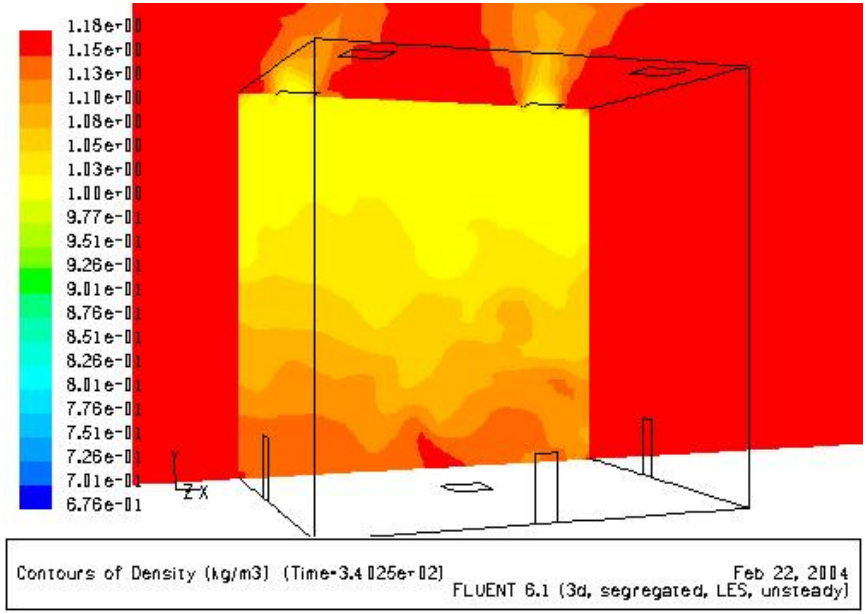




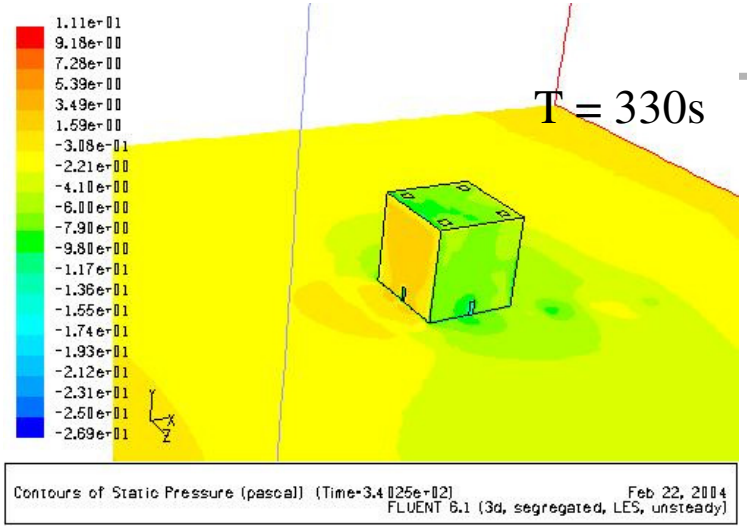
3-d Cube: LES, U = 2 m/s Density Contours

