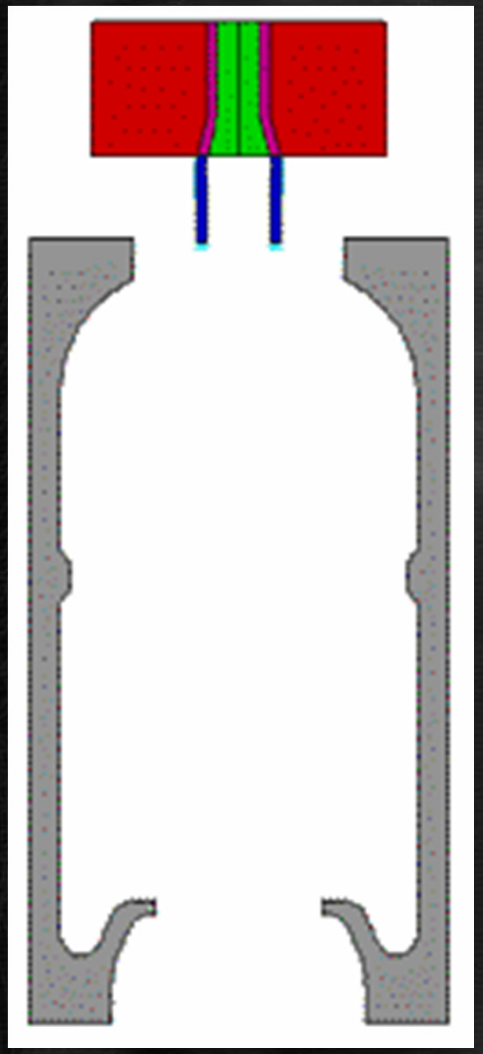
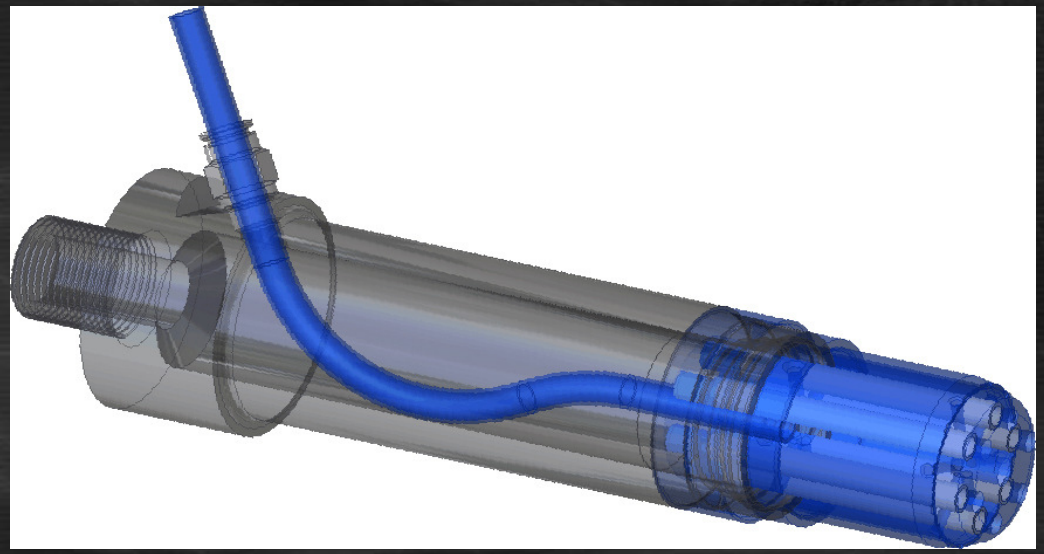
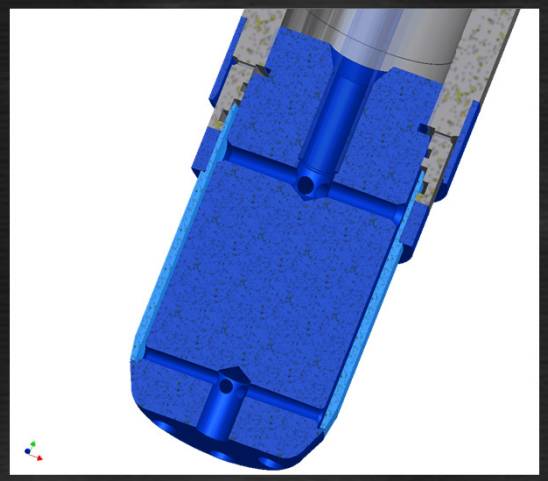
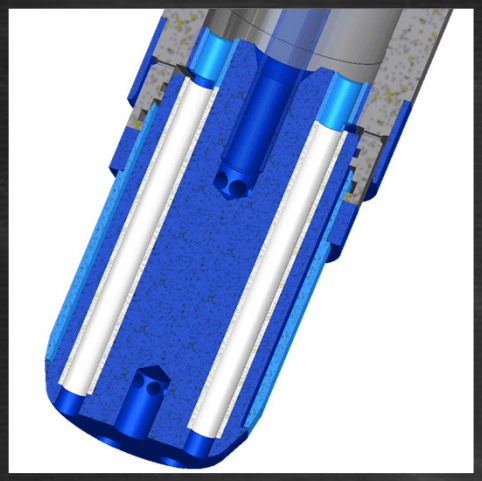
Heat transfer in blowmolding

Choise of the design







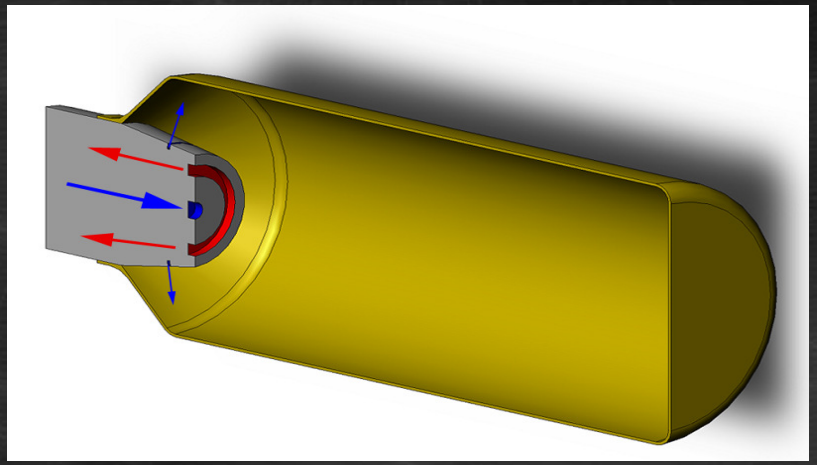


Choise of geometry

Actual blowthorn is replaced by a simplified geometry

Adjustments:

- Side inlets are replaced by a ring with same area.
- Outlet tubes are replaced by one ring with same area.



Grid

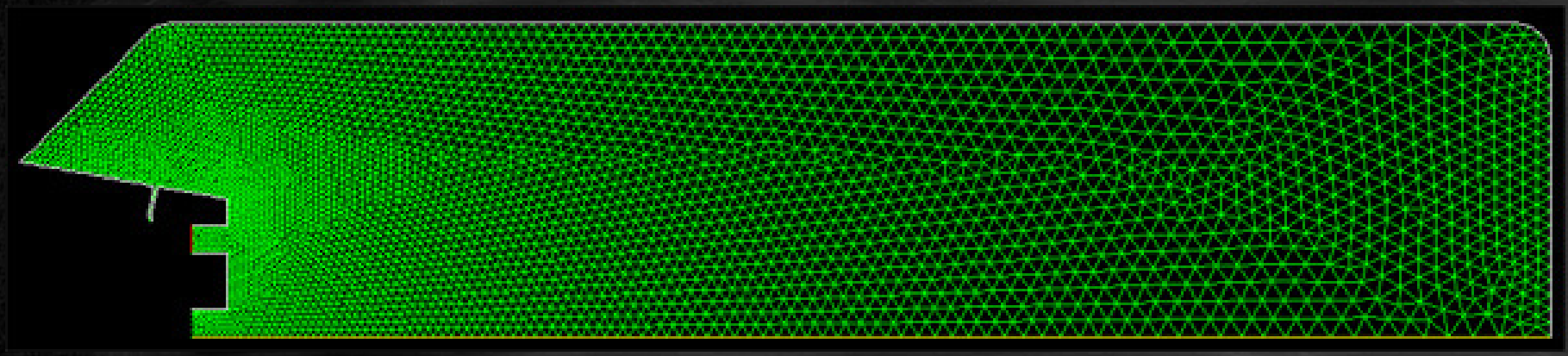
Node Distribution

- Most important areas
  - Inlets and outlets
  - Base –for distribution of the jet

