CFD SIMULATION OF PORT PURGE INTERACTION WITH THERMAL REACTOR PROCESS GAS

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DISCLAIMER

This presentation contains simulation results associated with an idealized system model. The material is only intended to illustrate qualitative trends observed for a range of system parameters. Parameter values disclosed here may not be safe for use in an actual system. Neither HEC Technologies nor any of its affiliates assume any liability for misapplication of the contents of this presentation.

For ports (typ. sight, scanner, ignitor, pyrometer) connected directly to TR hot zone through a refractory opening, purging prevents process gas ingress **to avoid**:

- S deposition,
- acidic condensation,
- port overheating (hot gas and radiation)

Purge flow rate:

Based on minimum purge gas velocity and port diameter (flow area)

What velocity (1, 2, 3, 4, 5……… ft/s)?

Purge velocity:

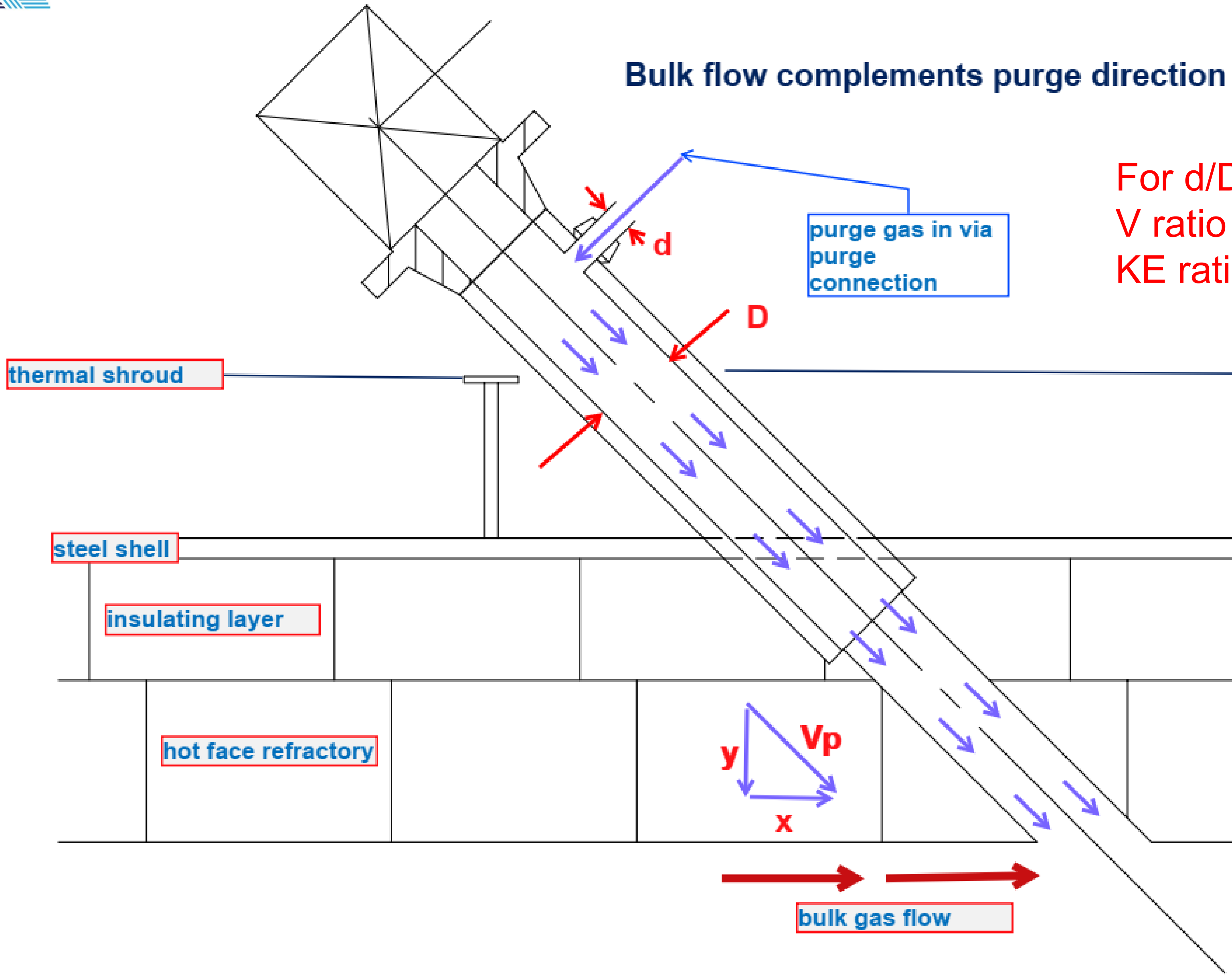
Sometimes a given purge gas velocity will provide sufficient protection for one port but not for another port on the same unit.

