A Preliminary Computational Fluid Mechanical Analysis of Skirts

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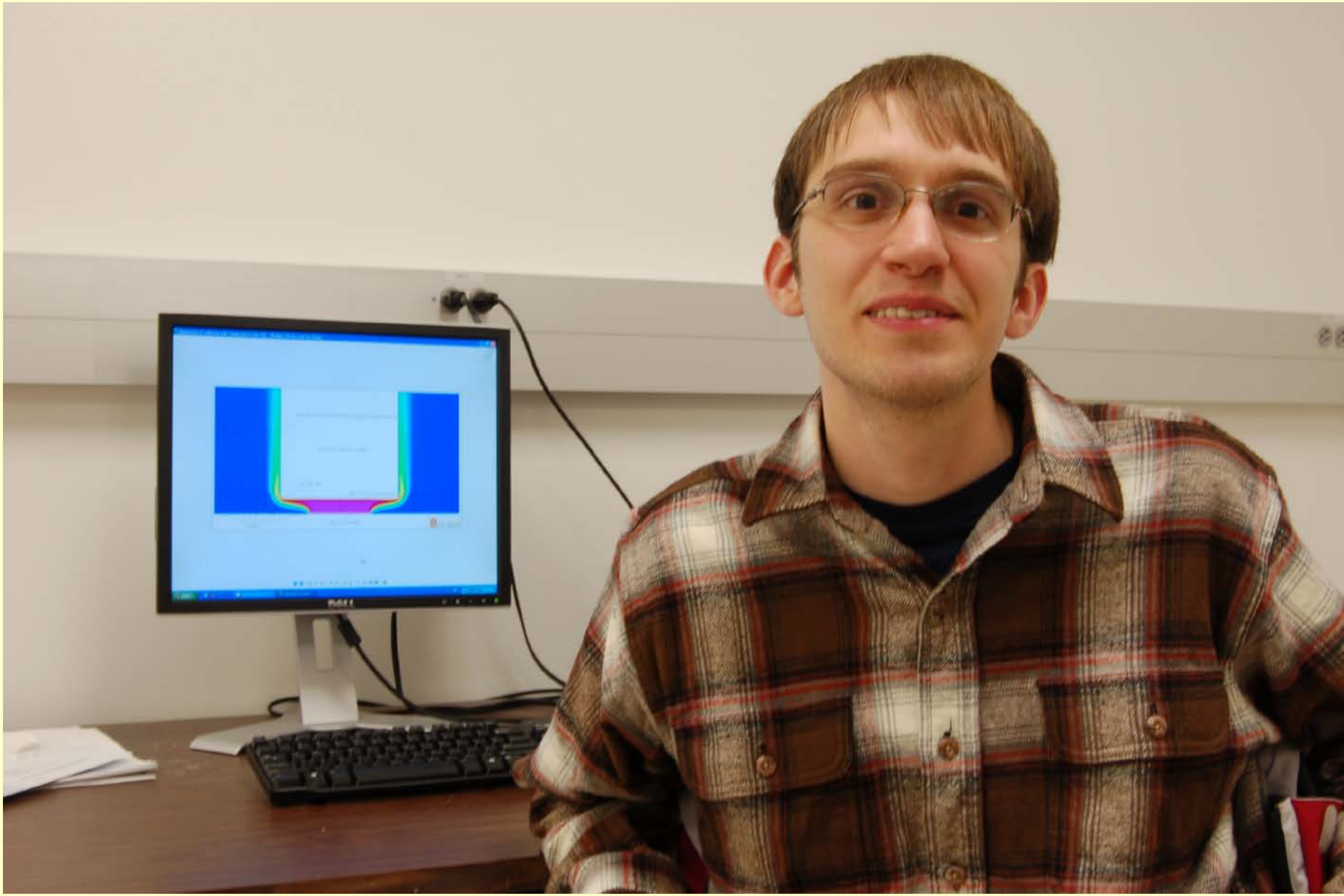


Two purposes to this talk

- 1. Introduce the idea of computational fluid mechanics as a way to analyze stoves.
- 2. Look at preliminary results to begin to understand skirts.
- No written document, this is still preliminary.
- Full document available in late 2009.
- Possible ASME paper this summer.