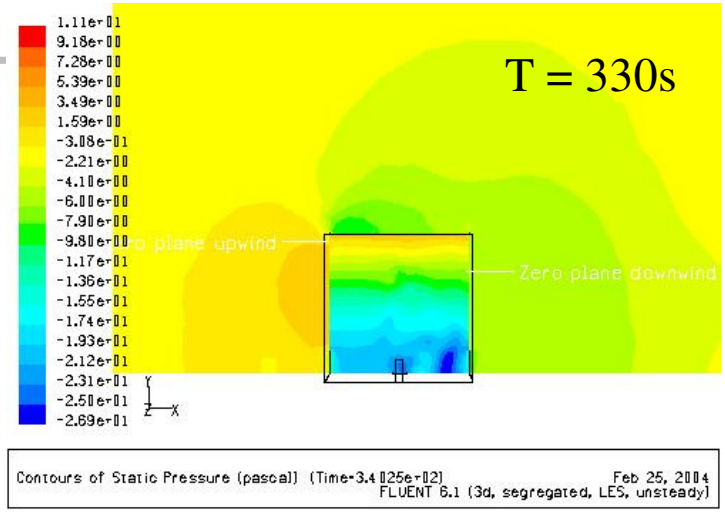


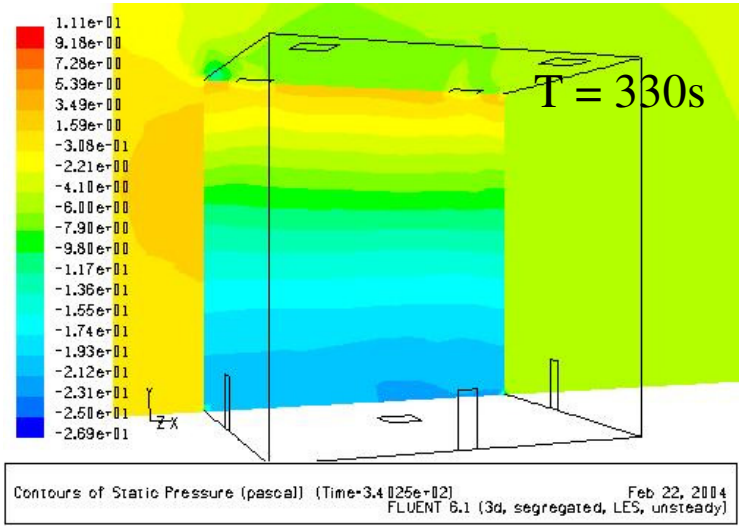
T = 330s

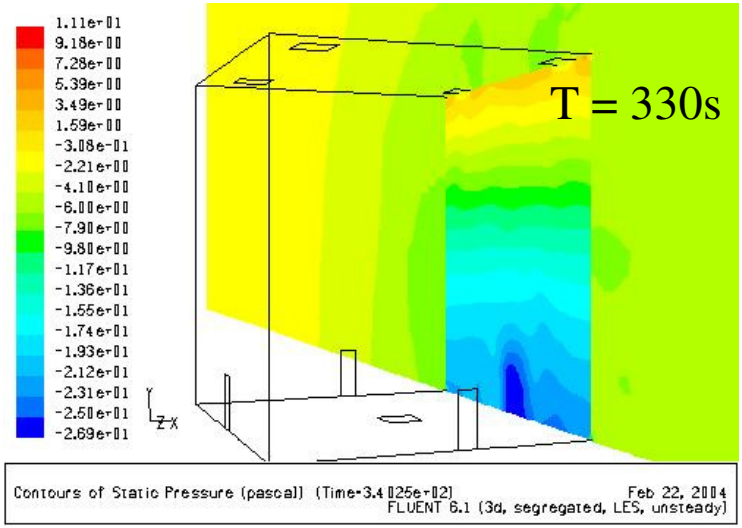


3-d Cube: LES, U = 2 m/s
Static Pressure Contours

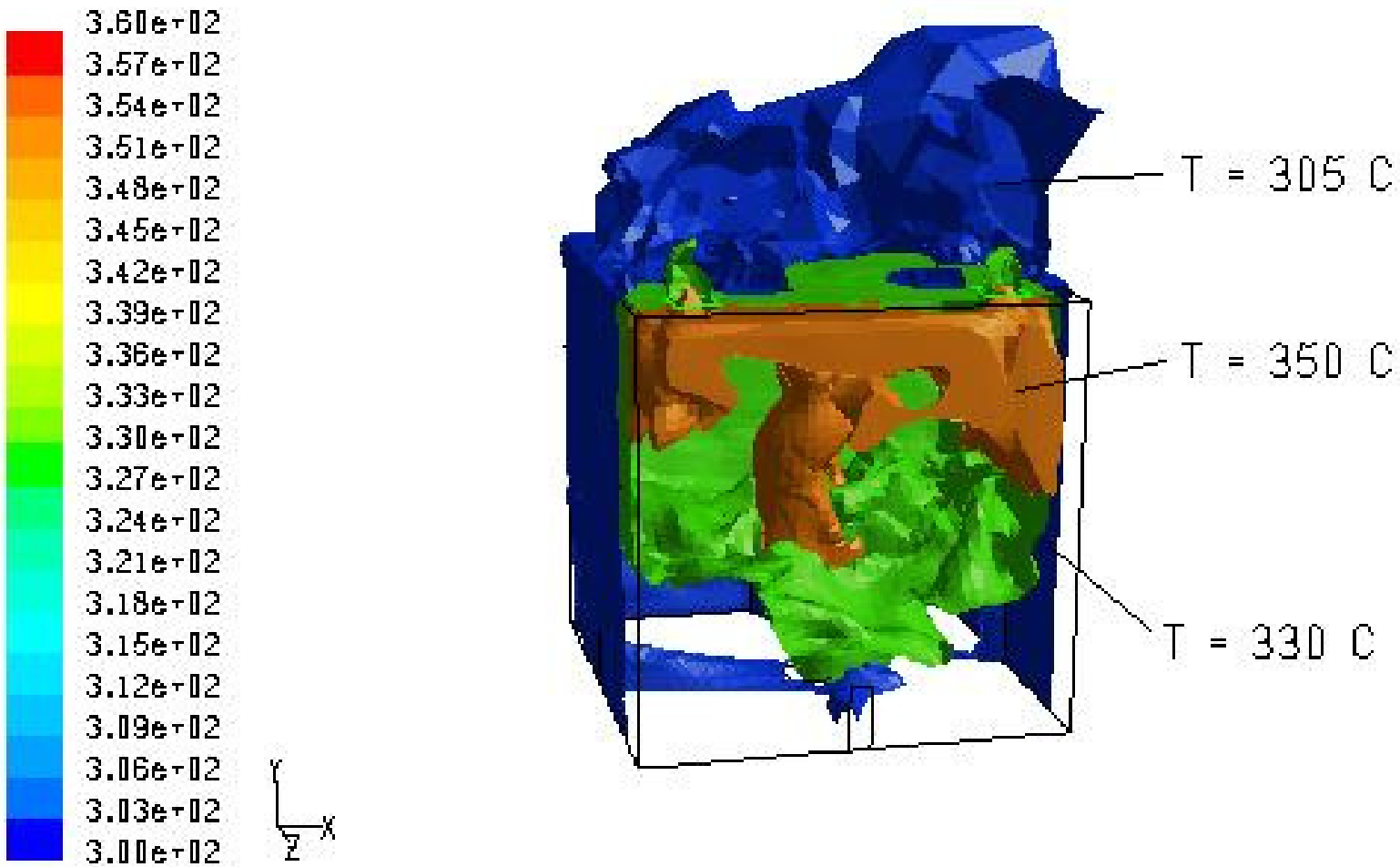






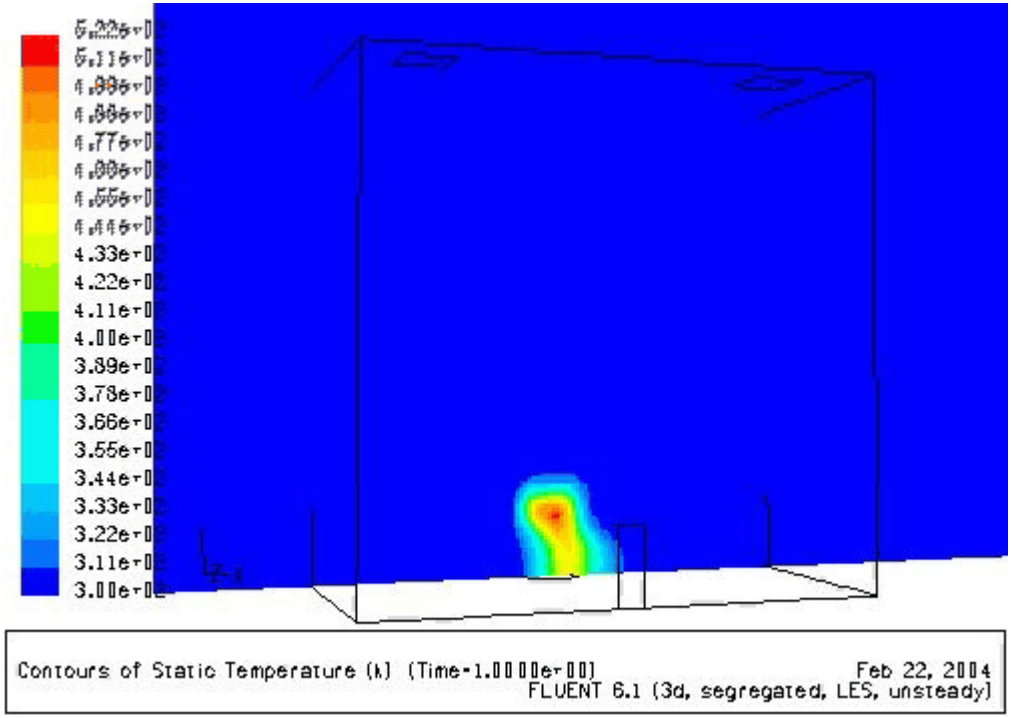


3-d Cube: LES, U = 2 m/s
Temperature Contours

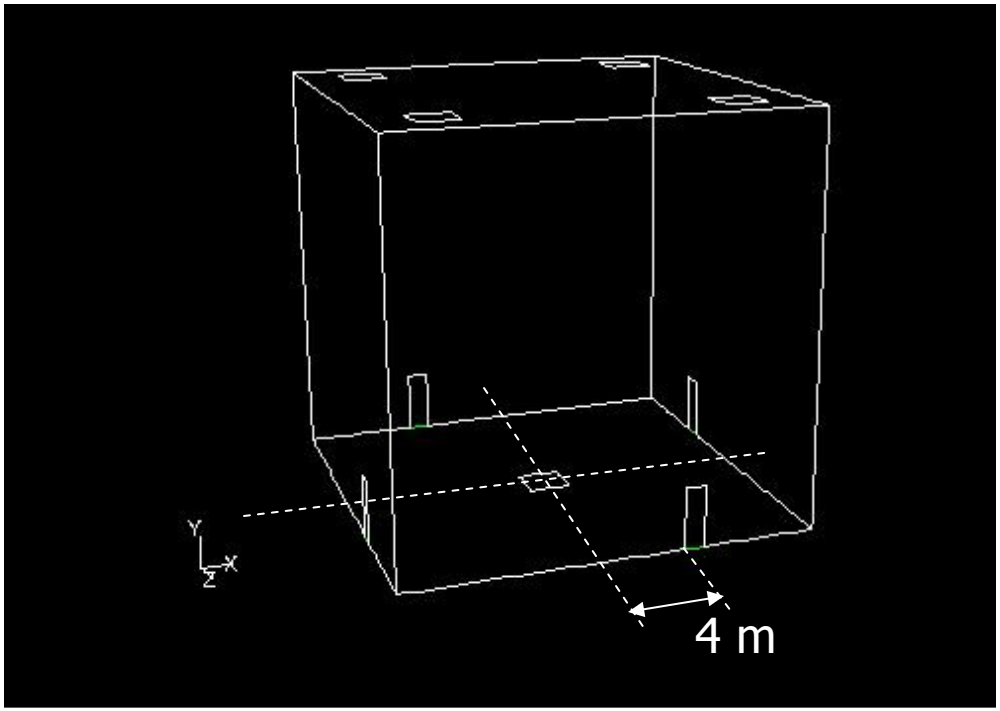


Contours of Static Temperature (k) (Time=3.4025e+02) Feb 22, 2004
FLUENT 6.1 (3d, segregated, LES, unsteady)

3-d Cube: LES, U = 2 m/s Temperature Contours Animated

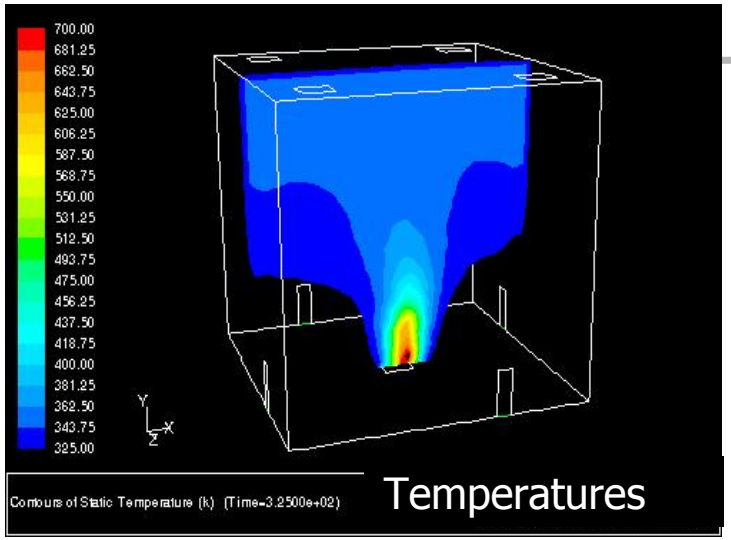


3-d Cube – rke - Offset doors, U = 0 m/s

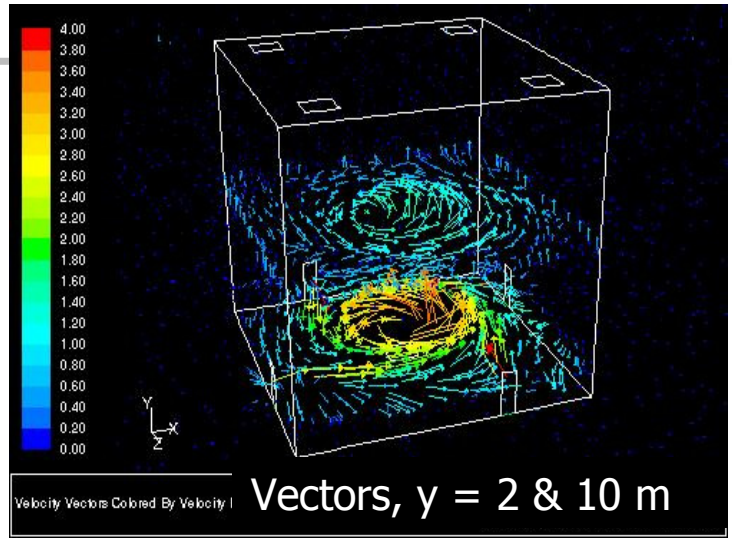


- Offset inlets can produce fire vortex behavior.
- Doors on 4 faces have been offset 4 m from center

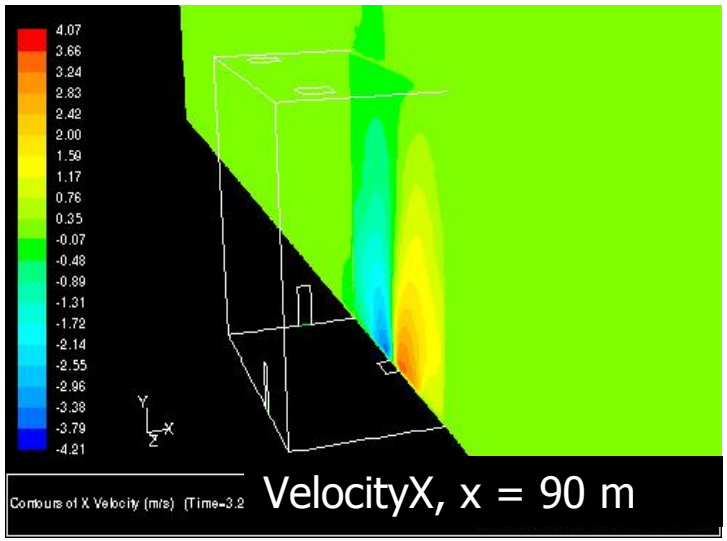
3-d Cube – rke Offset doors, U = 0 m/s, t = 325 sec