Some factors that may influence adequacy:

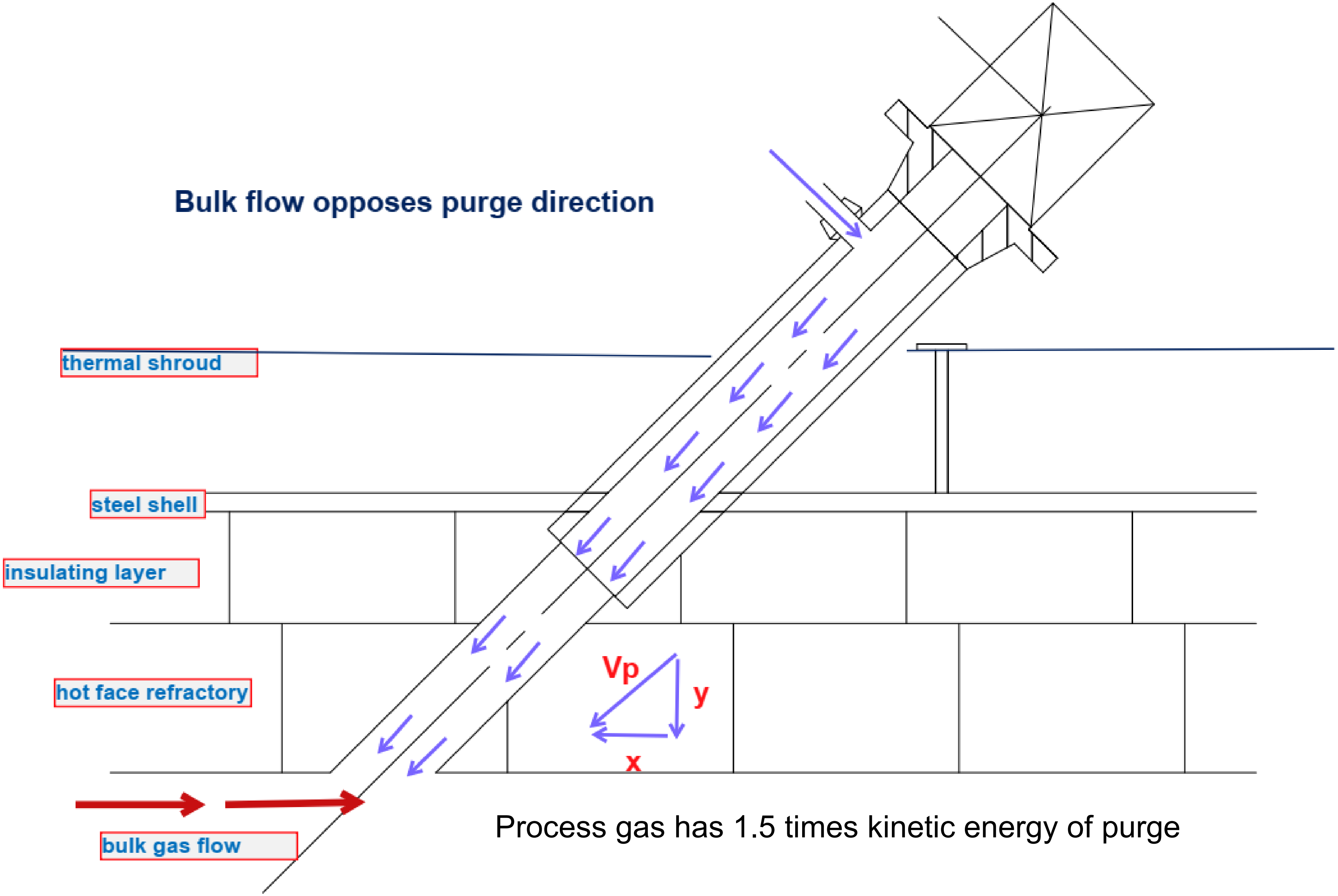
- Port Size
- Port Direction Relative to Bulk Flow
- Buoyancy Effects
- Purge Medium Selection