Mesh specs:

- 2D Model (axisymetric)
- Tri-elements
- Type: Pave
- started from: 7333 cells

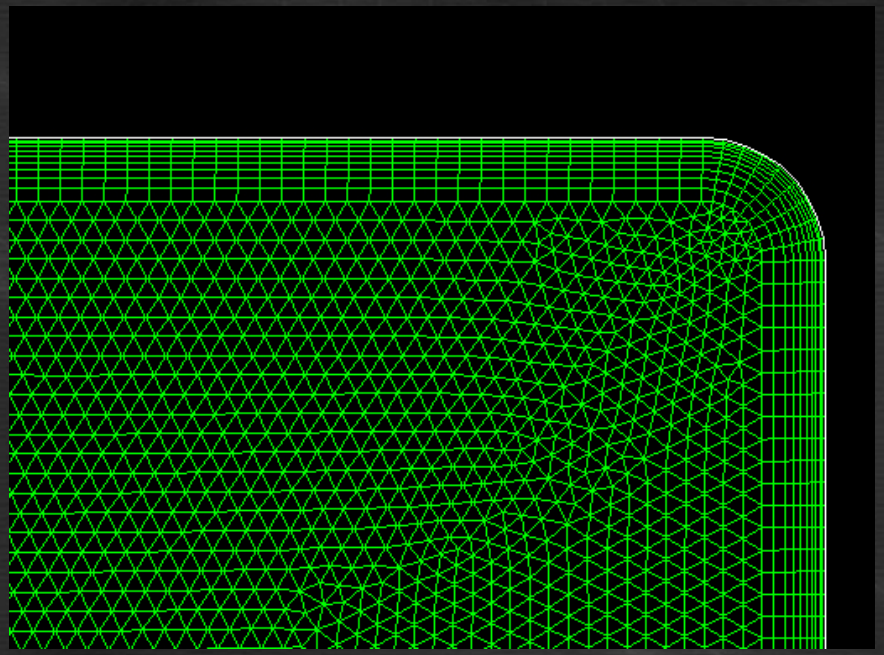
Double sided ratio op longest edges



Adjusted geometry

- Adjusted diameters of inlet and outlet
- Boundary layer added in combination with an unstructured mesh

(in order to get larger accuracy in the wall interaction with the air)



Setup

Solver:

• Pressure based: low speeds so the air can be assumed as quasi incompressible

• Gradientoption: Green-Gauss Node Based

• Axisymmetric, Implicit, Steady

Energy Equation

• needed to calculate temperatures

Viscous Model:

• k-ε model (realizable)

• Also k-ε standard en k-ω SST calculated in one specific case

Boundary conditions

Conditions: volume flow rate chosen at 5,10,20 times the volume of the bottle

Operating conditions: 101325 Pa (1Atm)

Inlets:

- velocity-inlet
- Speed (using mass-law) is 62.3 m/s 126.6 m/s 253.13 m/s
- turbulence: intensity and hydraulic diameter
- Inlet Temperature: -35℃, 4℃ en 30℃

Outlet:

- Pressure-outlet
- 3 bar counterpressure (to atmosphere)
- turbulence: intensity and hydraulic diameter

$T_{(℃)}$ \ $Q_{(m^3/s)}$	0,0065	0,013	0,026
-35			
4			
30			

Boundary conditions (2)

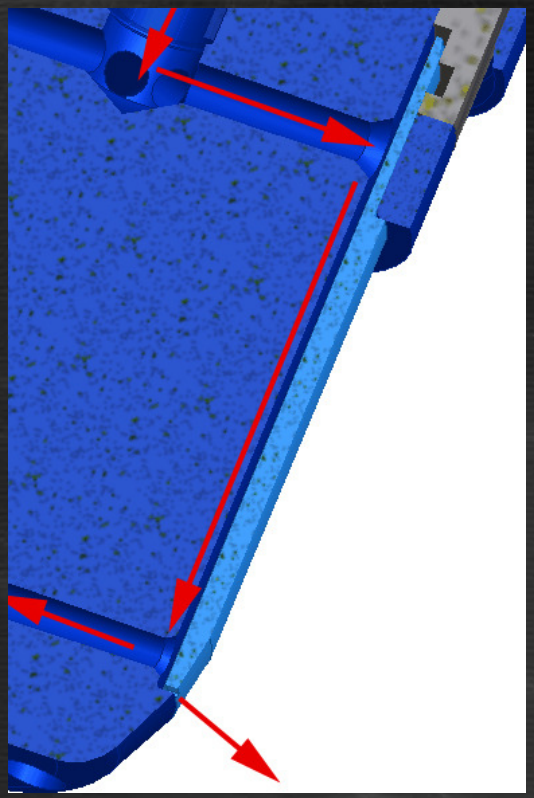
Wall of the bottle:

• Assumed at constant temperature of 473 K (PE just after production)

Thorn:

• Same temperature as incoming air

(chosen by the large area that comes in contact with the air in the actual situation)



Results

Temperature:

- At –35℃ for the different flow rates
- At 0.0026 m^3/s on different temperatures

At largest flow rate, grid adaption is used in order to get correct Y+ values)

(following is at 0.0026 m^3/s and –35℃ Inlet temperature)

Contourplot

- Velocity magnitude → flow rate almost no influence on path, only on magintude

Vectorplot: around the thorn

Heat Flux on the wall

K-ε (realizable – Standard) K-ω (SST)

Results

Temperature:

- At –35℃ for the different flow rates
- At 0.0026 m^3/s on different temperatures

At largest flow rate, grid adaption is used in order to get correct Y+ values)

(following is at 0.0026 m^3/s and –35℃ Inlet temperature)