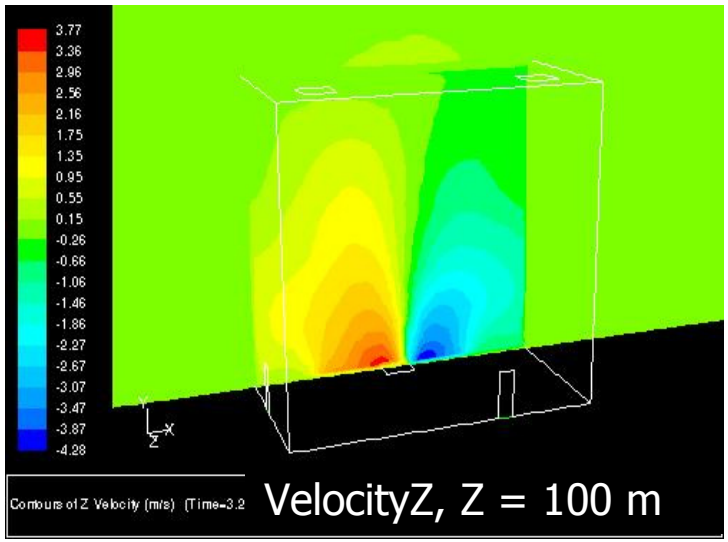
Temperatures



Vectors, y = 2 & 10 m

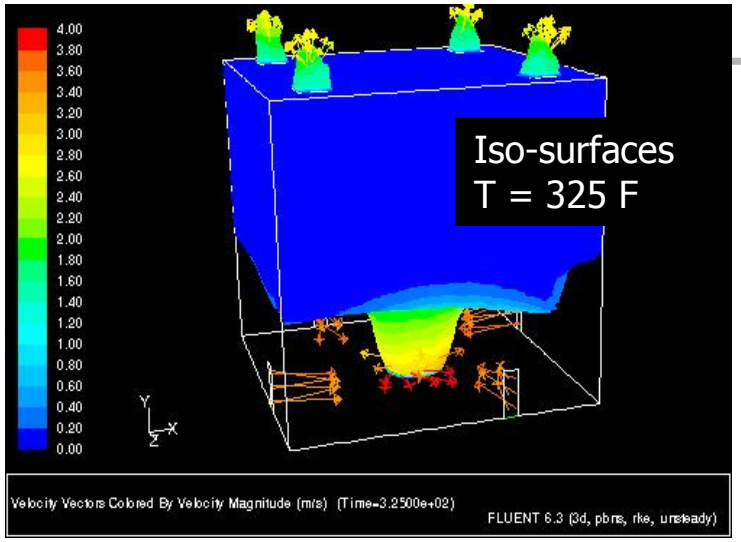


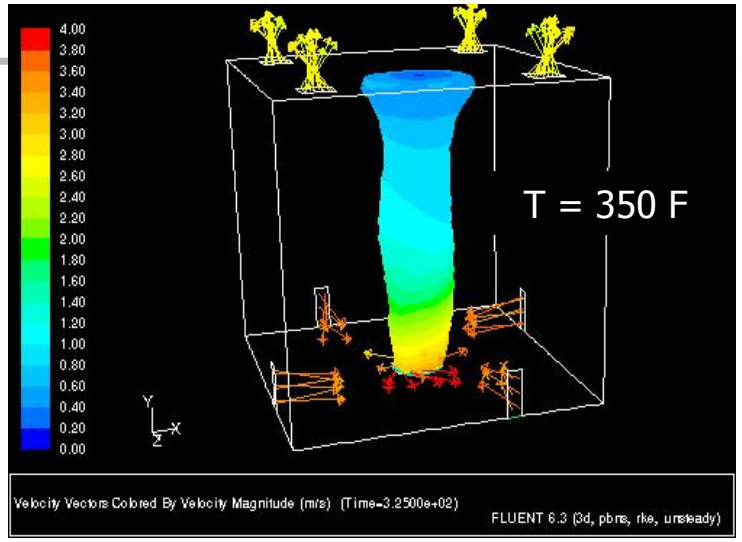
VelocityX, x = 90 m

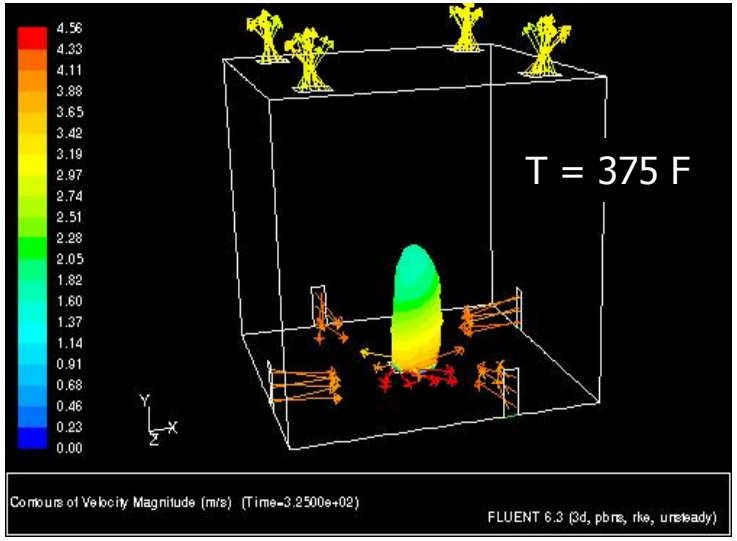


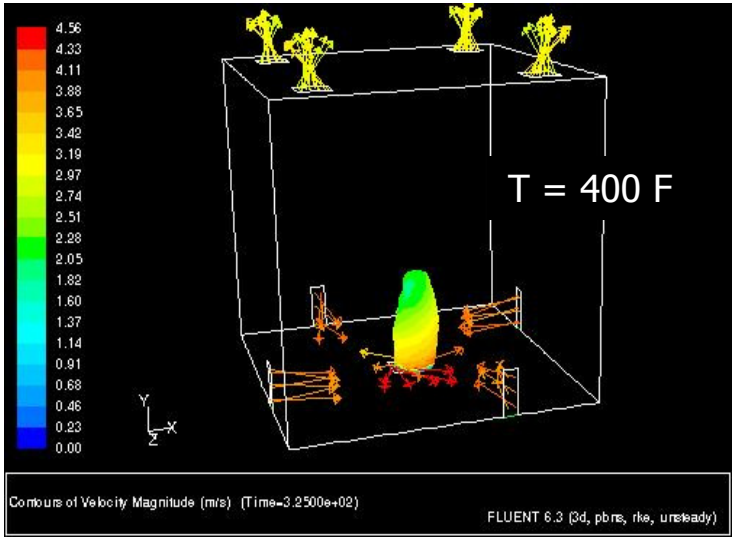
VelocityZ, Z = 100 m

3-d cube – rke - Offset doors, U = 0 m/s, t = 325 sec

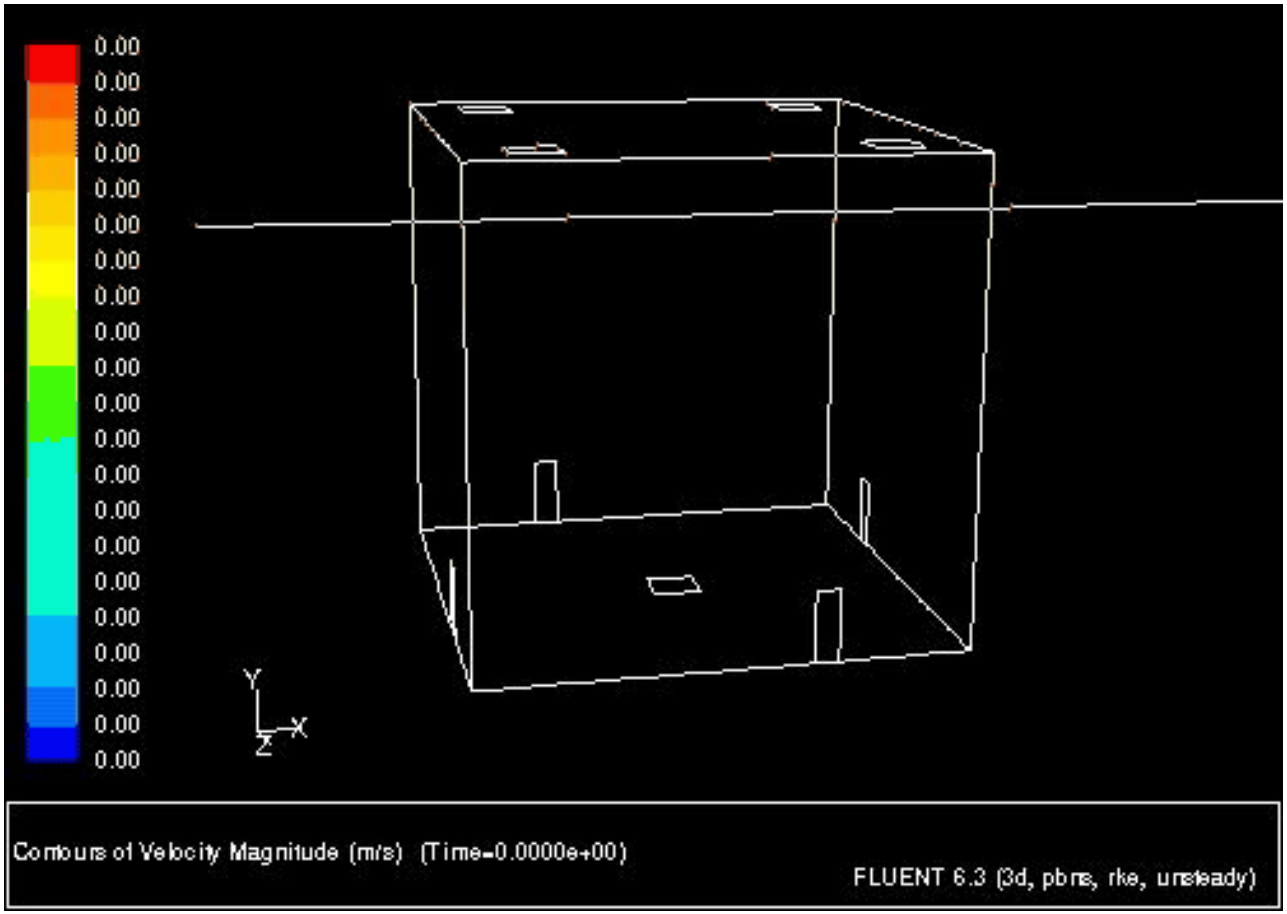




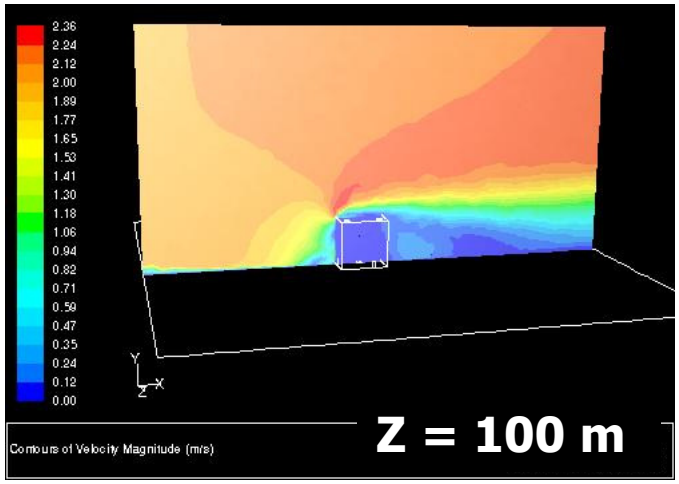


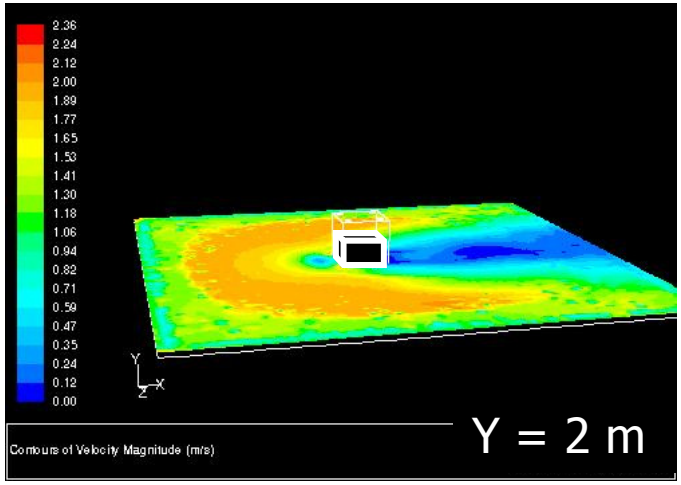


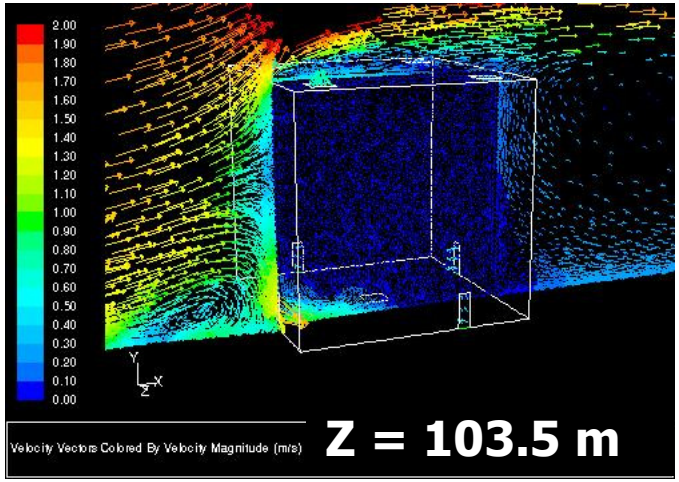
3-d Cube – rke - Offset doors, U = 0 m/s, Iso Temp Surface = 400 > 375 > 350 F