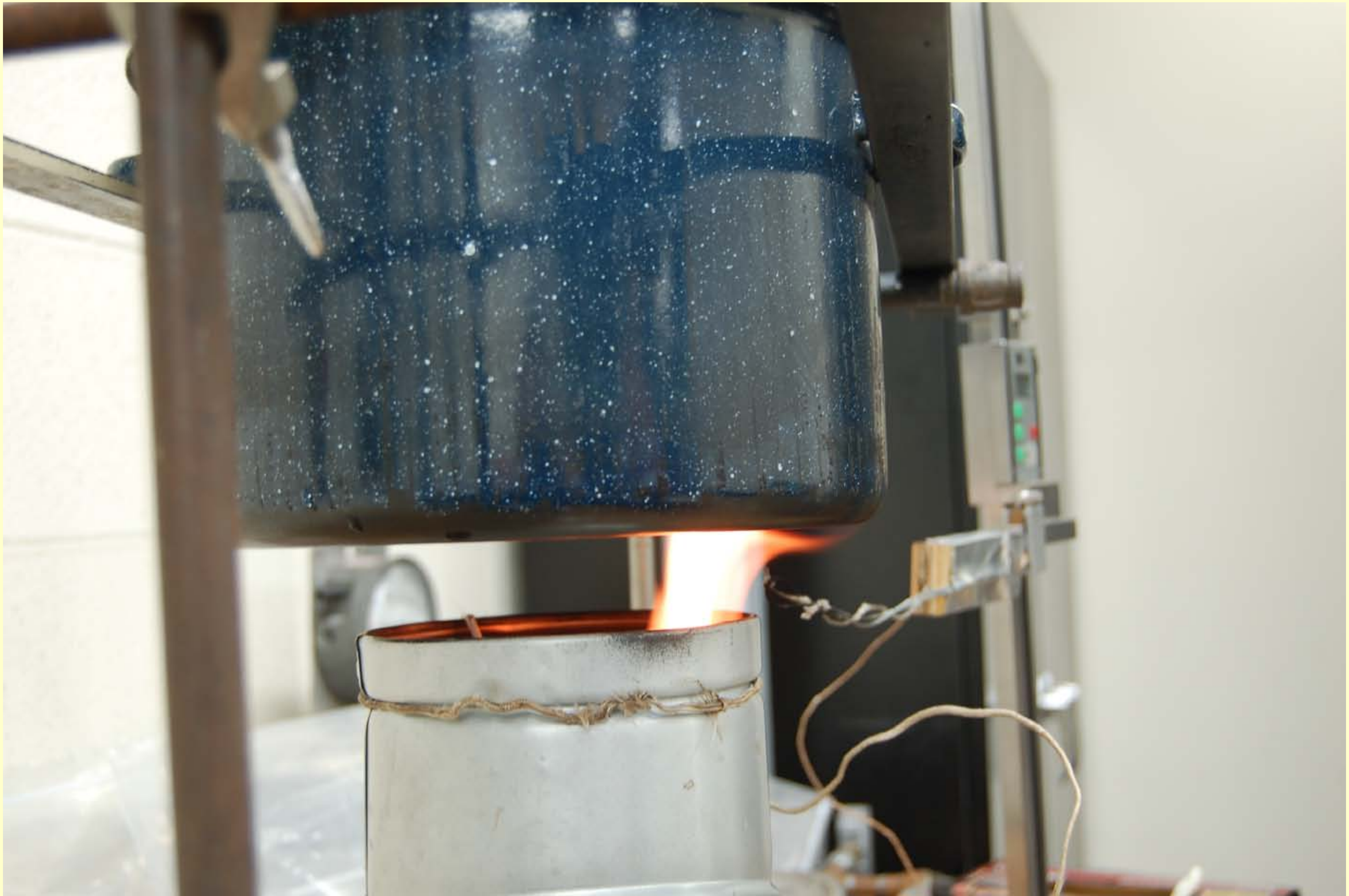
Computational Fluid Mechanics

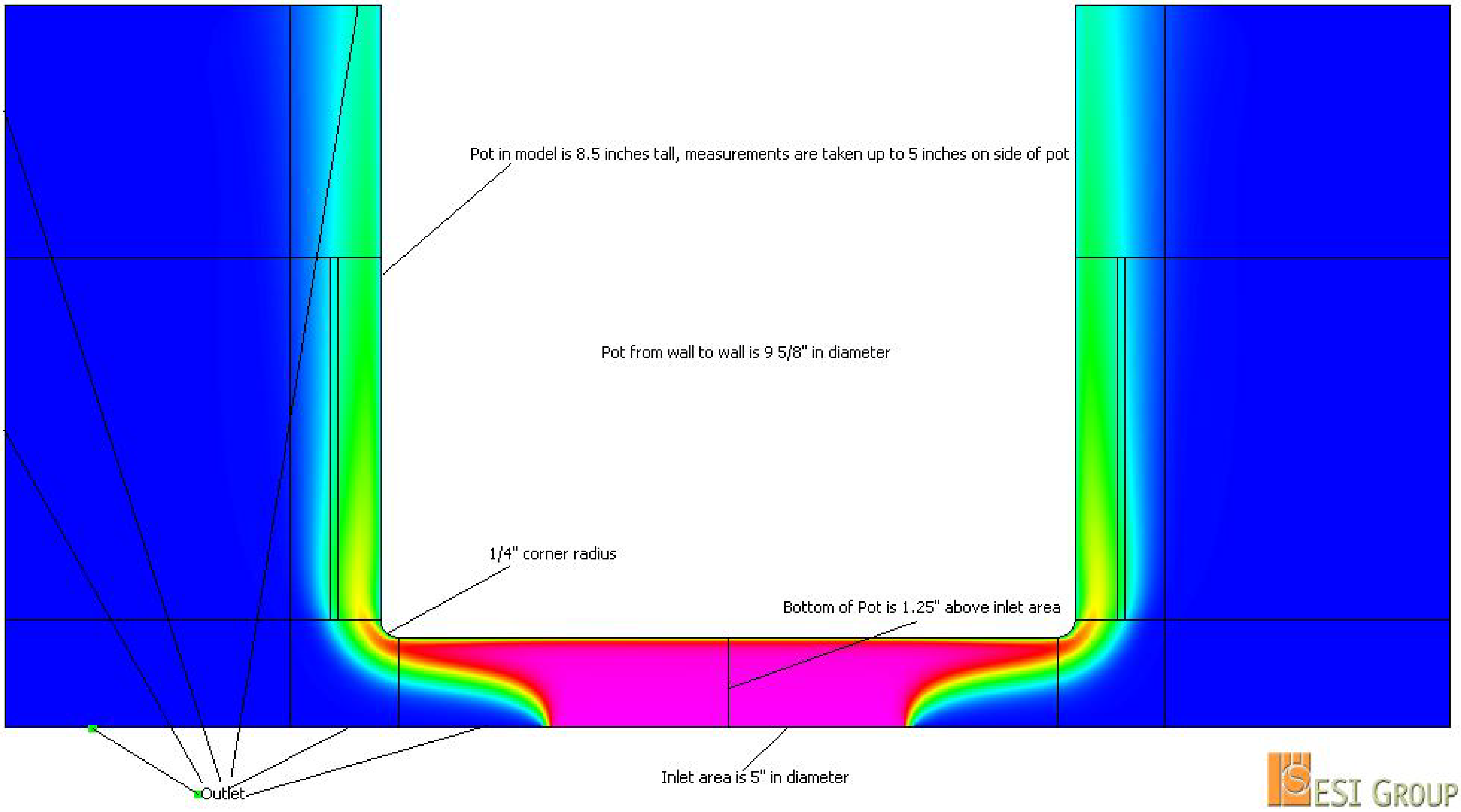
- Use a computer to figure out how much heat transfer.
- We know what’s coming out of the stove, what temperature, what velocity, what turbulence level, and what soot loading.
- Calculate what’s happening at all points in the flow field.

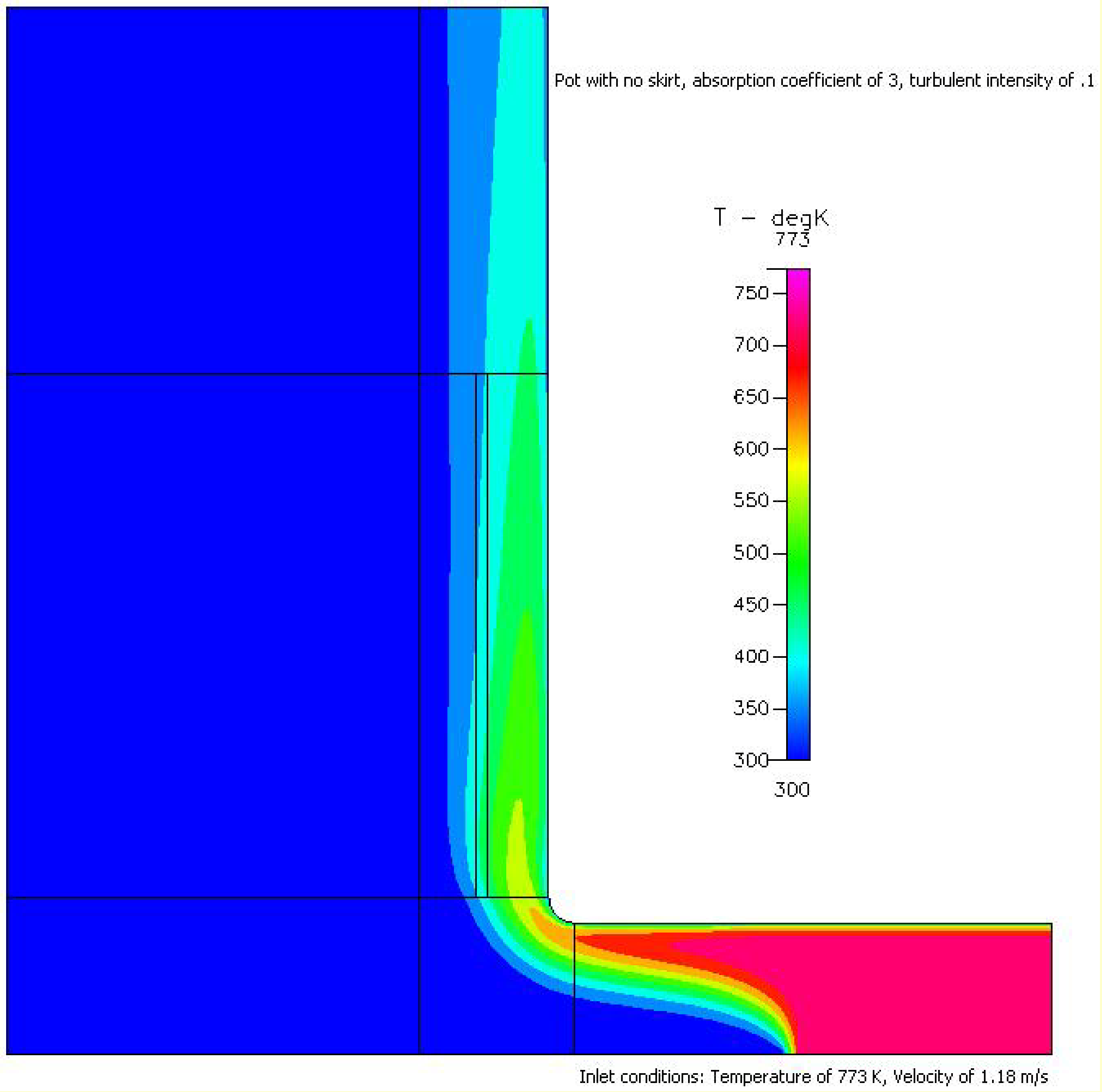
We can tell:

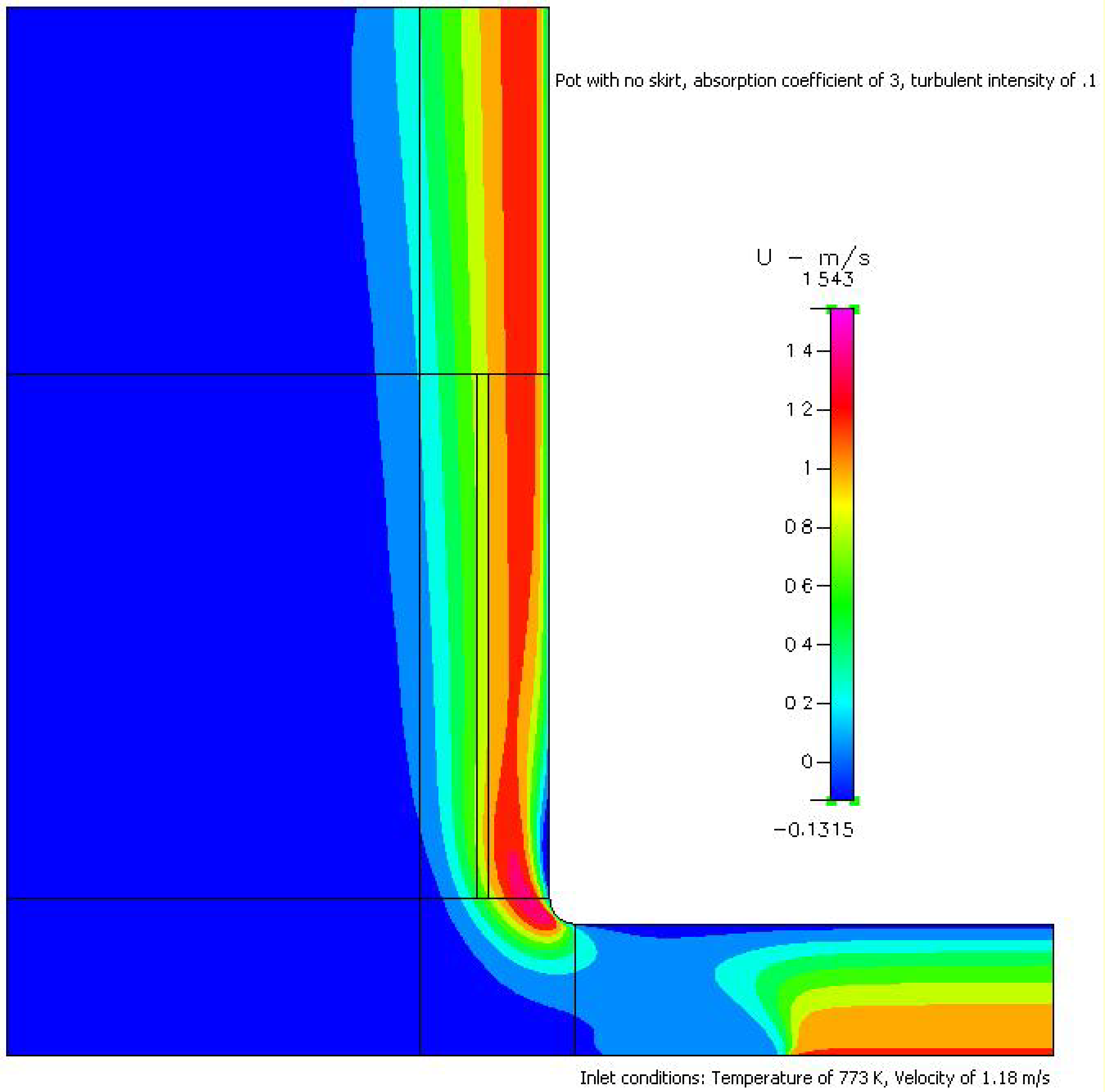
- How much heat is going into the pot at any location on the pot.
- Separate radiation and convection.
- Compare with experiments.
- Vary the design (for example, add a skirt) and see what difference it makes.