Contourplot

- Velocity magnitude → flow rate almost no influence on path, only on magintude

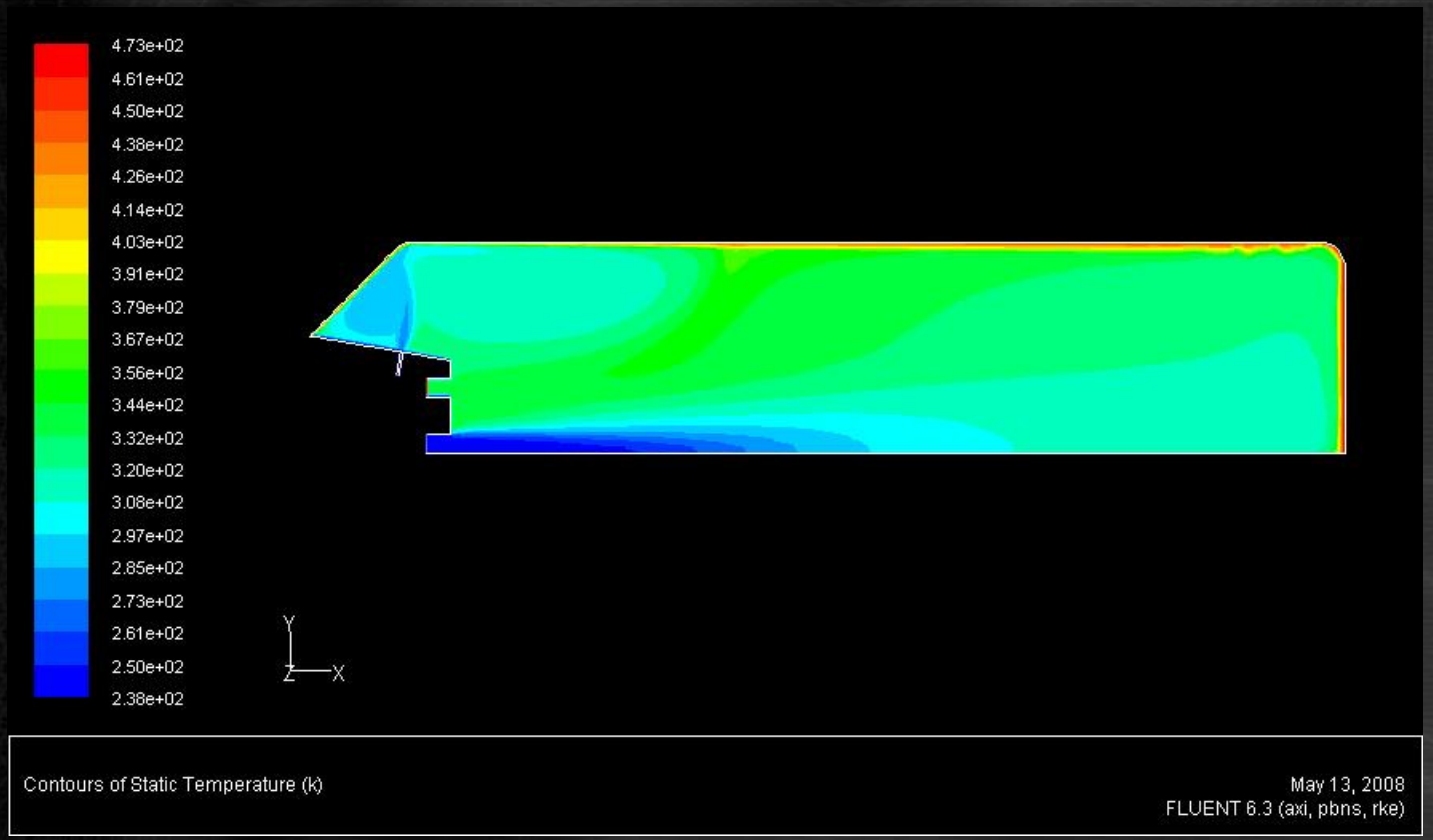
Vectorplot: around the thorn

Heat Flux on the wall

K-ε (realizable – Standard) K-ω (SST)