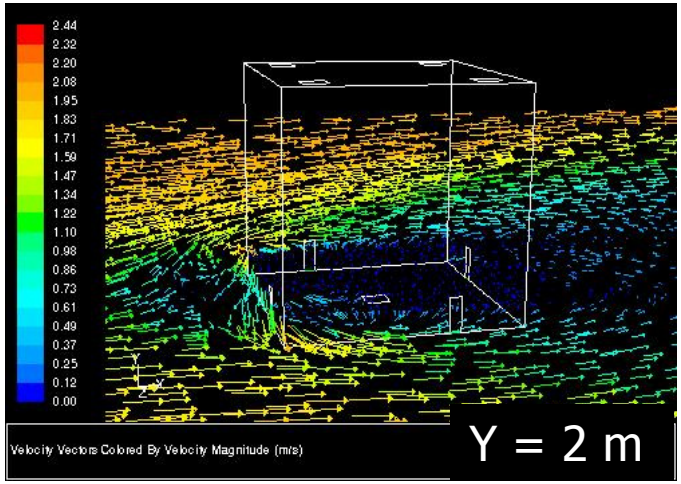


3-d cube – rke - Offset doors, U = 2 m/s, t = 0 sec

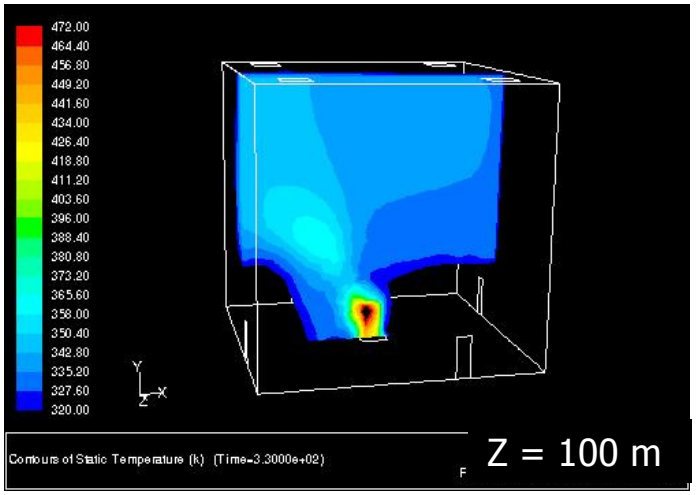


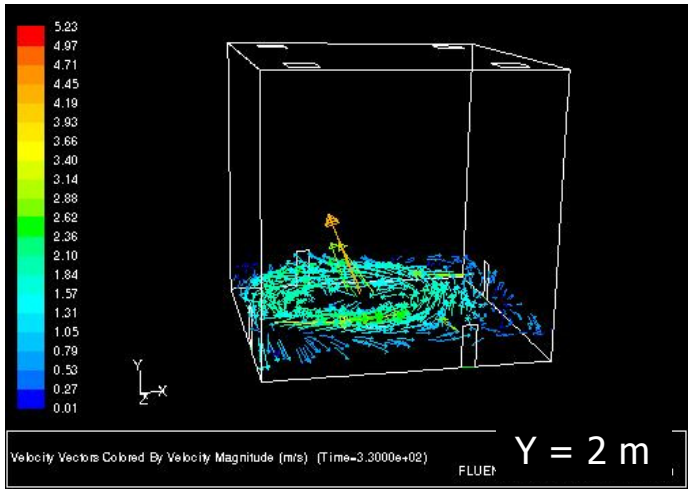


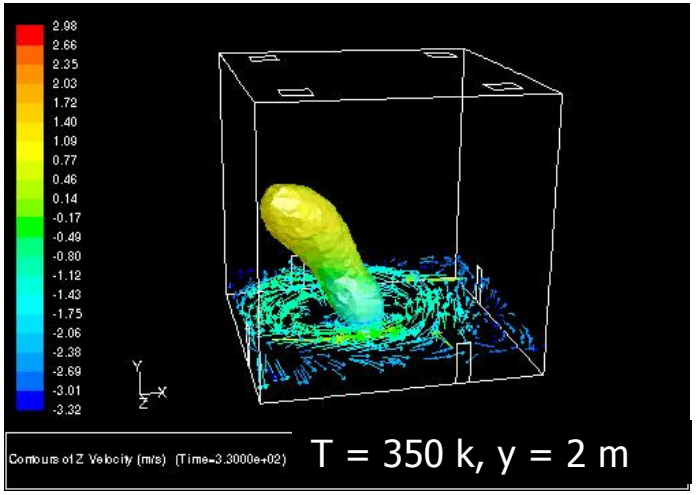


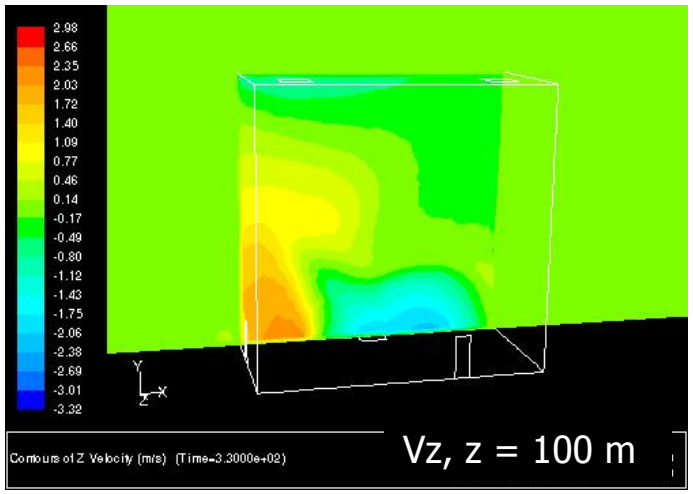


3-d cube – rke - Offset doors, U = 2 m/s, t = 325 sec

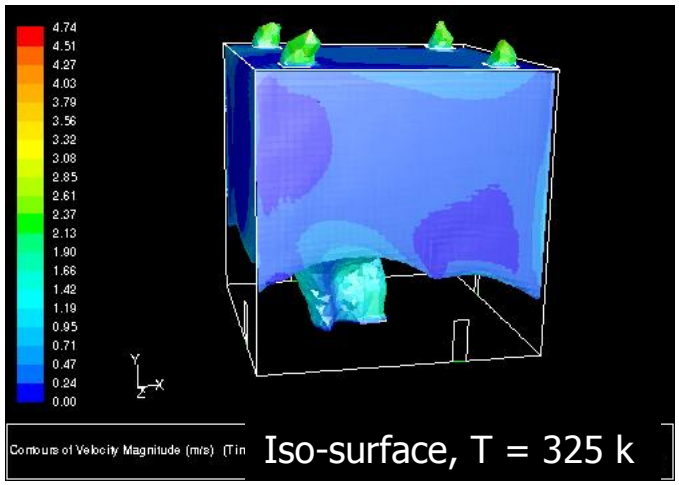


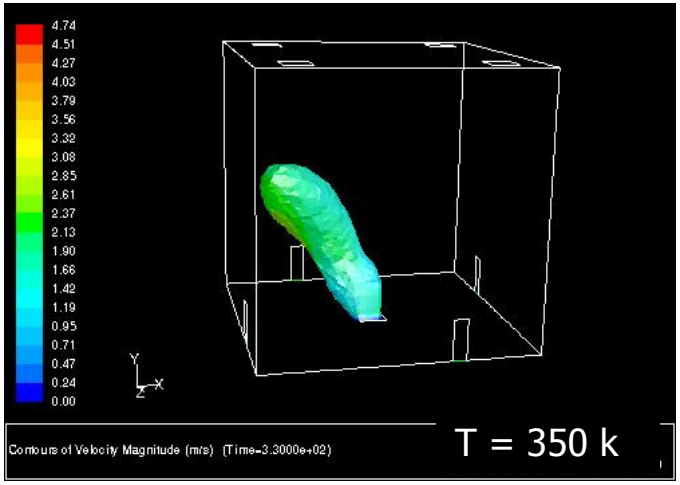