Bulk flow complements purge direction

For d/D = 0.25,
V ratio = 16/1,
KE ratio = 256/1



Bulk flow opposes purge direction



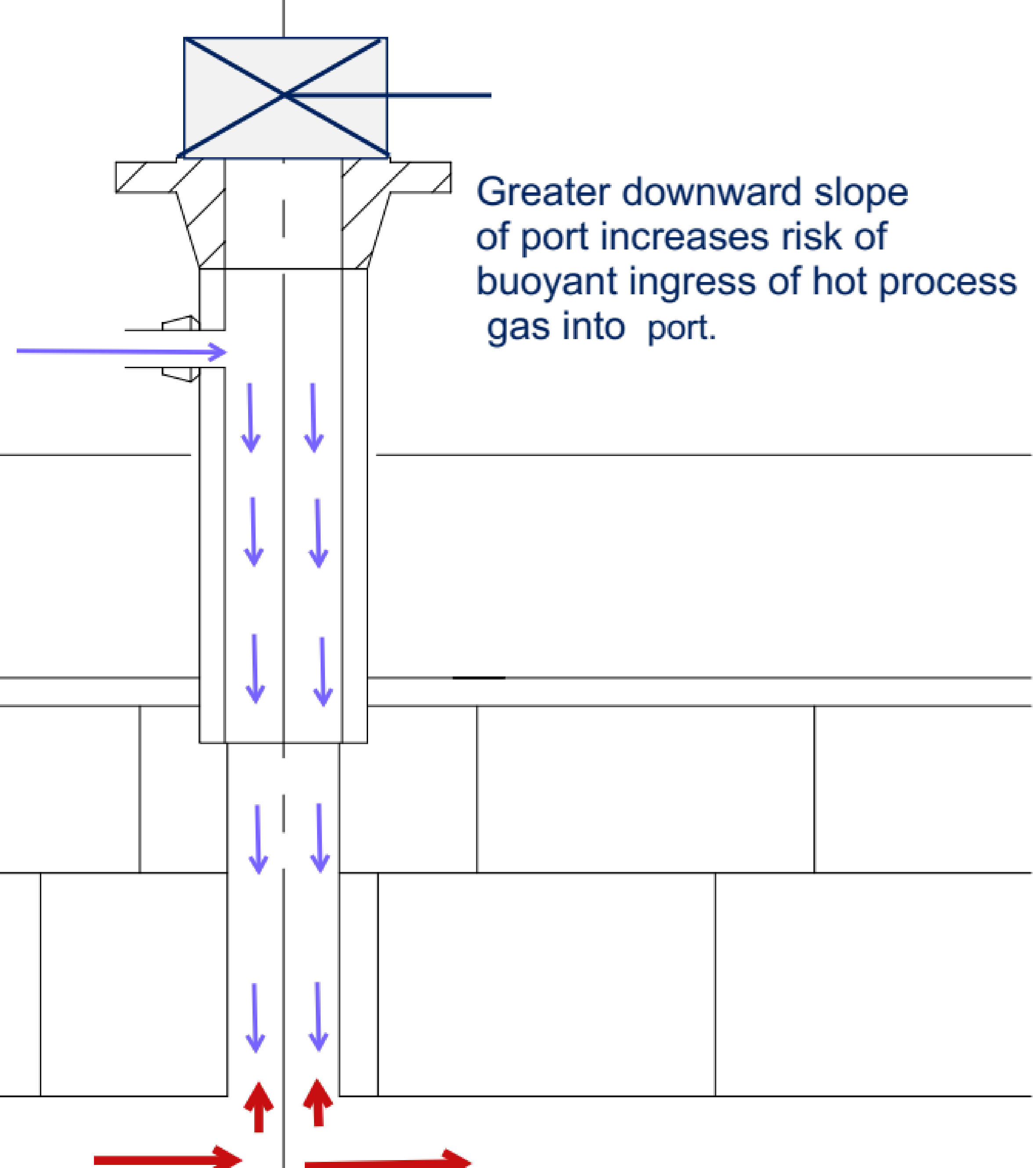
Process gas has 1.5 times kinetic energy of purge