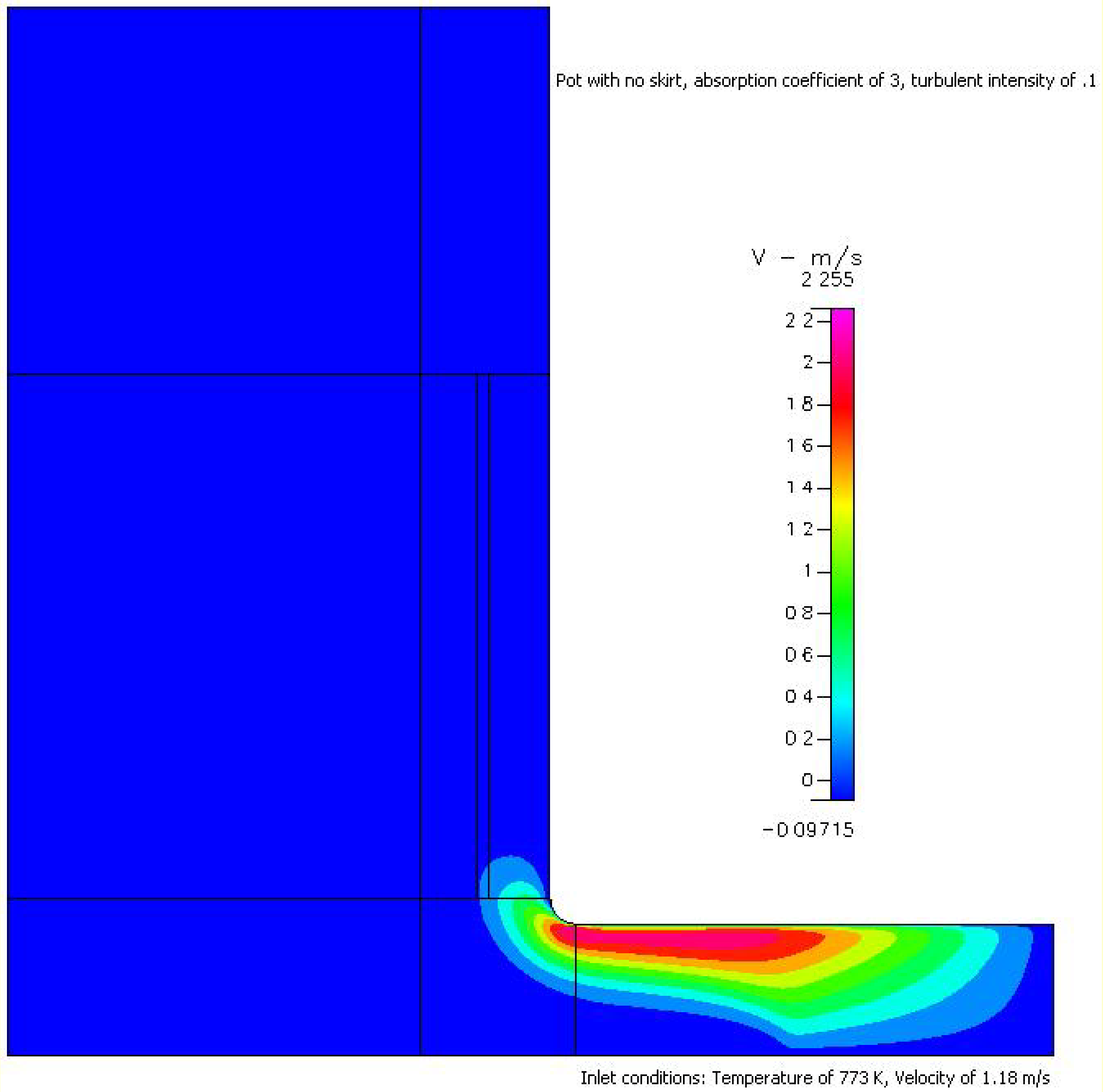
The physical situation (note temperature probe)

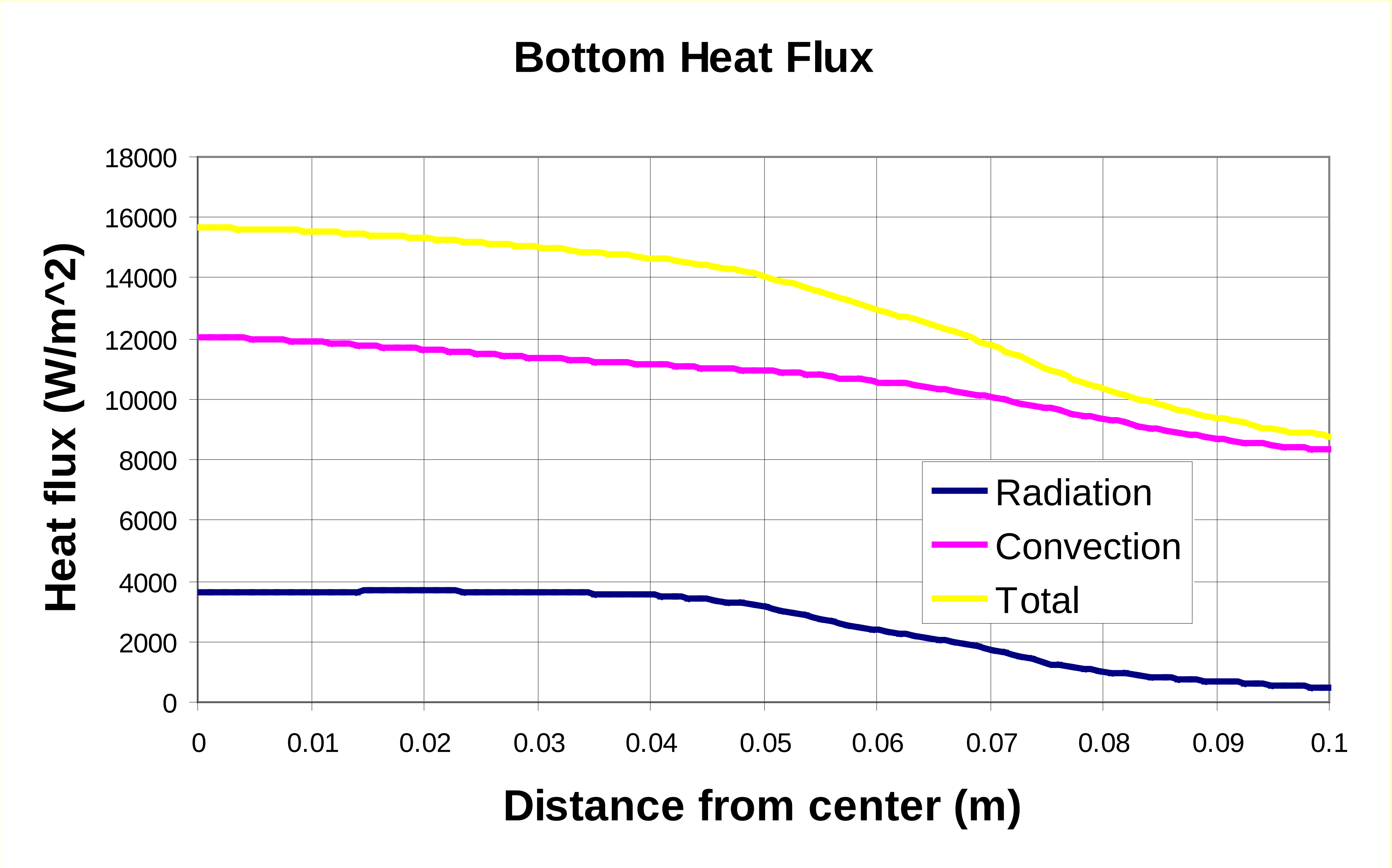



Pot in model is 8.5 inches tall, measurements are taken up to 5 inches on side of pot
Pot from wall to wall is 9 5/8" in diameter
1/4" corner radius
Bottom of Pot is 1.25" above inlet area
Outlet
Inlet area is 5" in diameter
ESI GROUP