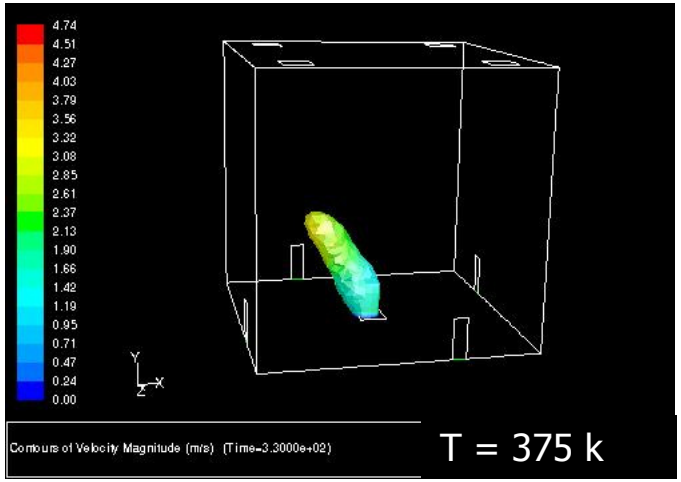


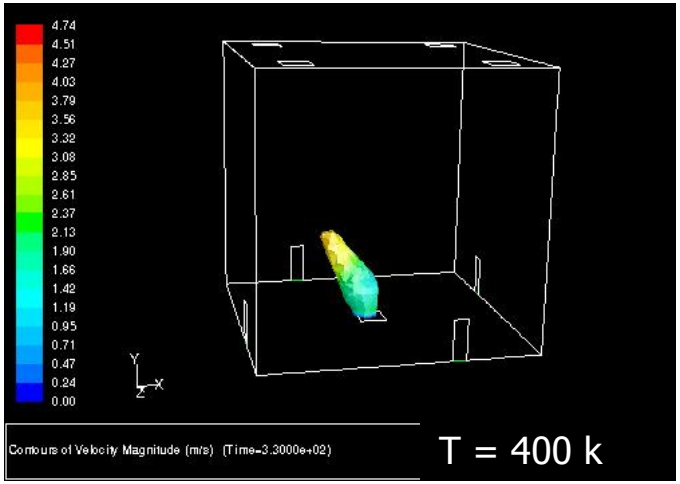


3-d cube – rke - Offset doors, U = 2 m/s, t = 325 sec

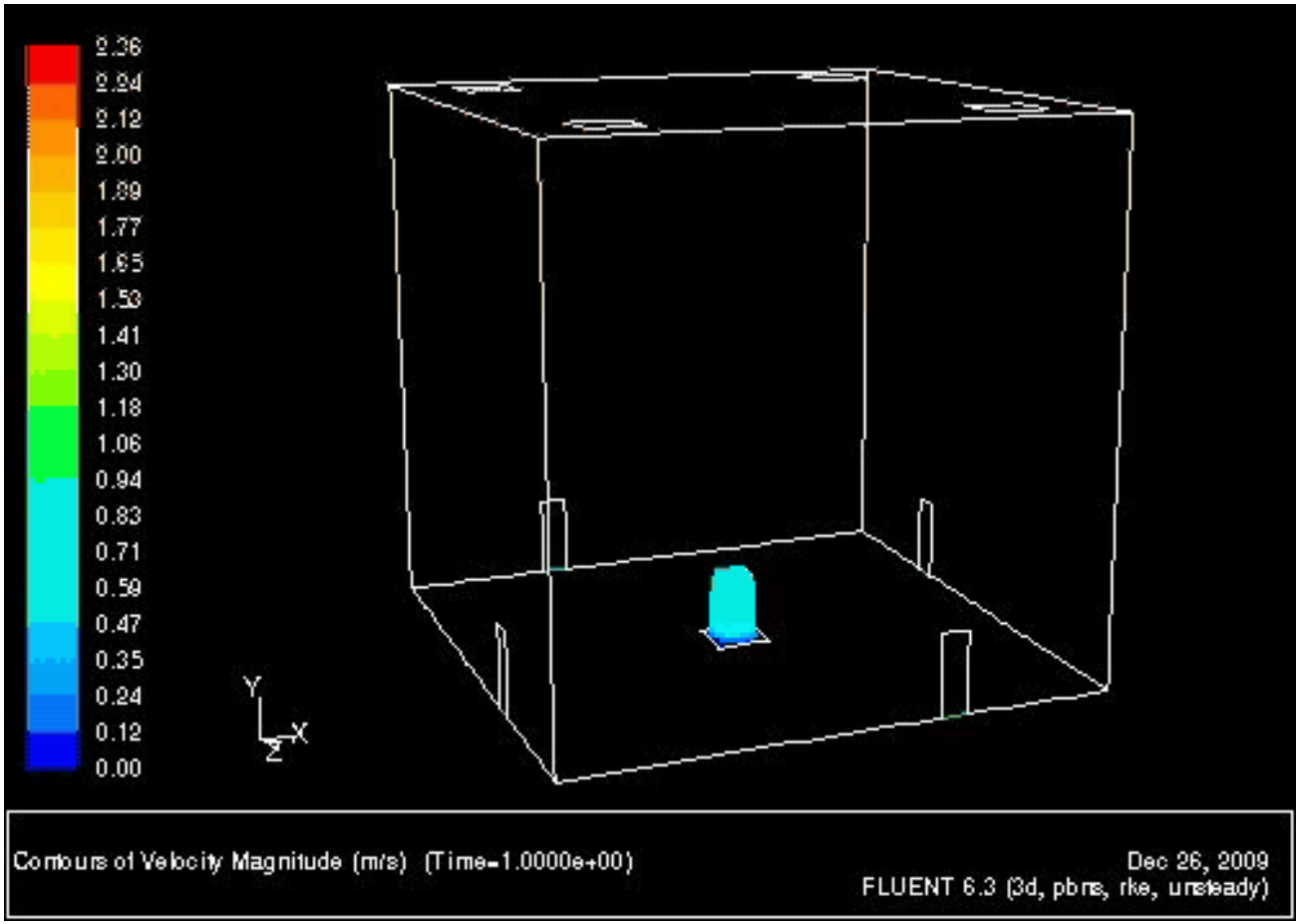




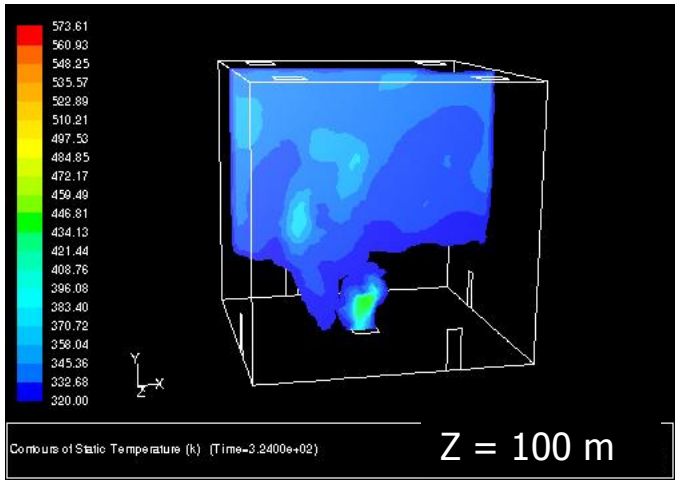


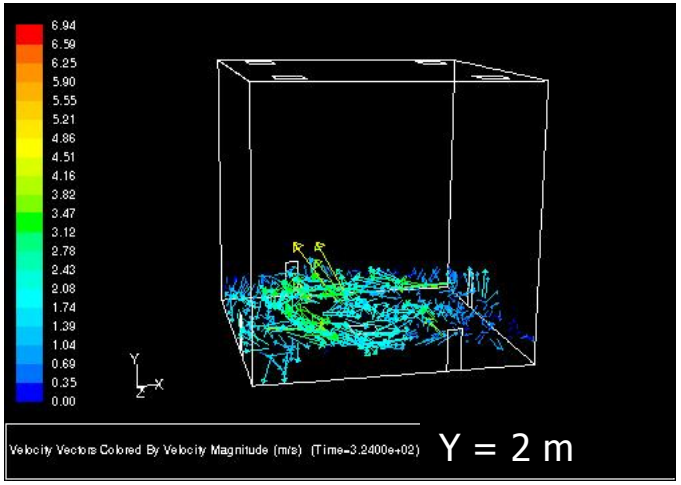


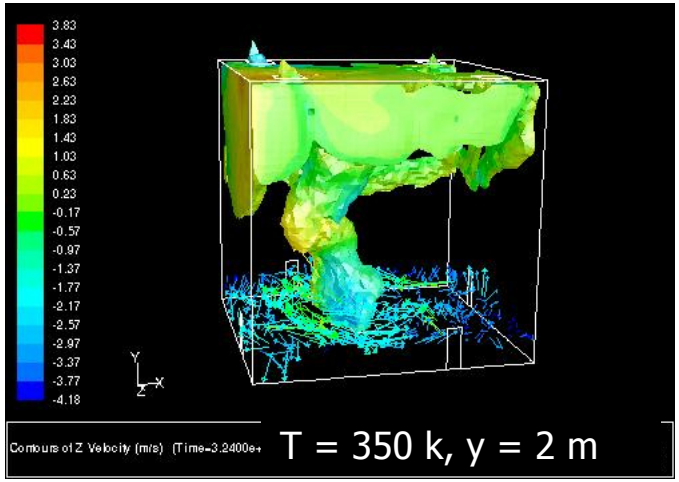
3-d Cube – rke - Offset doors, U = 2 m/s, Iso Temp Surface = 400 > 375 > 350 F