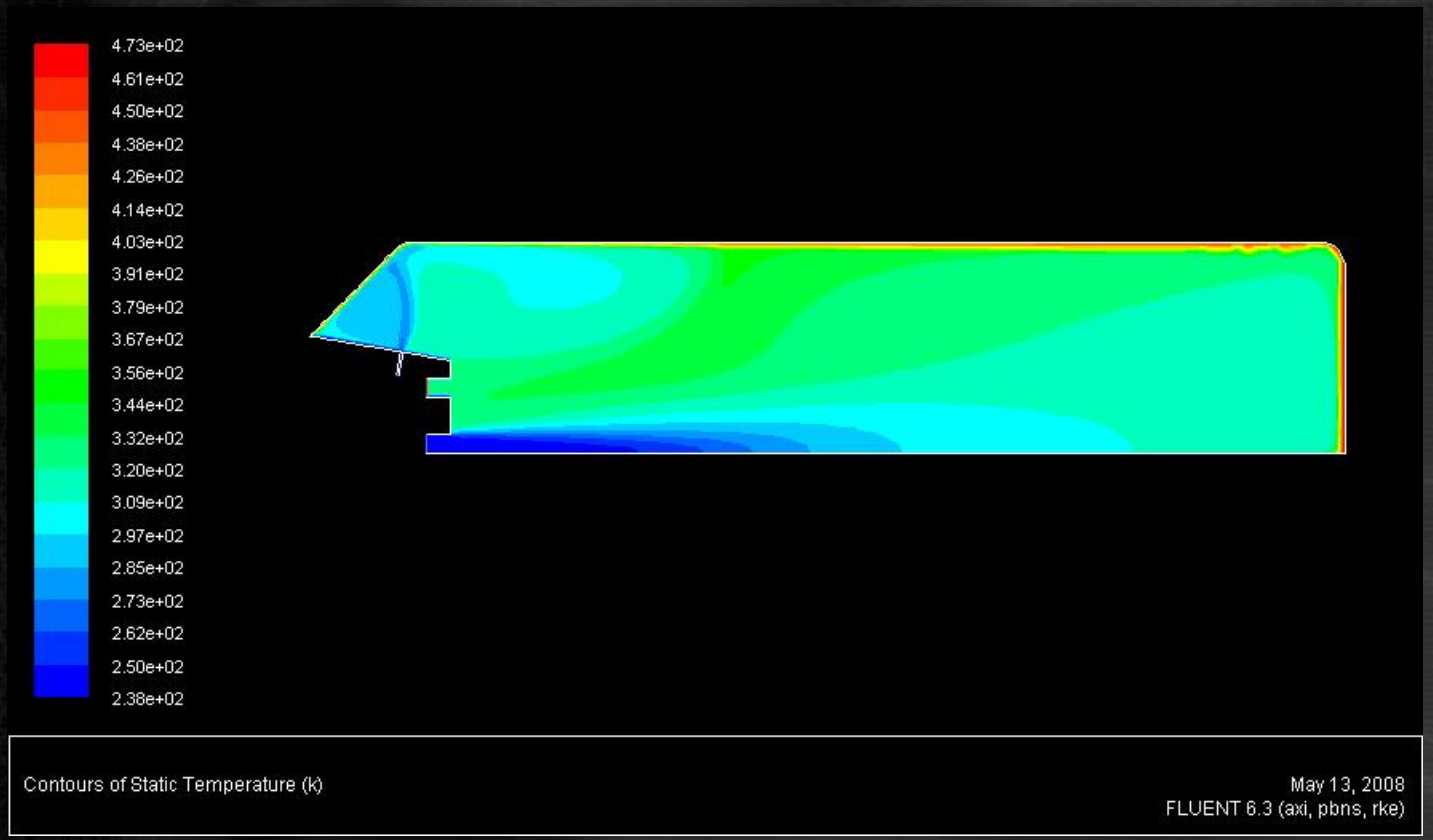
Static temperature 0.0065 m³/s

Temperatuur outlet: 64,7 ℃



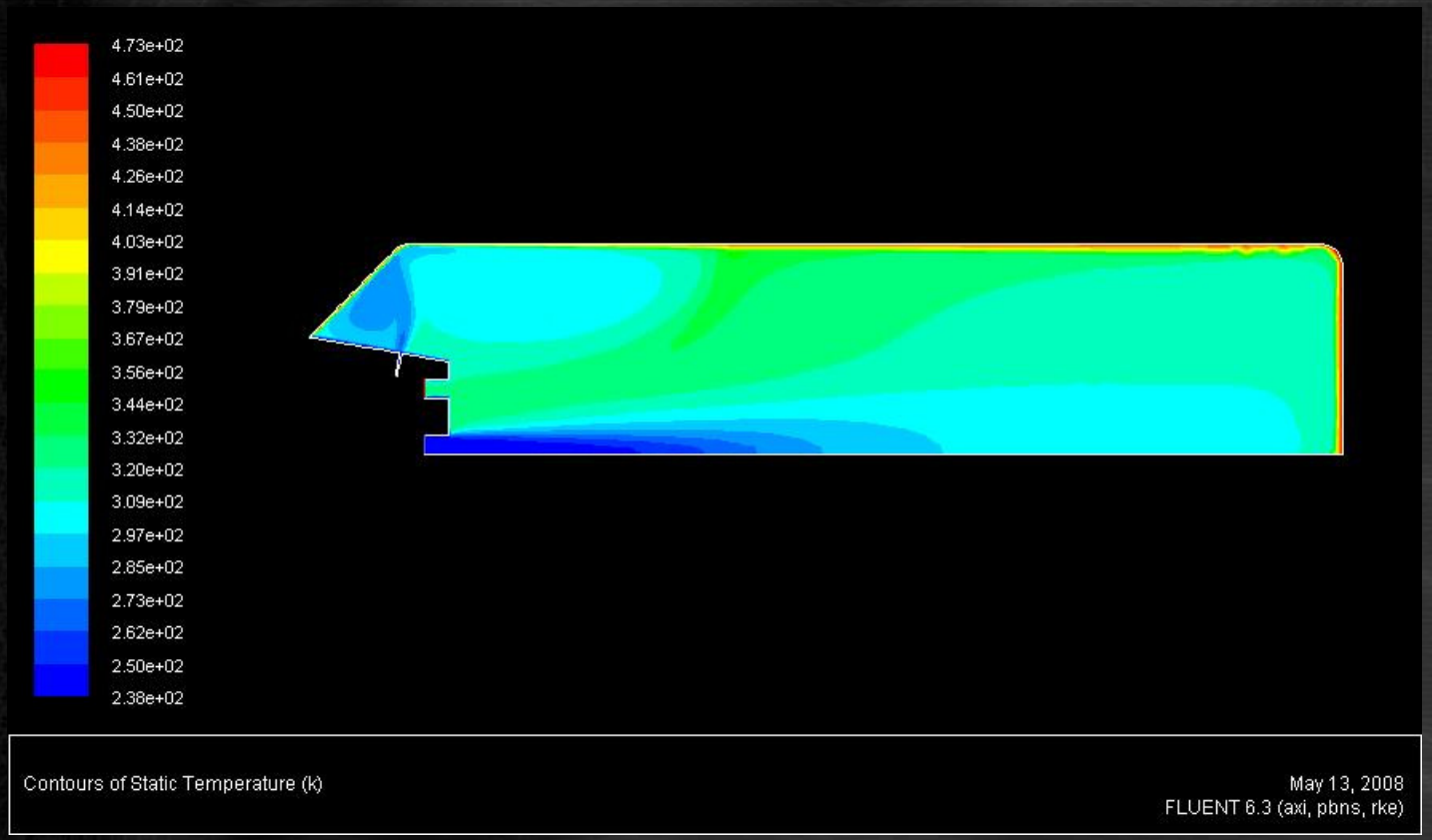
Static temperature 0.013 m³/s

Temperatuur outlet: 53 ℃



Static temperature 0.026 m³/s

Temperatuur outlet: 47,3 ℃



Results

Temperature:

- At –35℃ for the different flow rates
- At 0.0026 m^3/s on different temperatures

At largest flow rate, grid adaption is used in order to get correct Y+ values)

(following is at 0.0026 m^3/s and –35℃ Inlet temperature)

Contourplot

- Velocity magnitude → flow rate almost no influence on path, only on magintude

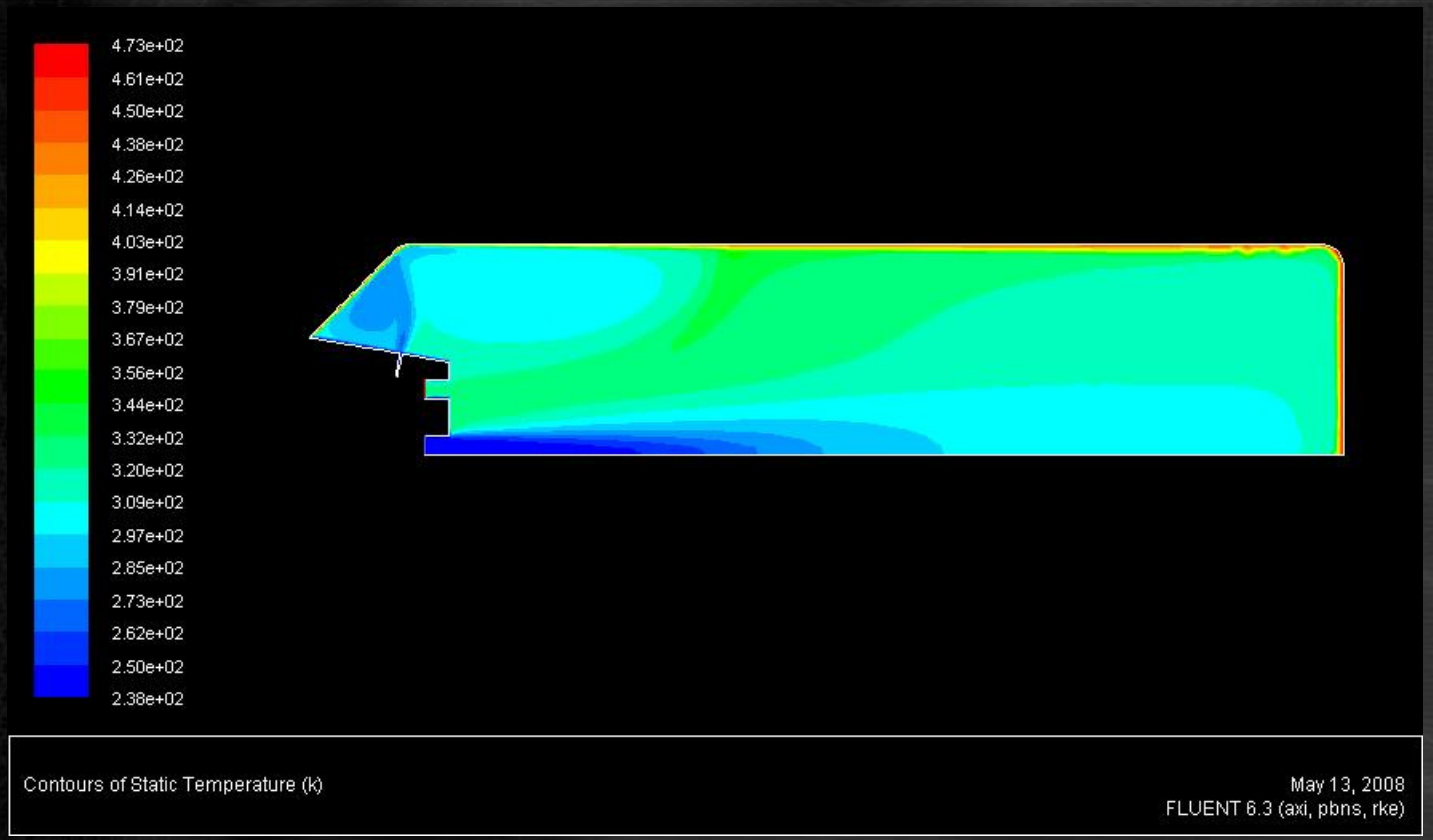
Vectorplot: around the thorn

Heat Flux on the wall

K-ε (realizable – Standard) K-ω (SST)