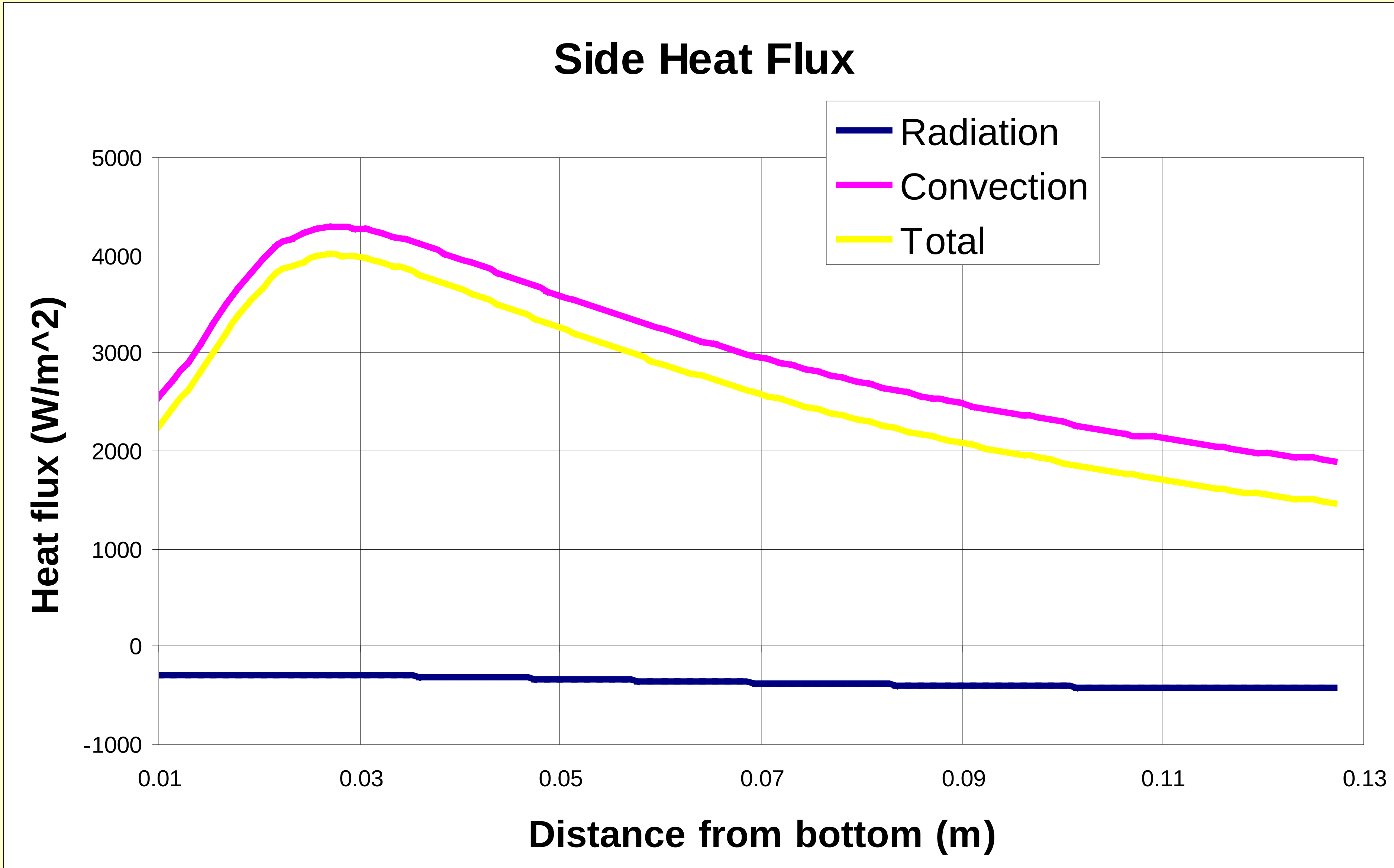

Pot with no skirt, absorption coefficient of 3, turbulent intensity of .1
T - degK
773
750
700
650
600
550
500
450
400
350
300
300
Inlet conditions: Temperature of 773 K, Velocity of 1.18 m/s


Pot with no skirt, absorption coefficient of 3, turbulent intensity of .1
U – m/s
1.543
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.1315
Inlet conditions: Temperature of 773 K, Velocity of 1.18 m/s


Pot with no skirt, absorption coefficient of 3, turbulent intensity of .1
V – m/s
2 255
2 2
2
1 8
1 6
1 4
1 2
1
0 8
0 6
0 4
0 2
0
–0 09715
Inlet conditions: Temperature of 773 K, Velocity of 1.18 m/s



Bottom Heat Flux
Heat flux (W/m^2)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Distance from center (m)
Radiation
Convection
Total


Side Heat Flux
Radiation
Convection
Total
5000
4000
3000
2000
1000
0
-1000
Heat flux (W/m^2)
0.01
0.03
0.05
0.07
0.09
0.11
0.13
Distance from bottom (m)

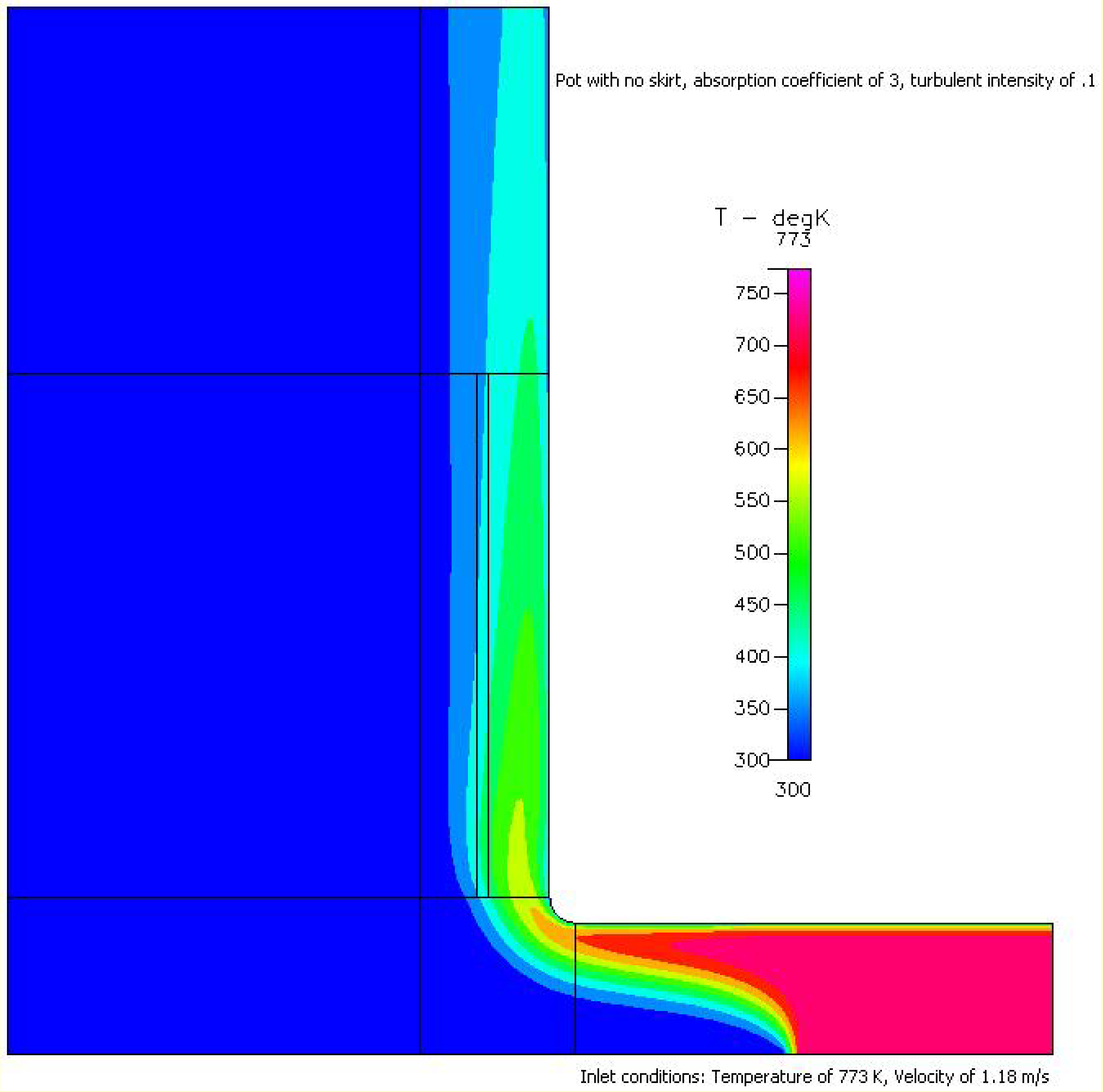
Now look at two types of skirts

- Insulated and uninsulated.
- 1 cm gap.
- Skirts improve the heat transfer, but why?