Buoyancy

Density Difference

Air – He balloon
= 1 kg/m^3

Process-Purge
= 1.37 kg/m^3



Greater downward slope of port increases risk of buoyant ingress of hot process gas into port.

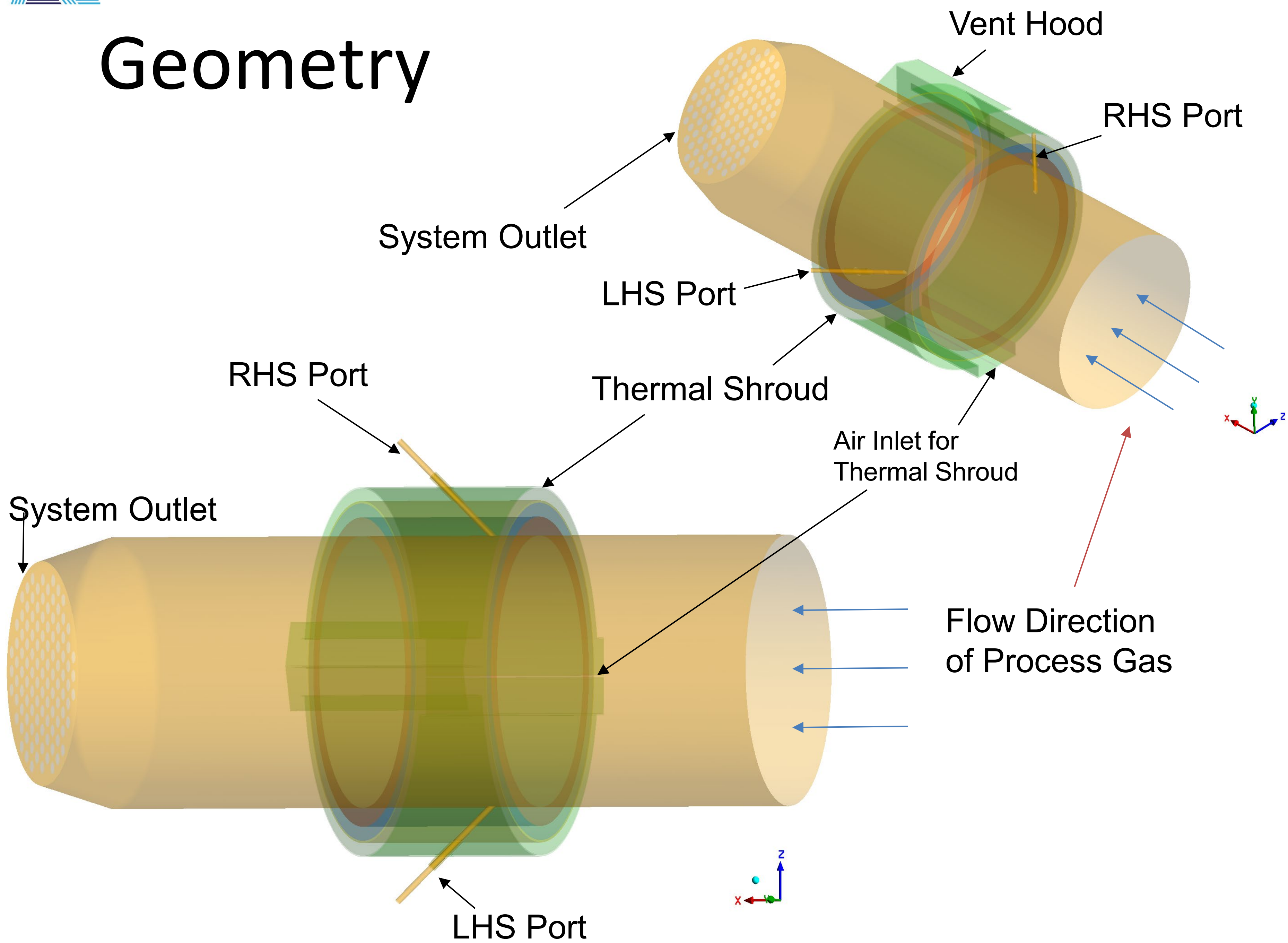
Purge medium:

Nitrogen – low risk, limited supply, may be disrupted, not available in some plants

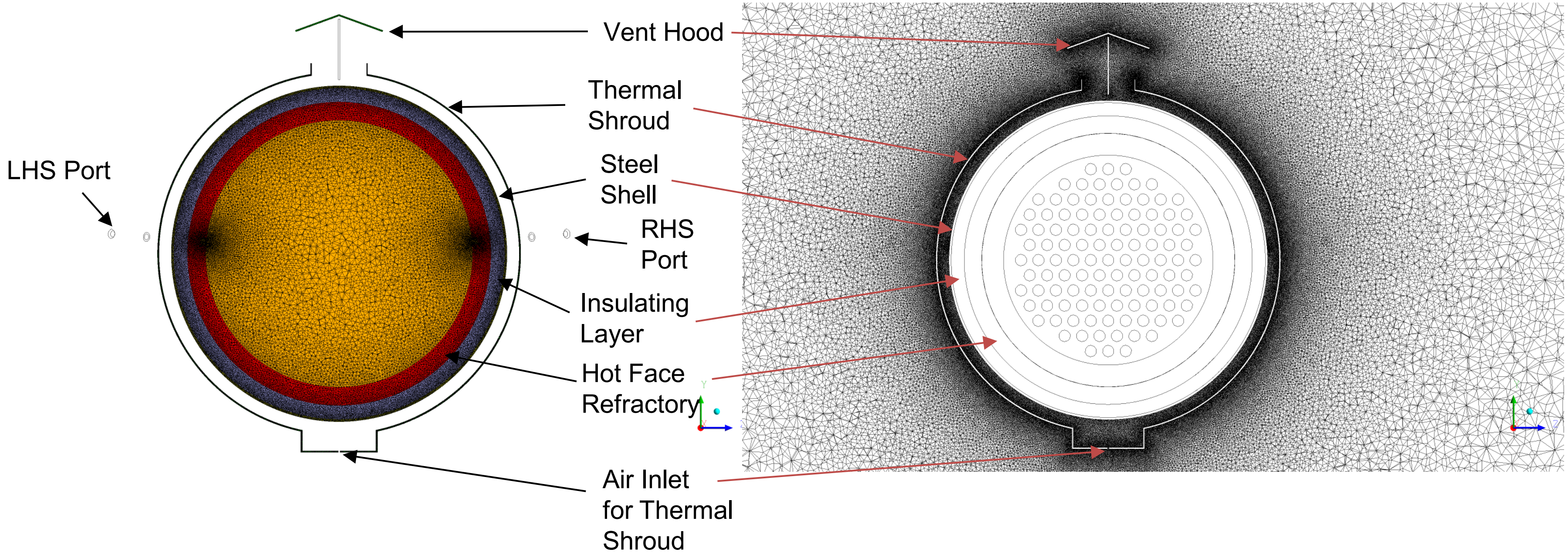
Air – high risk: fire in port, secondary combustion at end of port, ***must be replaced by nitrogen if system trips***

- This CFD study compares the use of nitrogen and air as port purge media at both 4 ft/s and 1 ft/s velocities in a 2” port.