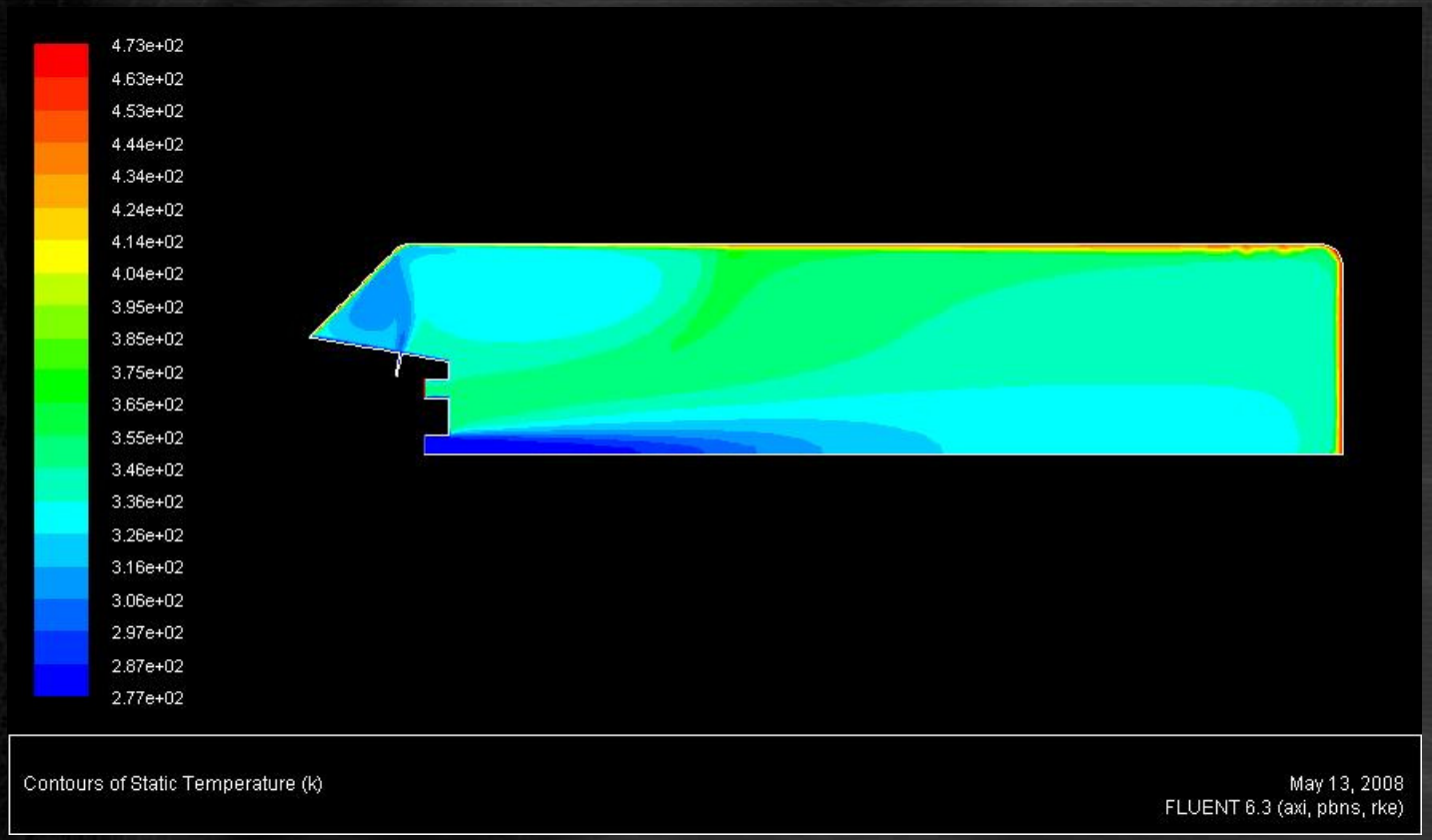
Static temperature –35 ℃

Temperatuur outlet: 47,3 ℃



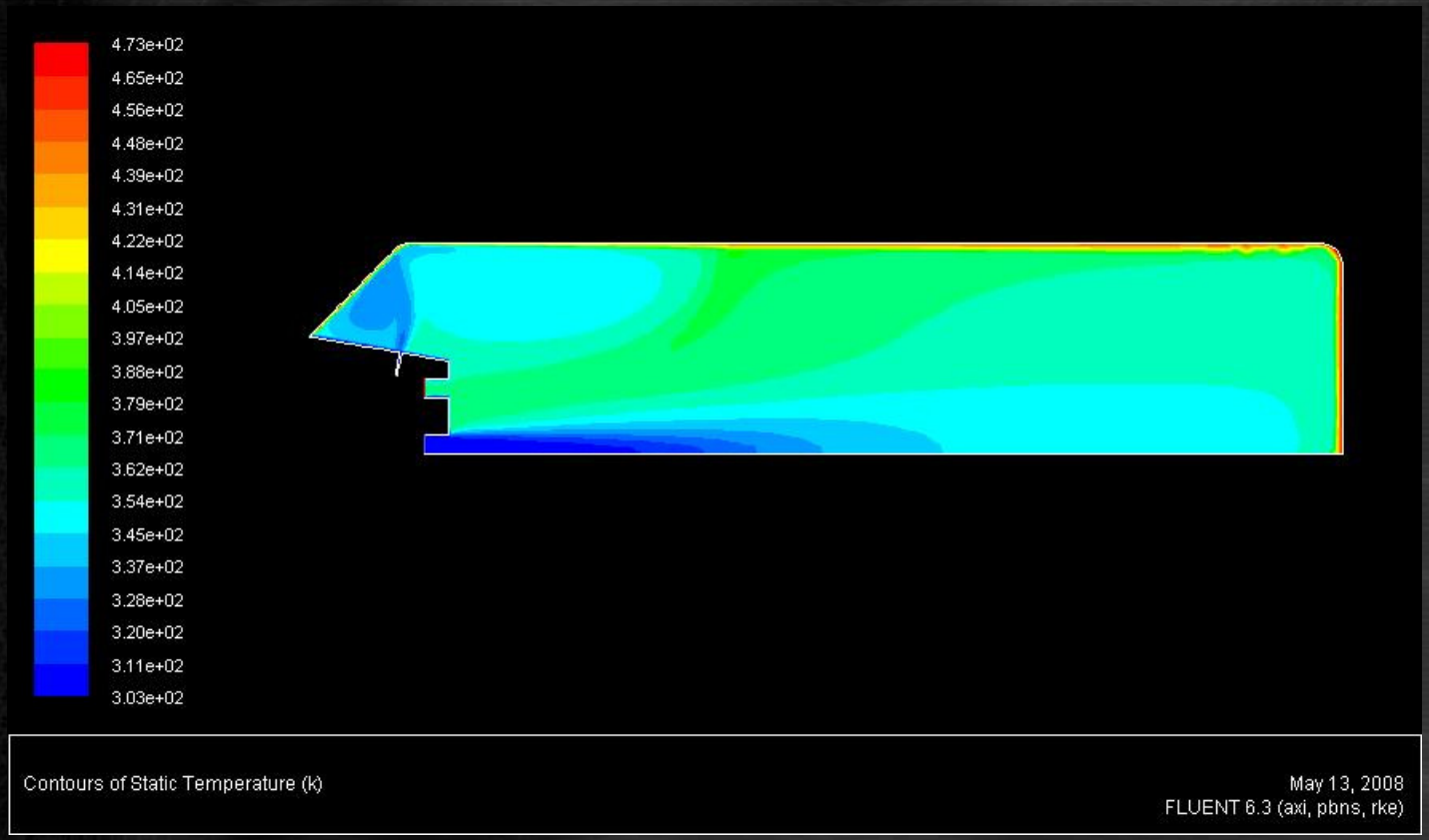
Static temperature 4 °C

Temperatuur outlet: 72,5 °C



Static temperature 30 ℃

Temperatuur outlet: 89,5 ℃



Results

Temperature:

- At –35℃ for the different flow rates
- At 0.0026 m^3/s on different temperatures

At largest flow rate, grid adaption is used in order to get correct Y+ values)

(following is at 0.0026 m^3/s and –35℃ Inlet temperature)