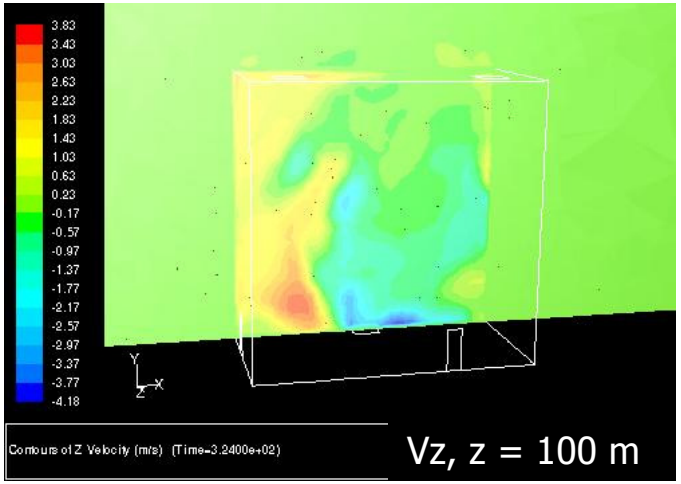


3-d Cube – LES - Offset doors, U = 0 m/s, t = 325 sec

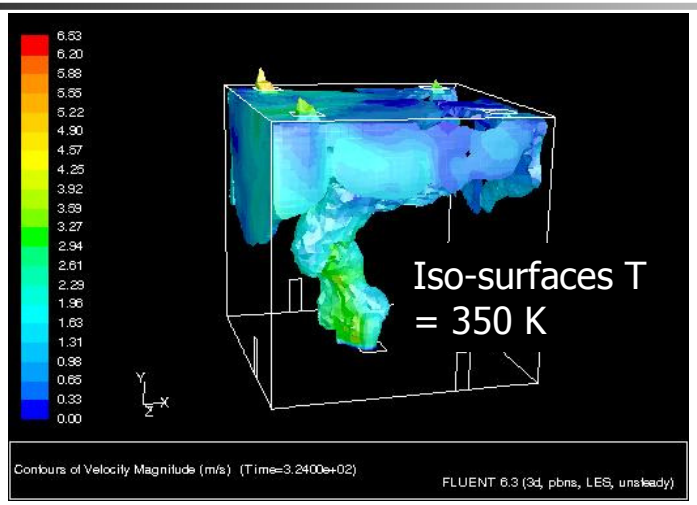


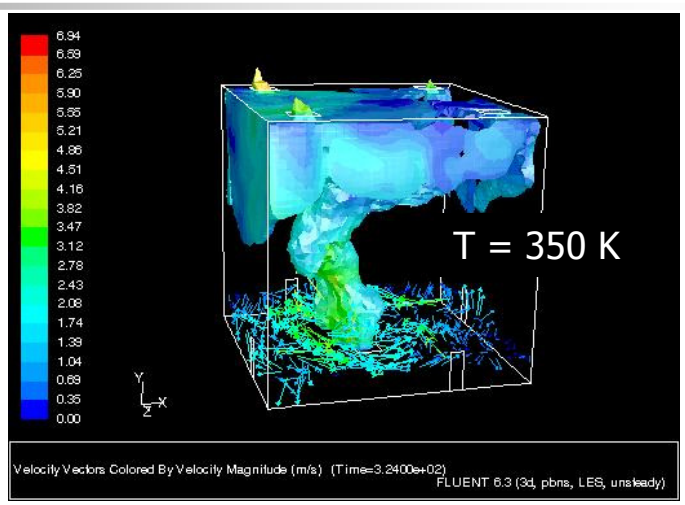


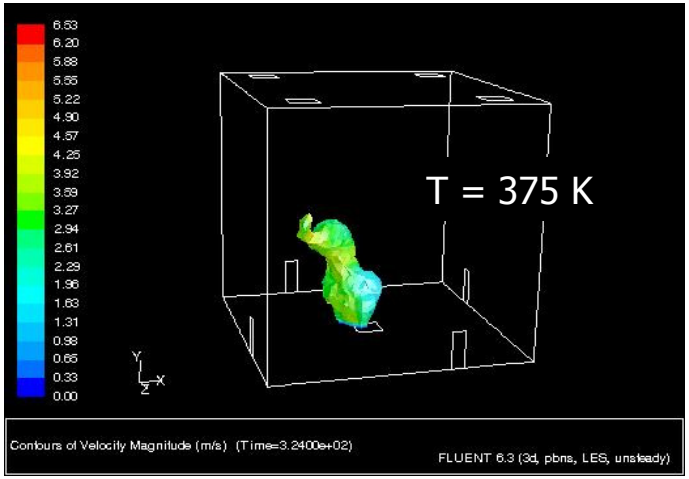


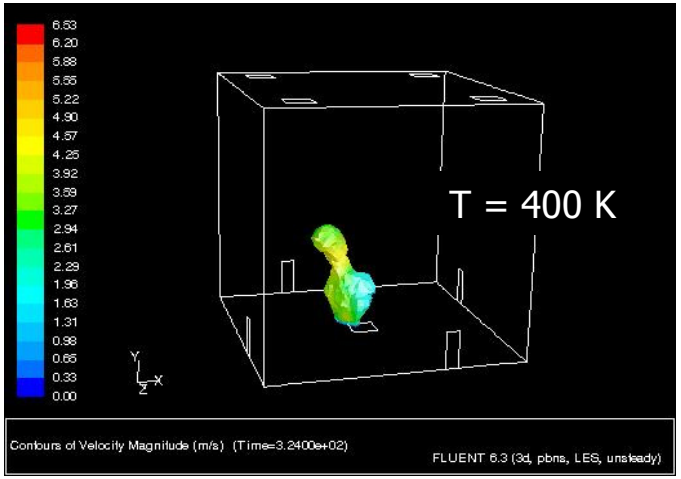


3-d Cube – LES - Offset doors, U = 0 m/s, t = 325 sec

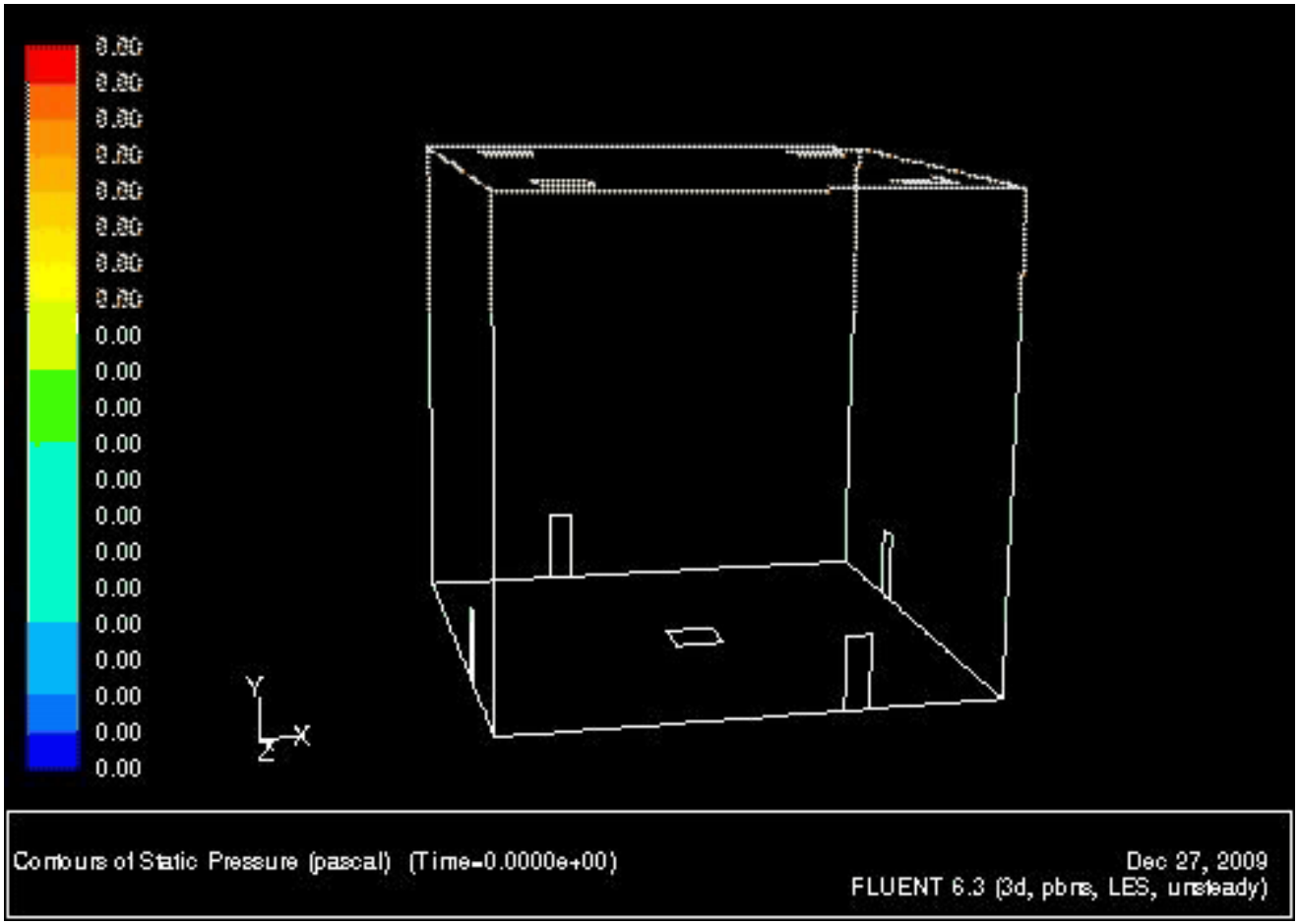




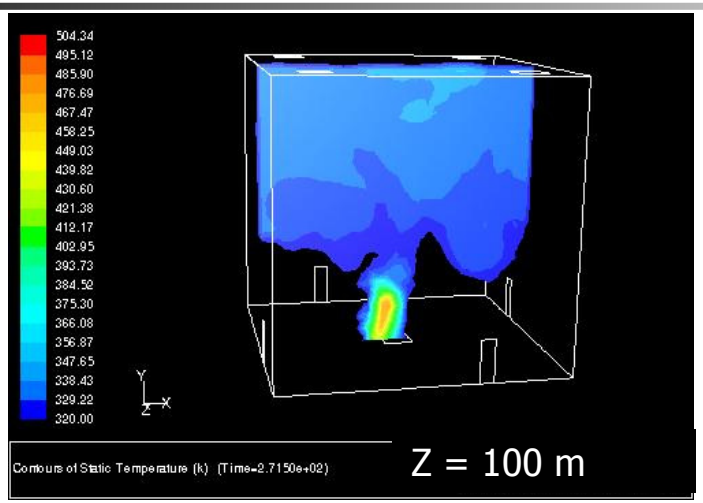


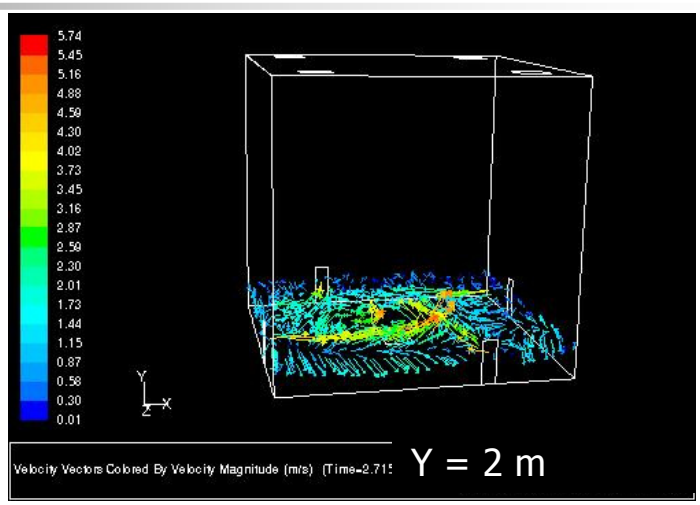


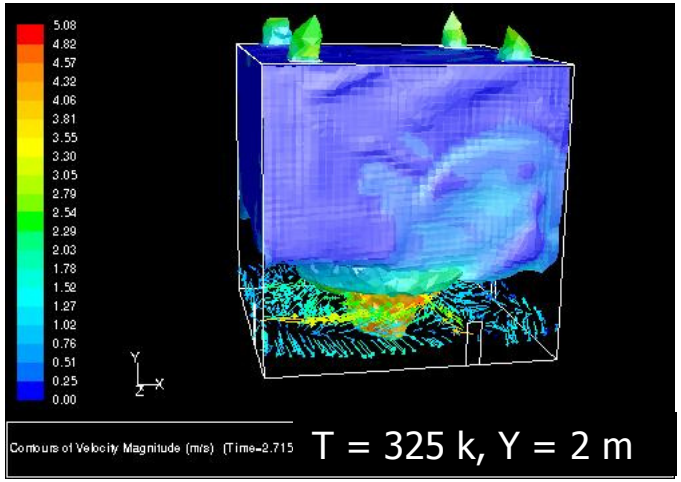
3-d Cube – LES - Offset doors, U = 0 m/s, Iso Temp Surface = 400 > 375 > 350 F