Skirts help because…..

- 1. They force hot gases to scrape the side of the pot (increasing convection to the side).

Without a skirt, hot gases rise alongside the pot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300
Inlet conditions: Temperature of 773 K, Velocity of 1.18 m/s

Skirts help because……

- 2. The skirt gets hot and radiates heat to the side of the pot.
- 3. Skirts block crosswinds.
- 4. Skirts reduce the excess air, leading to hotter gases coming out of the stove.

Suppose:

- Experiment says 500 Watts with no skirt.
- Computer says 500 Watts with no skirt.

Now suppose skirt is added with SAME stove exit conditions, and computer says:

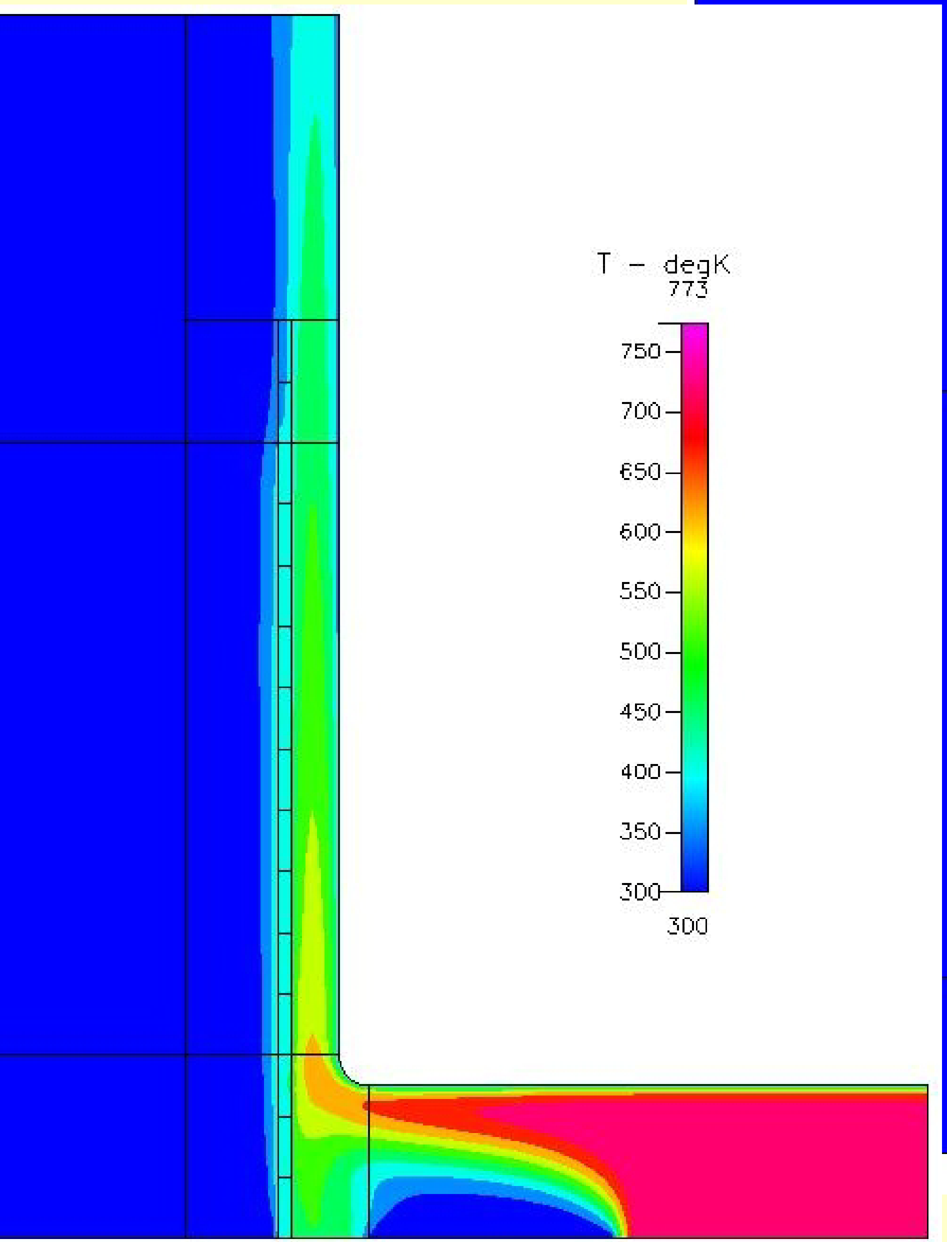
- Convective heat transfer increased by 100 Watts.
- Radiative heat transfer increased by 100 Watts.
- Total heat transfer should be 700 Watts.