Contourplot

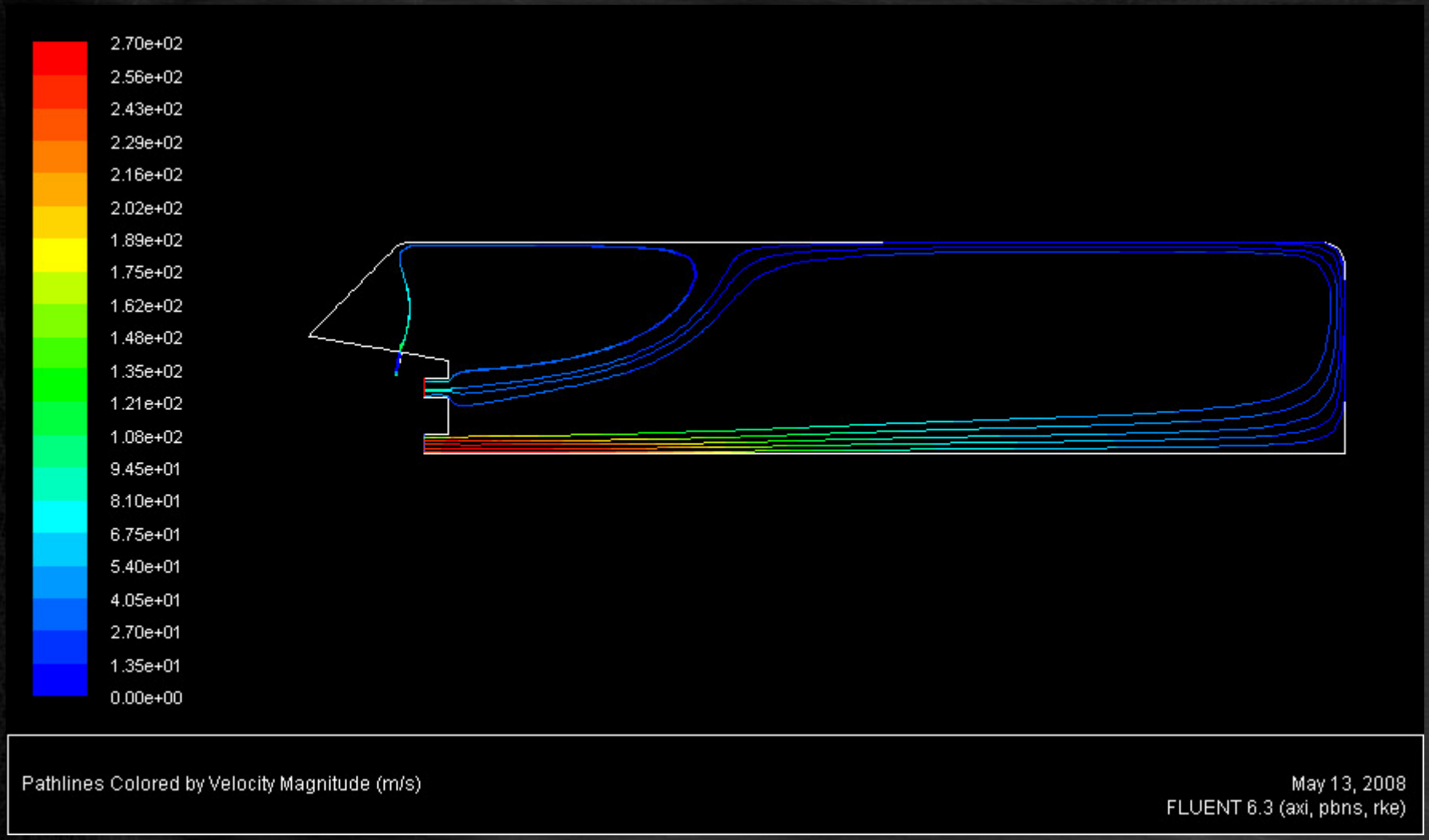
- Velocity magnitude → flow rate almost no influence on path, only on magintude

Vectorplot: around the thorn

Heat Flux on the wall

K-ε (realizable – Standard) K-ω (SST)

Pathlines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2.56e+02
2.43e+02
2.29e+02
2.16e+02
2.02e+02
1.89e+02
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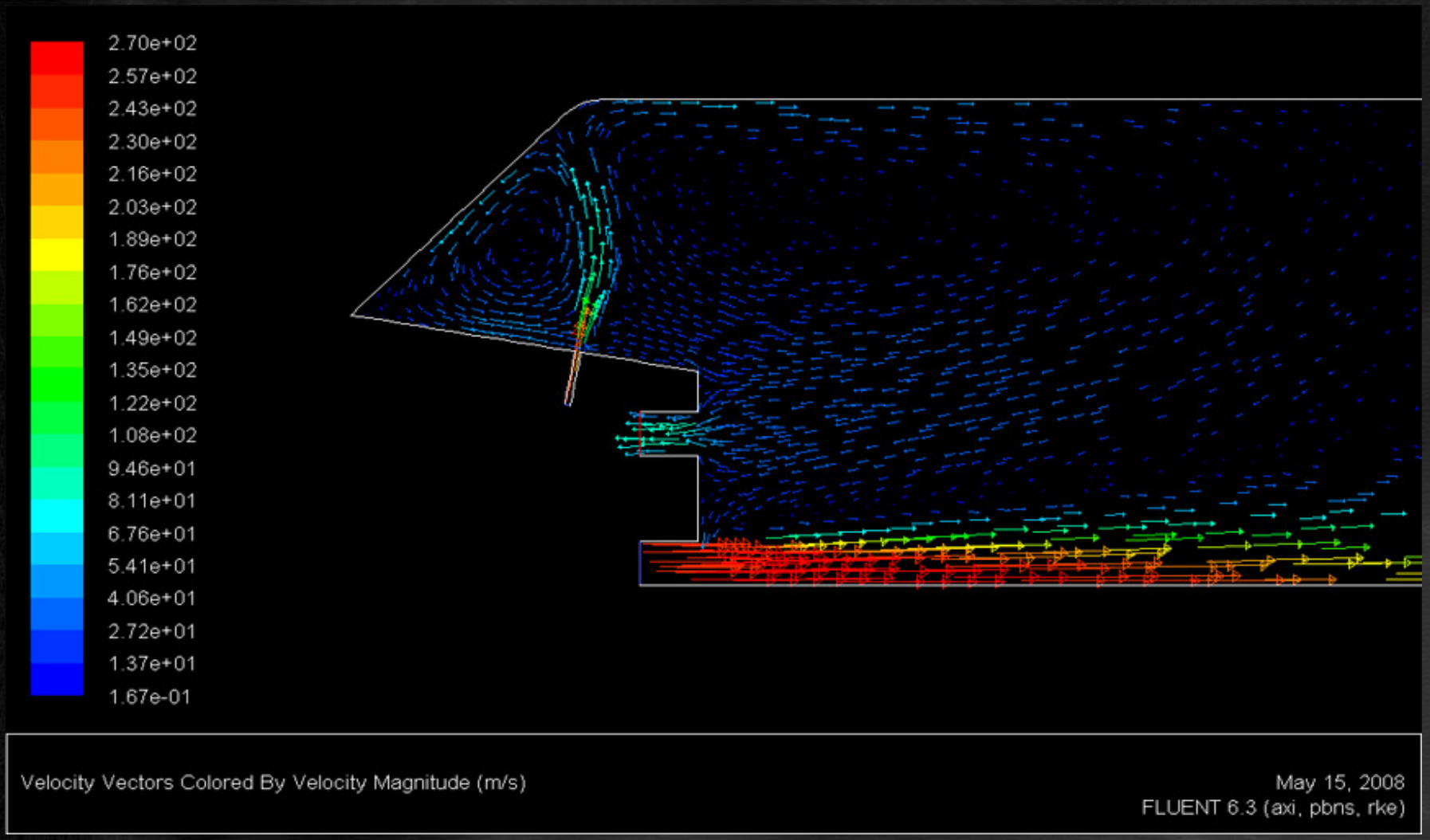
1.62e+02
1.48e+02
1.35e+02
1.21e+02
1.08e+02
9.45e+01
8.10e+01
6.75e+01
5.40e+01
4.05e+01
2.70e+01
1.35e+01
0.00e+00
Pathlines Colored by Velocity Magnitude (m/s)
May 13, 2008
FLUENT 6.3 (axi, pbns, rke)