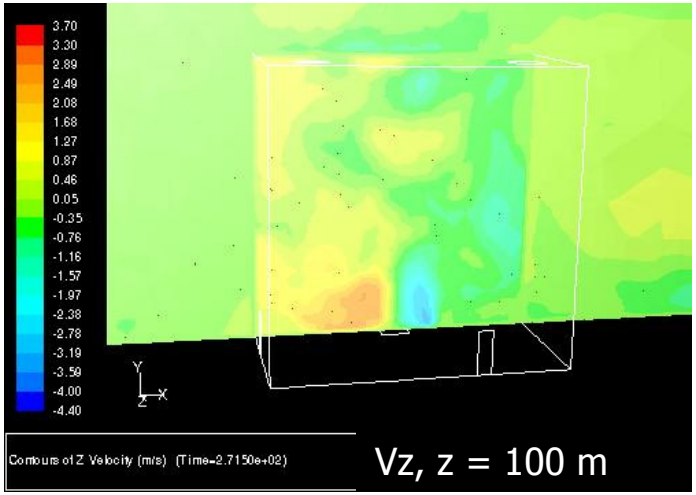


3-d Cube – LES - Offset doors, U = 2 m/s, t = 260 sec

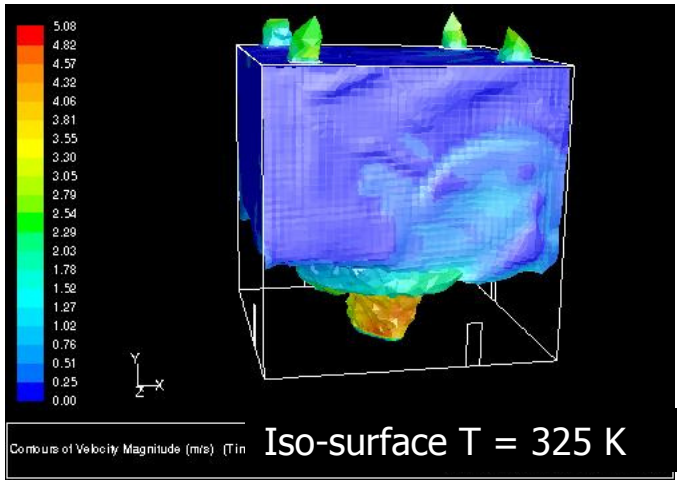


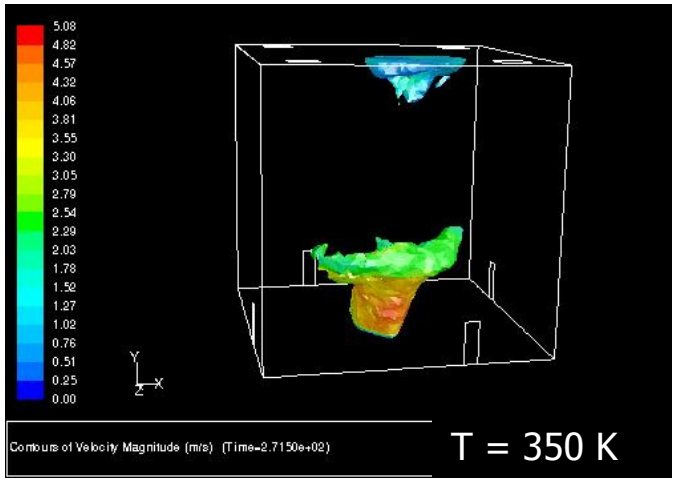


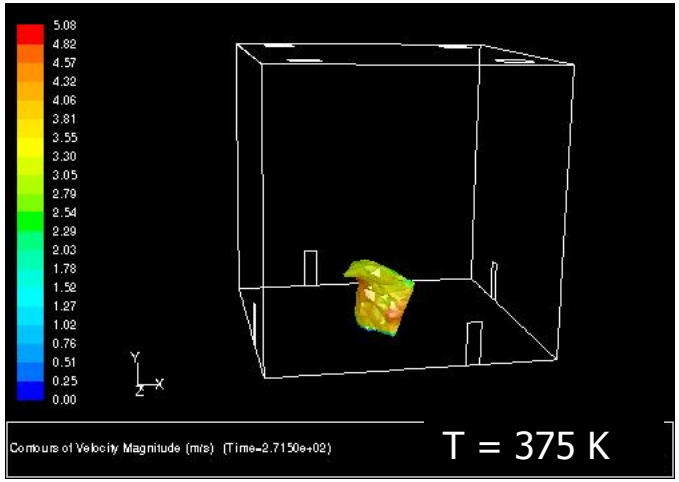


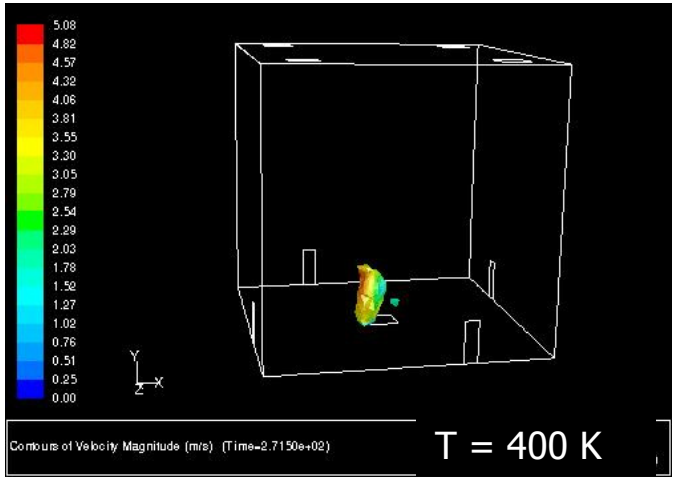


3-d Cube – LES - Offset doors, U = 2 m/s, t = 260 sec

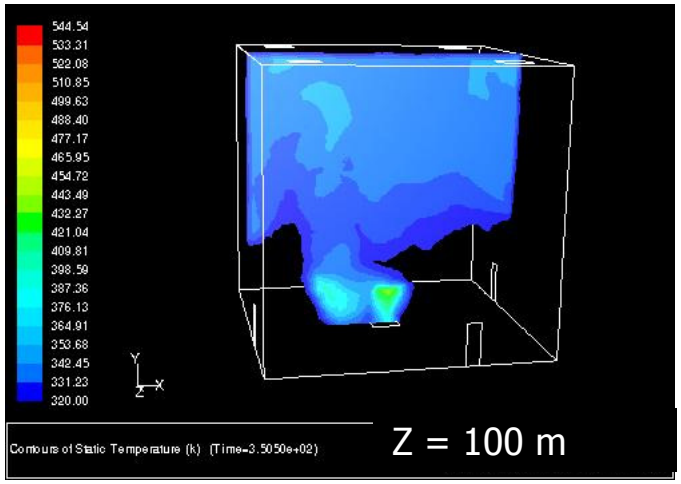


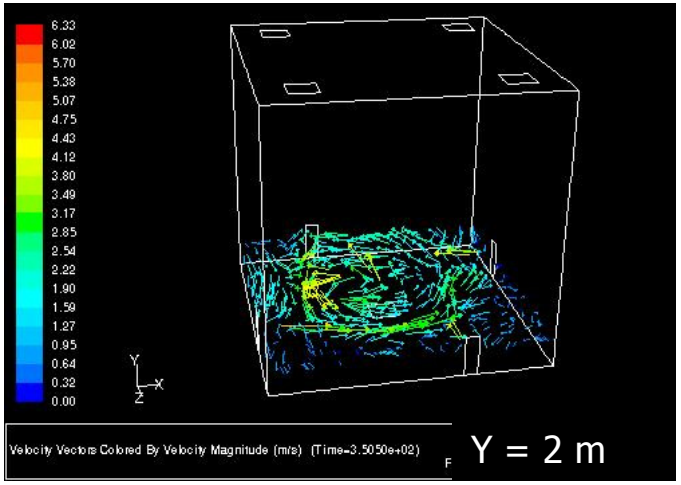


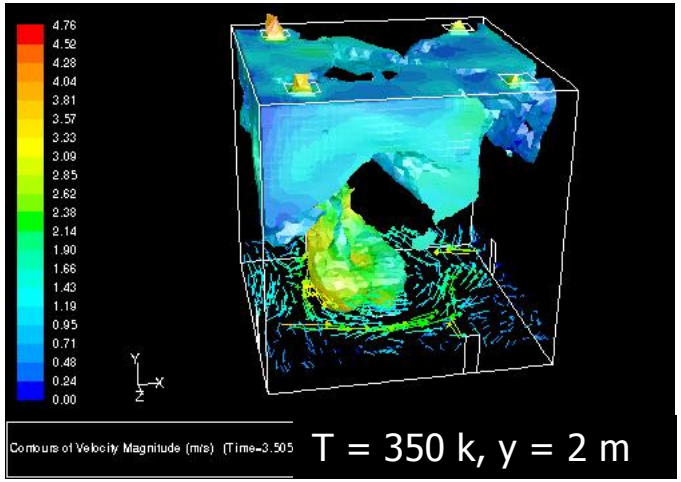


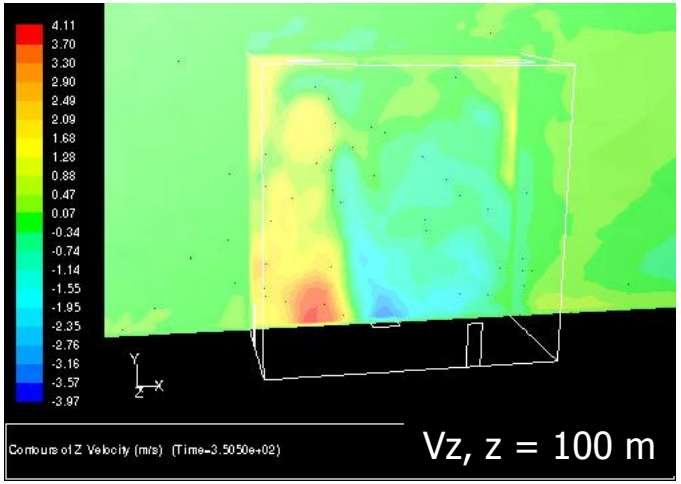


3-d Cube – LES - Offset doors, U = 2 m/s, t = 350 sec

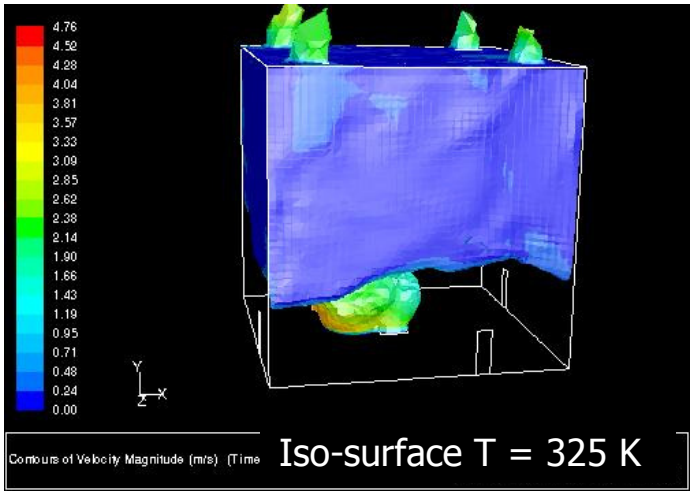