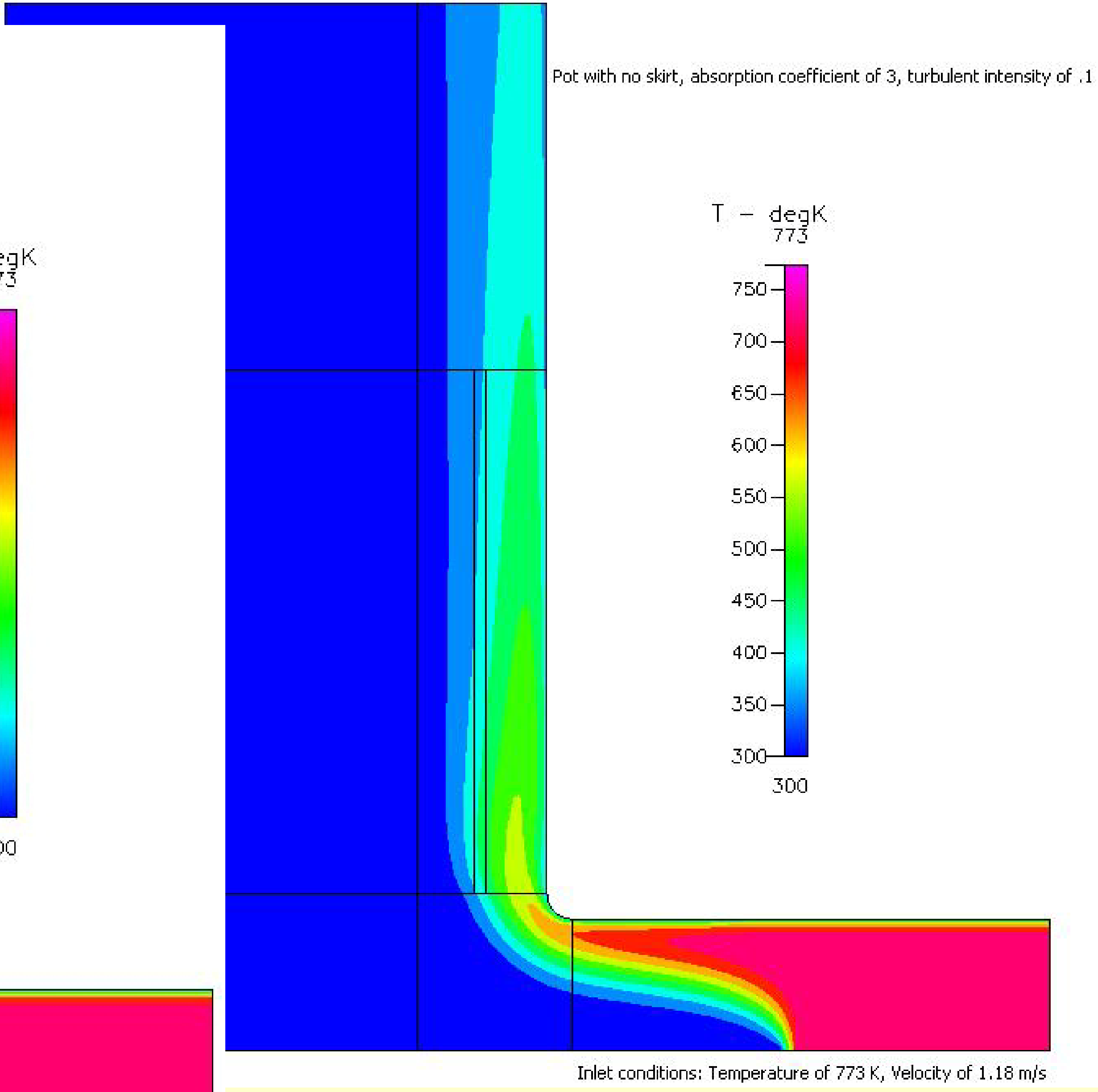
Suppose experiment says 1000 Watts, which is 300 greater than the 700 that was predicted:

- Assuming there was no crosswind effect, the extra 300 Watts must come from an change in the stove exit conditions caused by the presence of the skirt.
- Could get the same benefit by simpler means.