Vectorplot


2.70e+02
2.57e+02
2.43e+02
2.30e+02
2.16e+02
2.03e+02
1.89e+02
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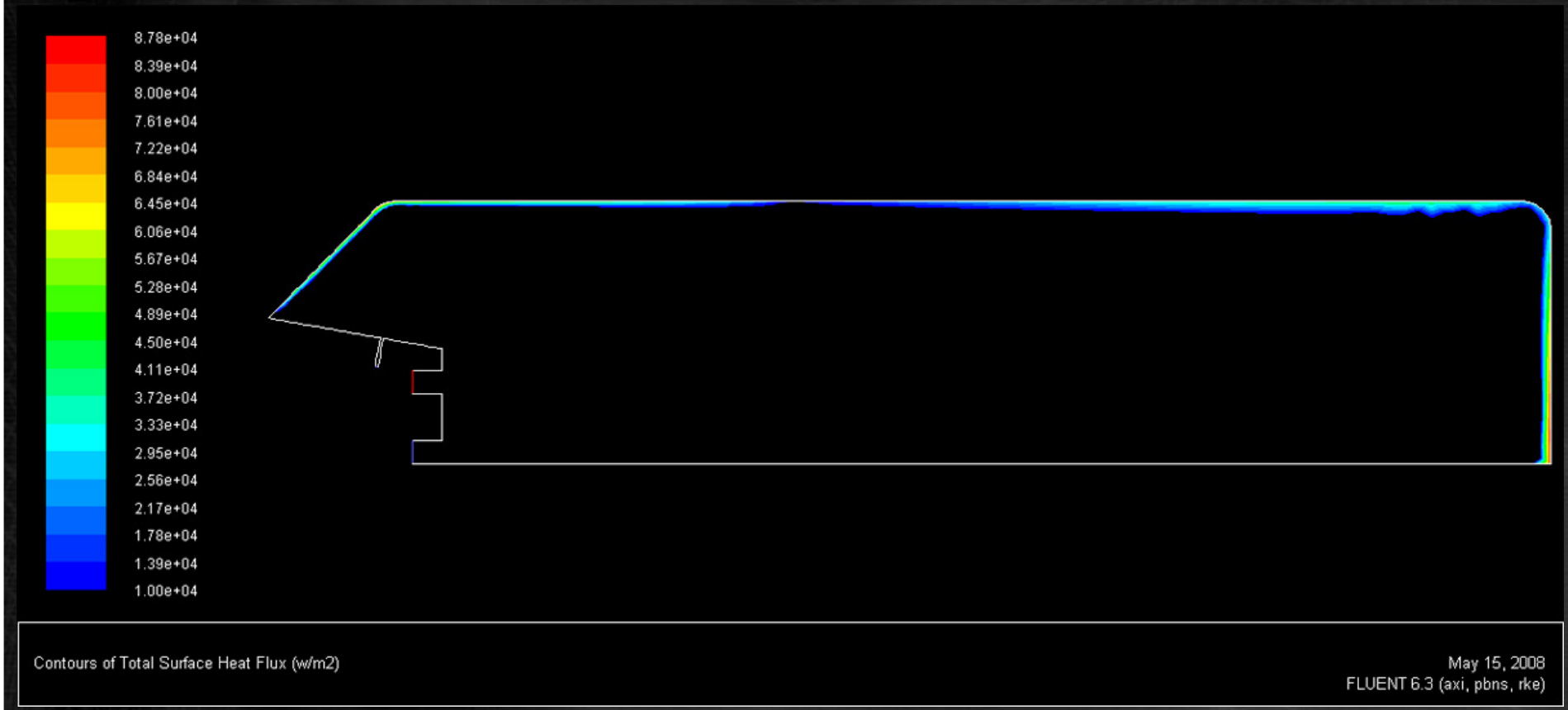
1.62e+02
1.49e+02
1.35e+02
1.22e+02
1.08e+02
9.46e+01
8.11e+01
6.76e+01
5.41e+01
4.06e+01
2.72e+01
1.37e+01
1.67e-01
Velocity Vectors Colored By Velocity Magnitude (m/s)
May 15, 2008
FLUENT 6.3 (axi, pbns, rke)

Heat flux

Bij 0,026 m^3/s en inlaattemperatuur –35 °C



Heat flux - Overview

Maximumvalues (situated at central of bottle base) in kW / m²

$T_{(°C)}$ \ $Q_{(m^3/s)}$	0,0065	0,013	0,026
-35	25,9	47,7	87,8
4	21,6	39,8	73,2
30	17.9	34,4	63,5

Results

Temperature:

- At –35℃ for the different flow rates
- At 0.0026 m^3/s on different temperatures

At largest flow rate, grid adaption is used in order to get correct Y+ values)

(following is at 0.0026 m^3/s and –35℃ Inlet temperature)

Contourplot

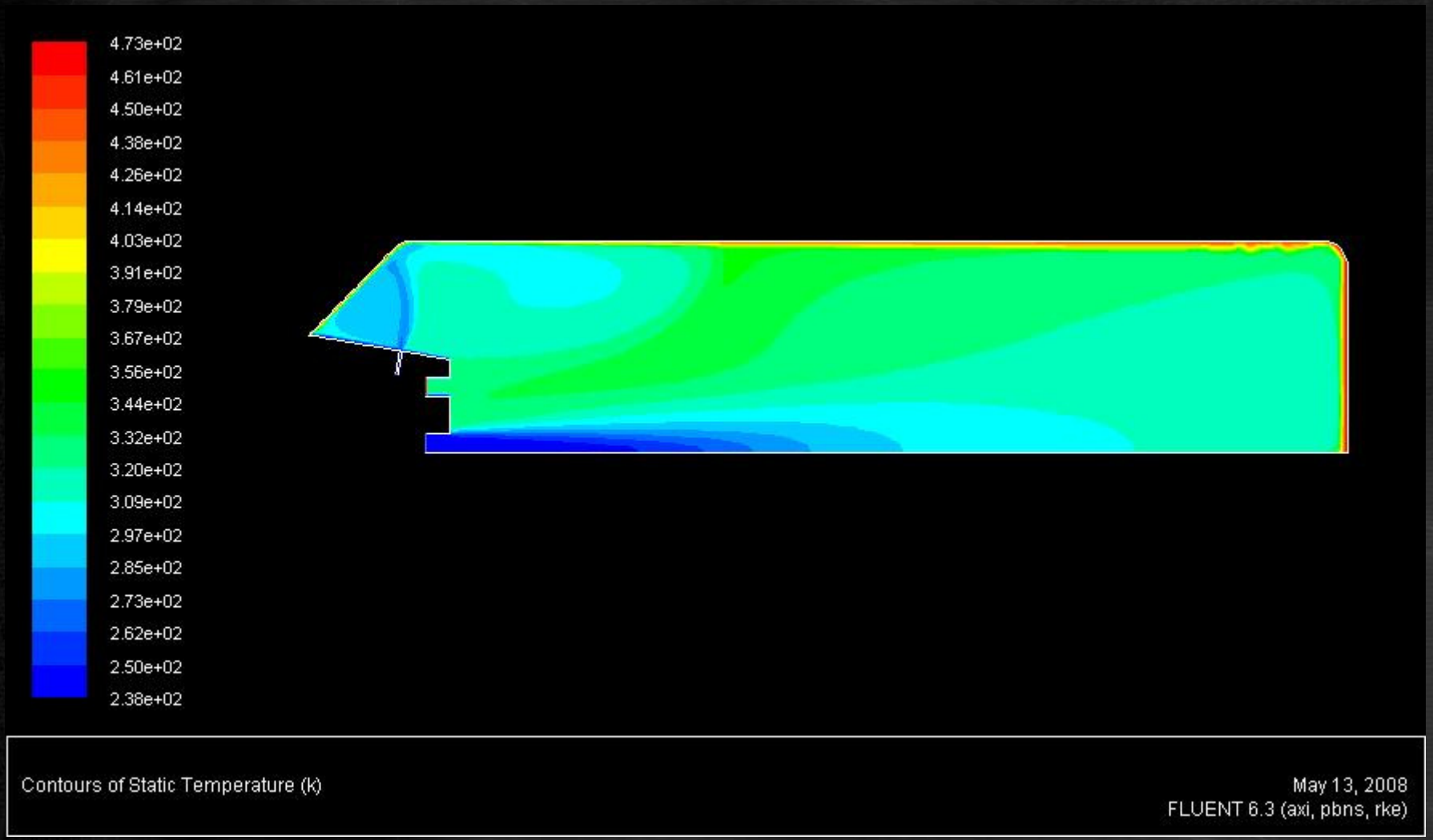
- Velocity magnitude → flow rate almost no influence on path, only on magintude