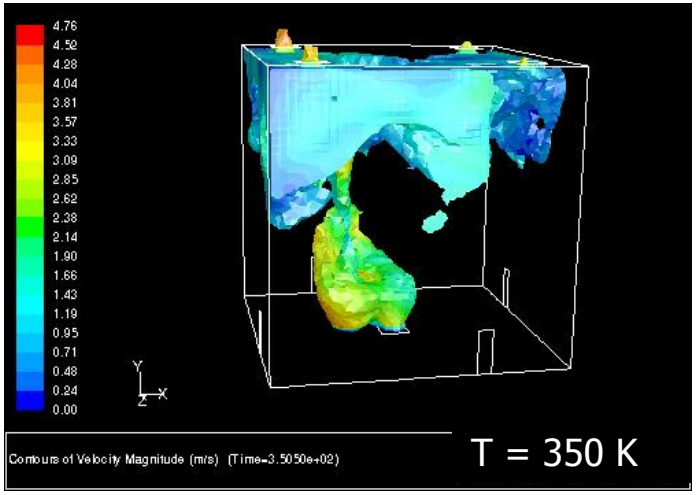


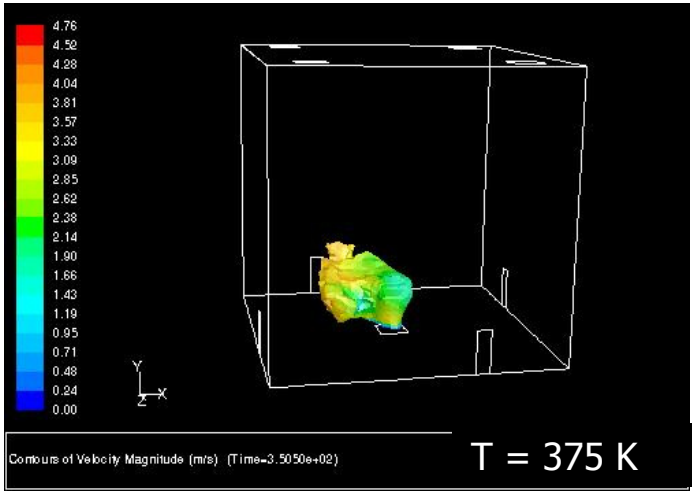


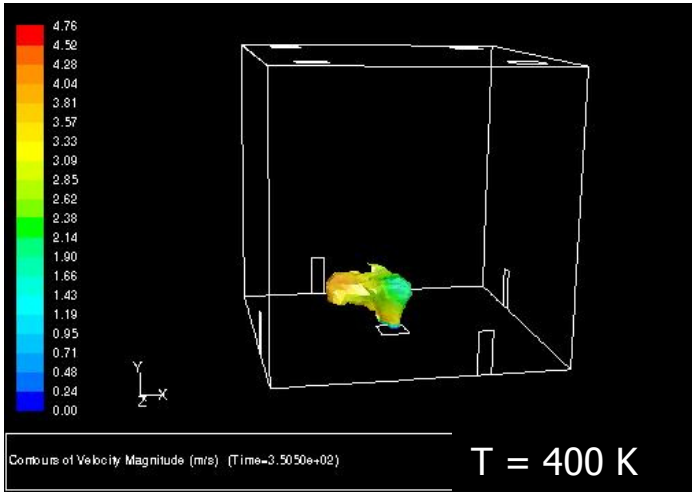


3-d Cube – LES - Offset doors, U = 2 m/s, t = 350 sec

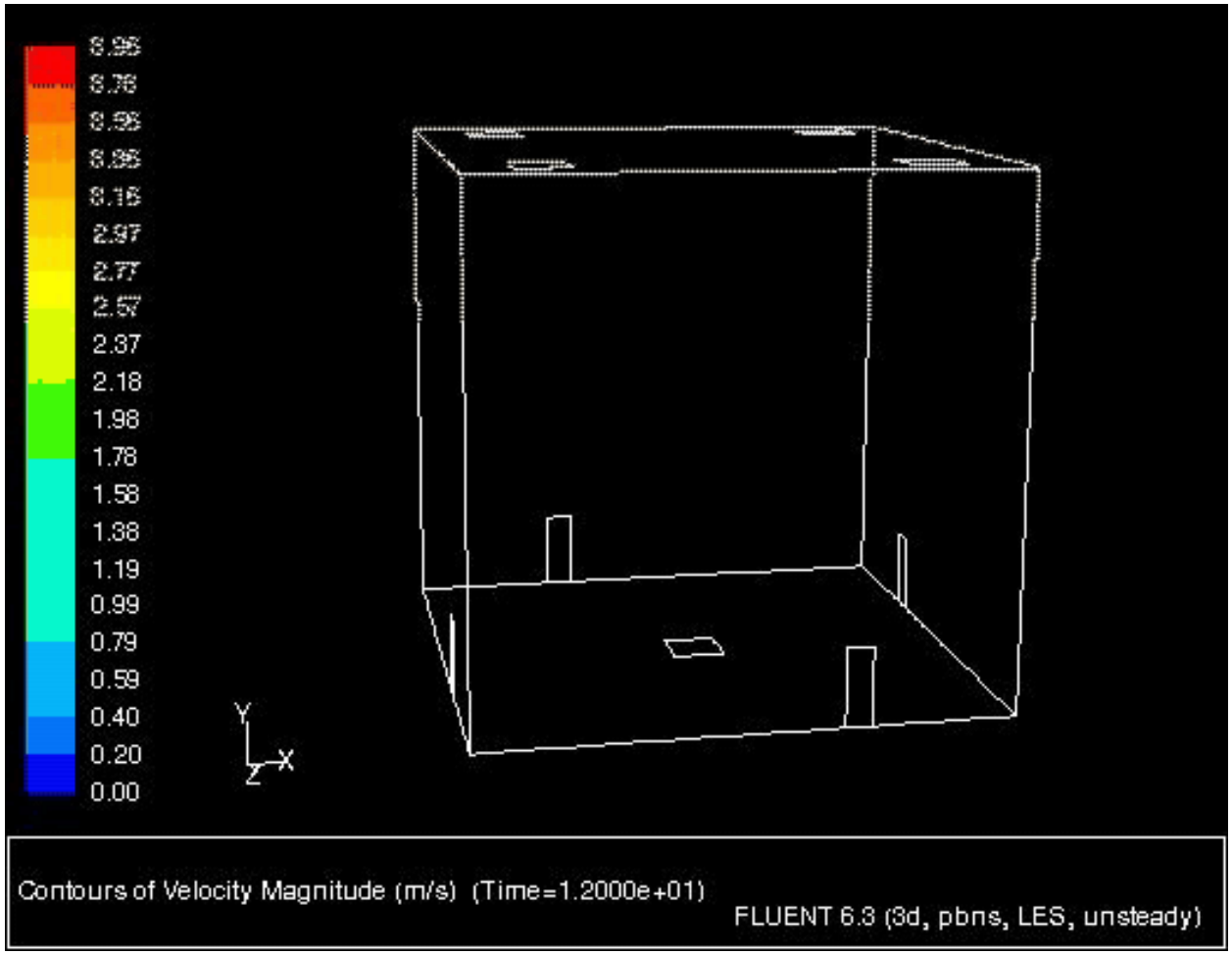








3-d Cube – LES - Offset doors, U = 2 m/s, Iso Temp Surface = 400 > 375 > 350 F



Conclusions

- Two dimensional simulation tends to exaggerate effects due to effective size of openings, but wind influence is demonstrated clearly.
- Three dimensional simulations are very dependent on placement of openings, but again wind influence is demonstrated clearly.

The End