Geometry

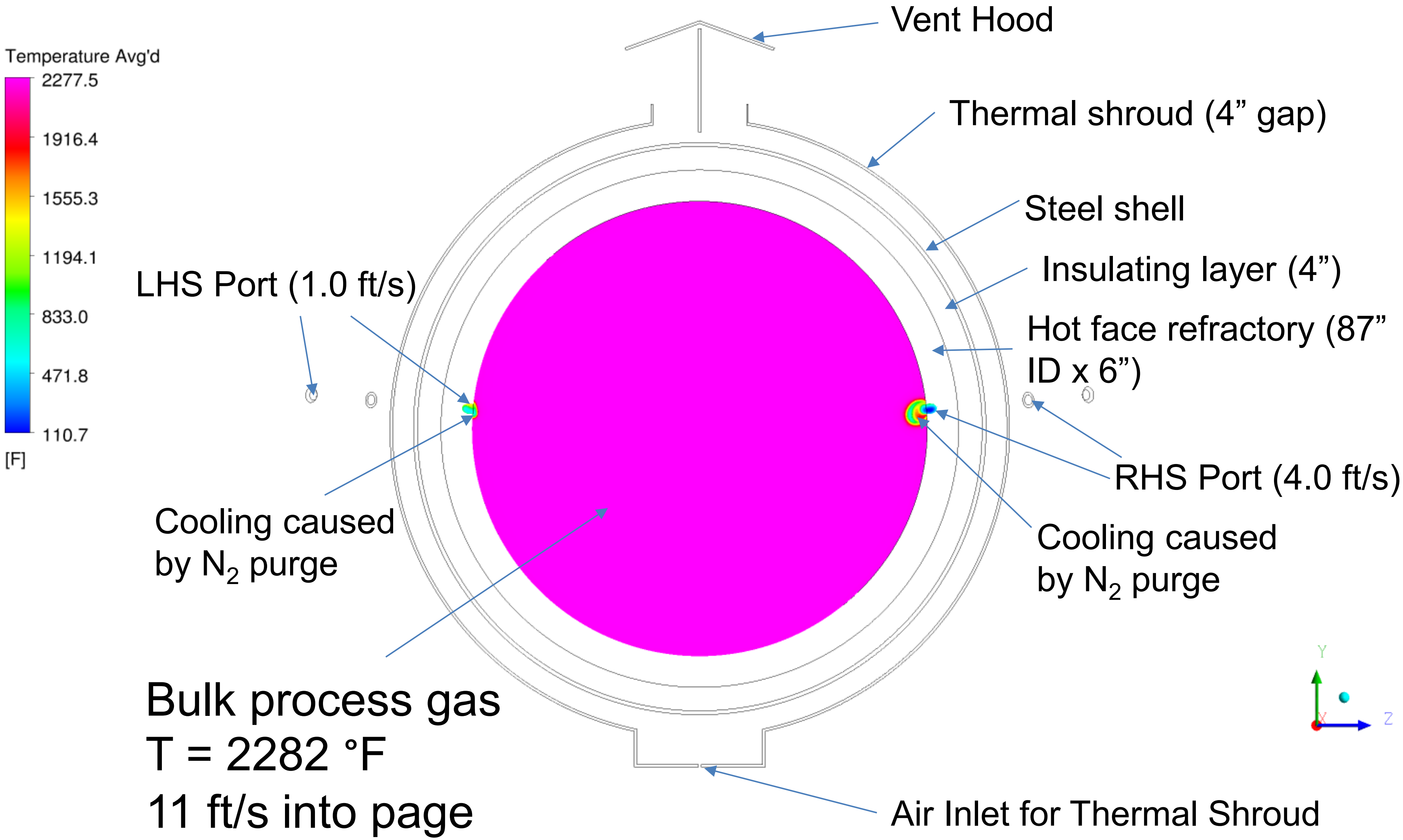

Vent Hood
RHS Port
System Outlet
LHS Port
Thermal Shroud
Air Inlet for
Thermal Shroud
RHS Port
System Outlet
Flow Direction
of Process Gas
LHS Port