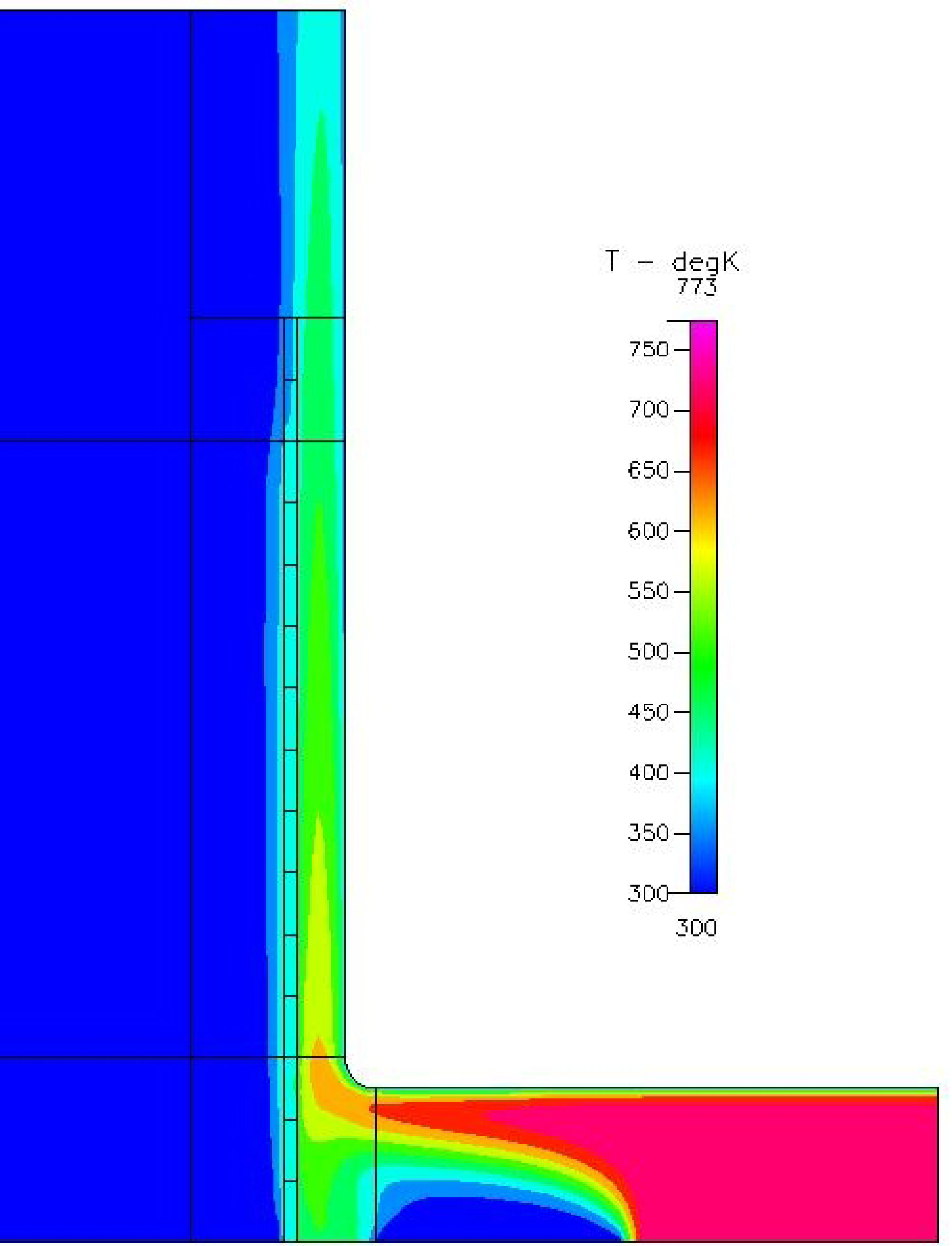
Uninsulated skirt

No skirt

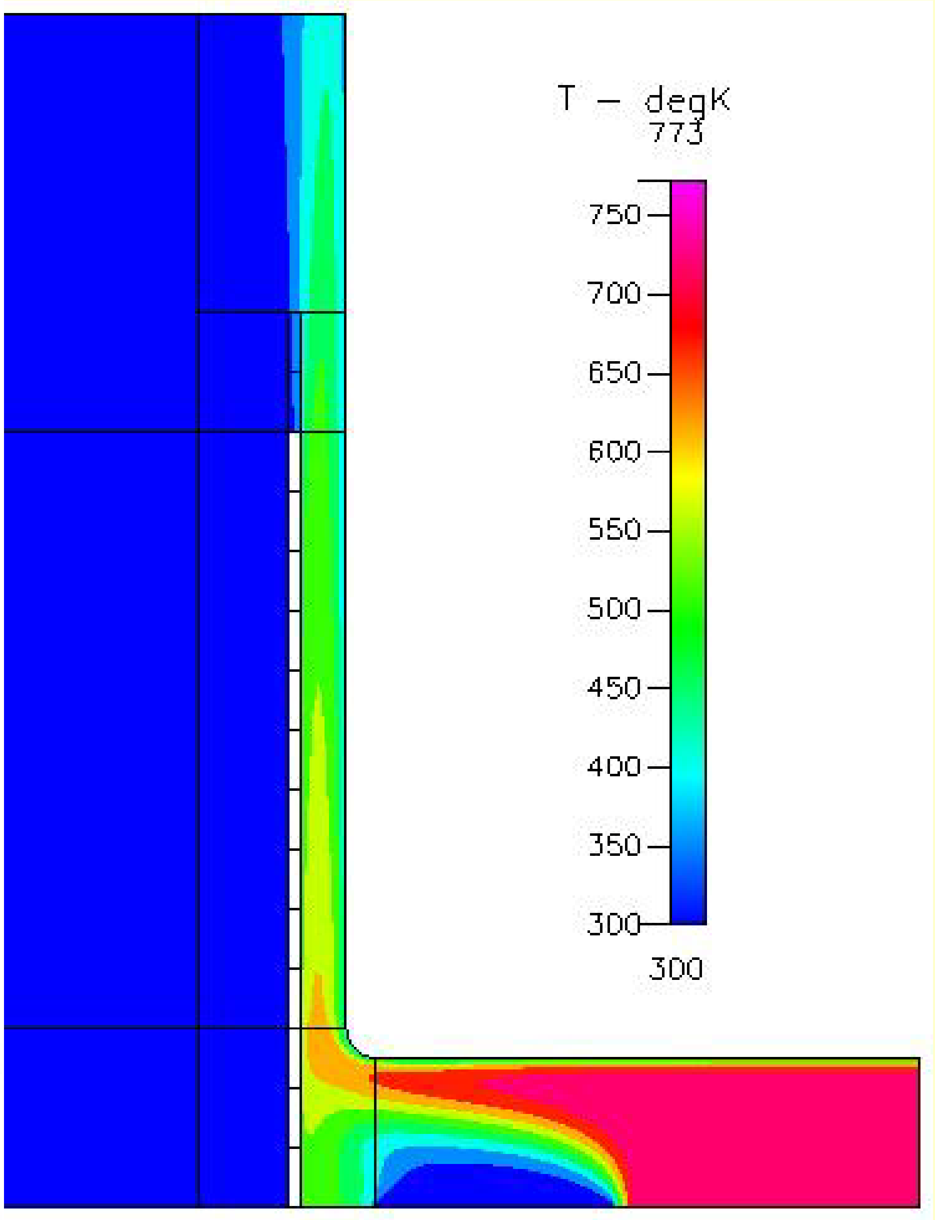




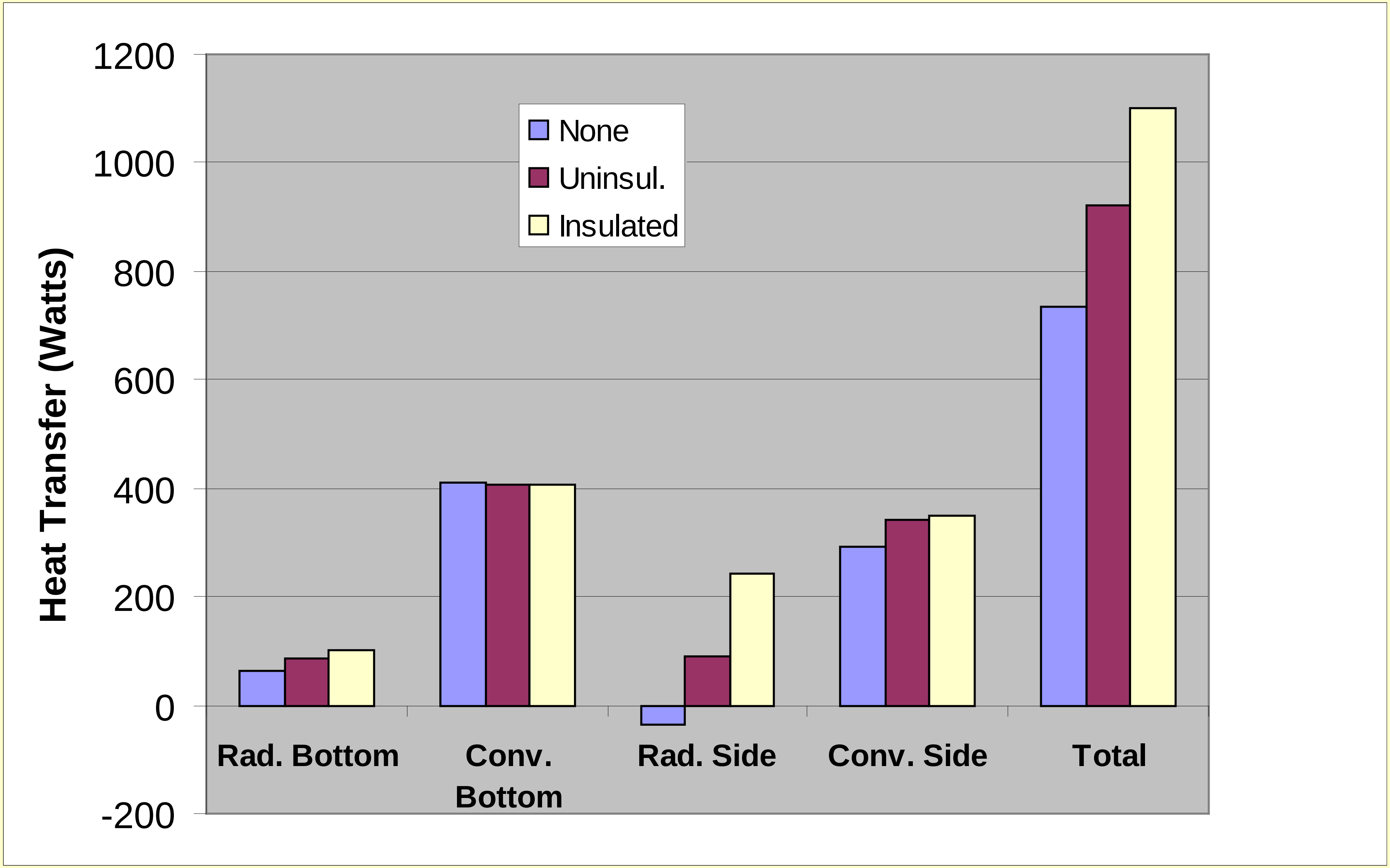
Unins. Skirt



Insulated skirt



Overall results



Overall results

- The skirt forced the hot gases to pass closer to the sides of the pot, resulting in increased heat transfer.
- However, the larger increase came from radiation on the sides.
- Increase in total heat transfer was about 50% over the case with no skirt.

Future Work

- Further study of skirts and channels and their optimum shapes and dimensions.
- Channels, tapered or straight?
- Shapes of pots, convex, flat, concave.