Vectorplot: around the thorn

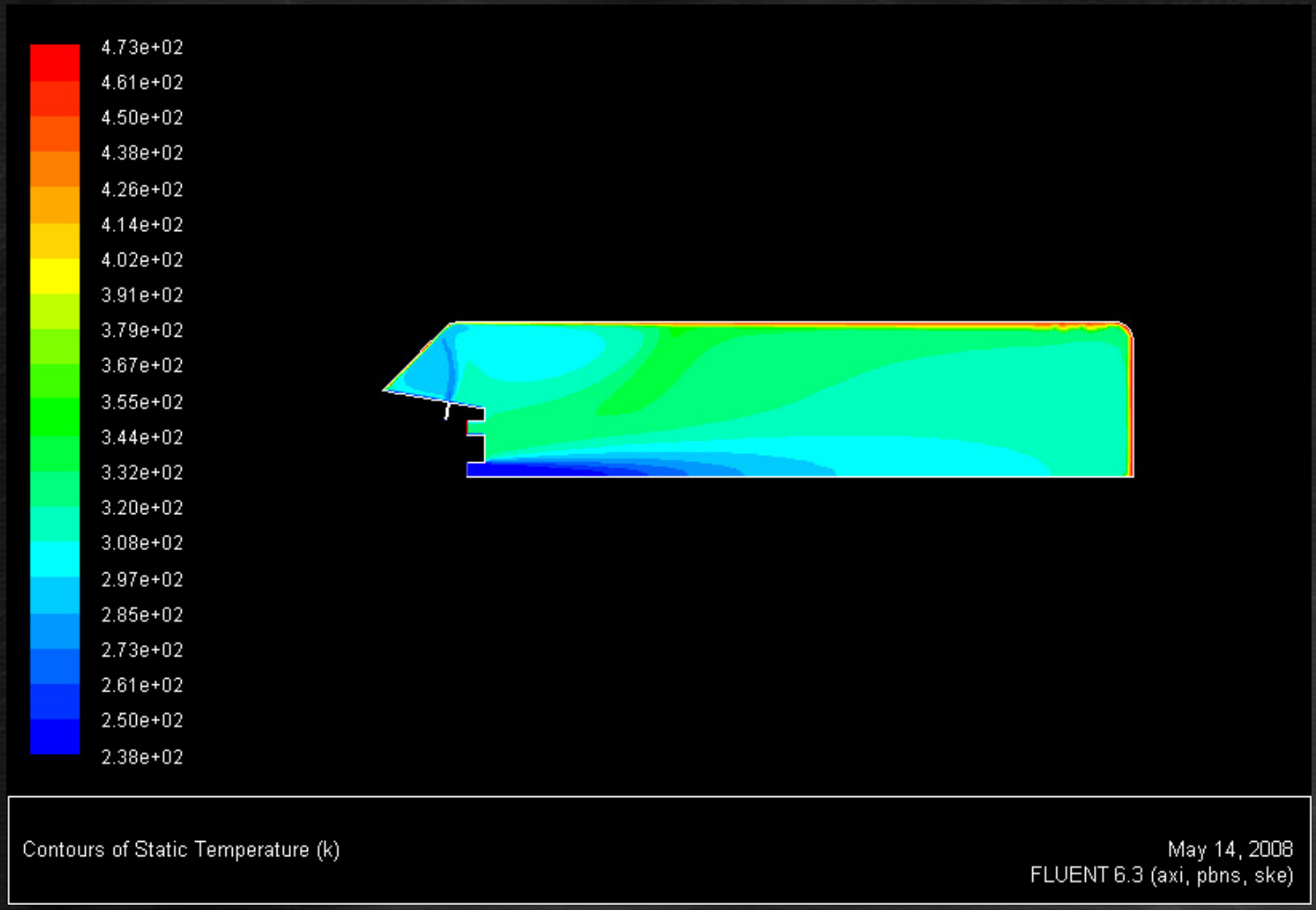
Heat Flux on the wall

K-ε (realizable – Standard) K-ω (SST)

K-E realizable



K-E Standard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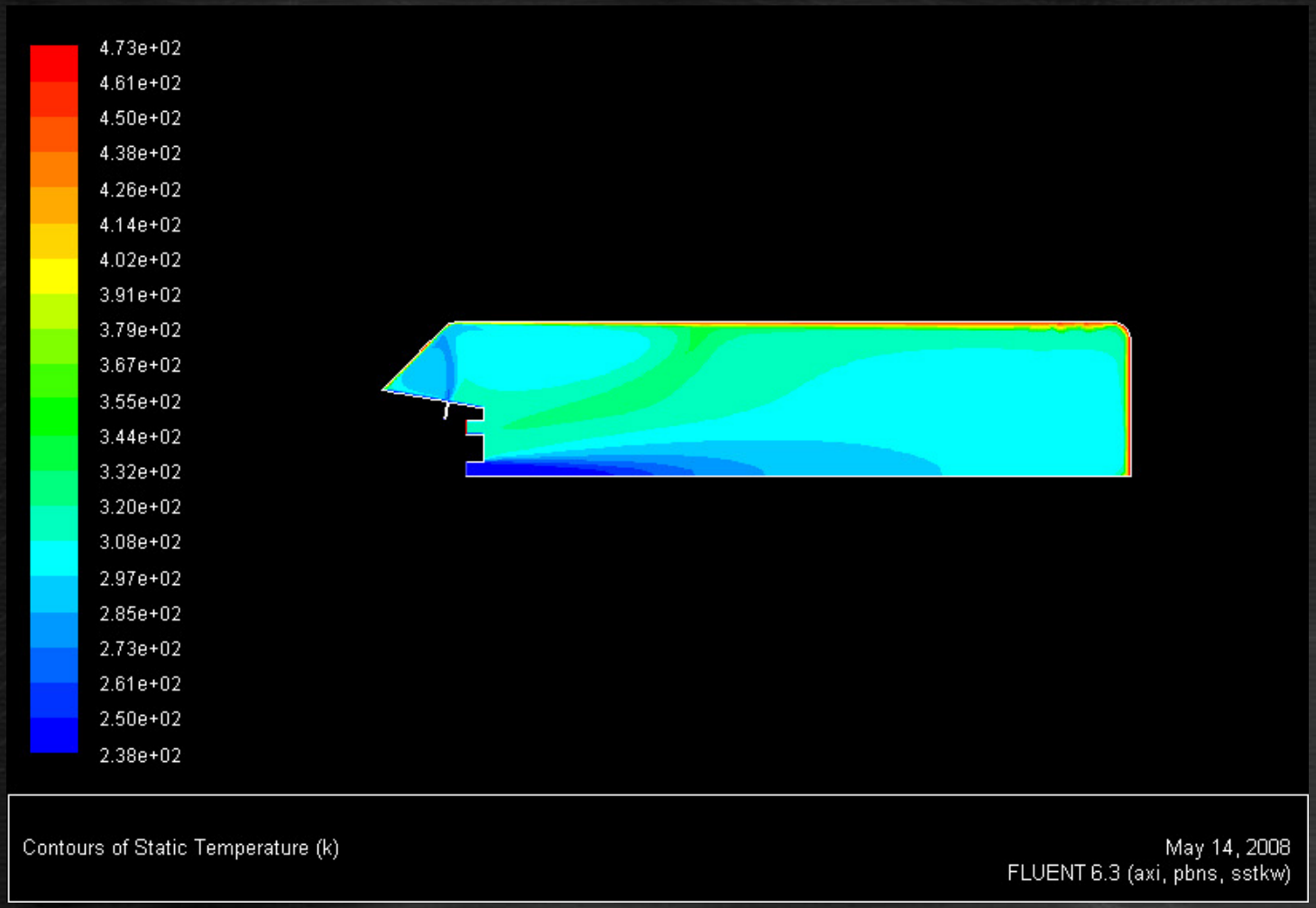
4.61e+02
4.50e+02
4.38e+02
4.26e+02
4.14e+02
4.02e+02
3.91e+02
3.79e+02
3.67e+02
3.55e+02
3.44e+02
3.32e+02
3.20e+02
3.08e+02
2.97e+02
2.85e+02
2.73e+02
2.61e+02
2.50e+02
2.38e+02
Contours of Static Temperature (k)
May 14, 2008
FLUENT 6.3 (axi, pbns, ske)

K-W SST


4.73e+02
4.61e+02
4.50e+02
4.38e+02
4.26e+02
4.14e+02
4.02e+02
3.91e+02
3.79e+02
3.67e+02
3.55e+02
3.44e+02
3.32e+02
3.20e+02
3.08e+02
2.97e+02
2.85e+02
2.73e+02
2.61e+02
2.50e+02
2.38e+02
Contours of Static Temperature (k)
May 14, 2008
FLUENT 6.3 (axi, pbns, sstkw)