Computational mesh

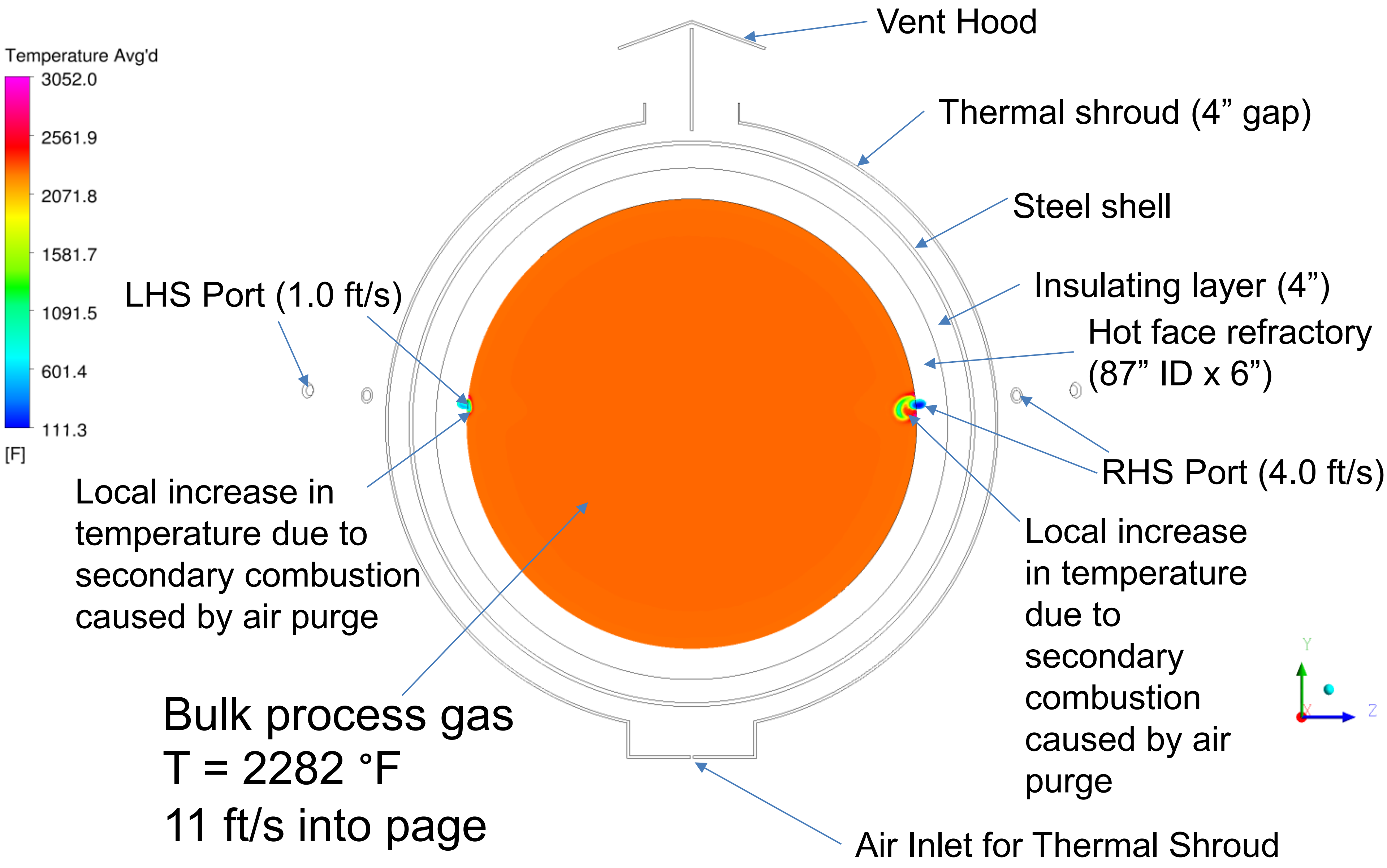


- Geometry is broken down into small pieces to be evaluated via CFD Simulation
- Just over 90 million volume elements total

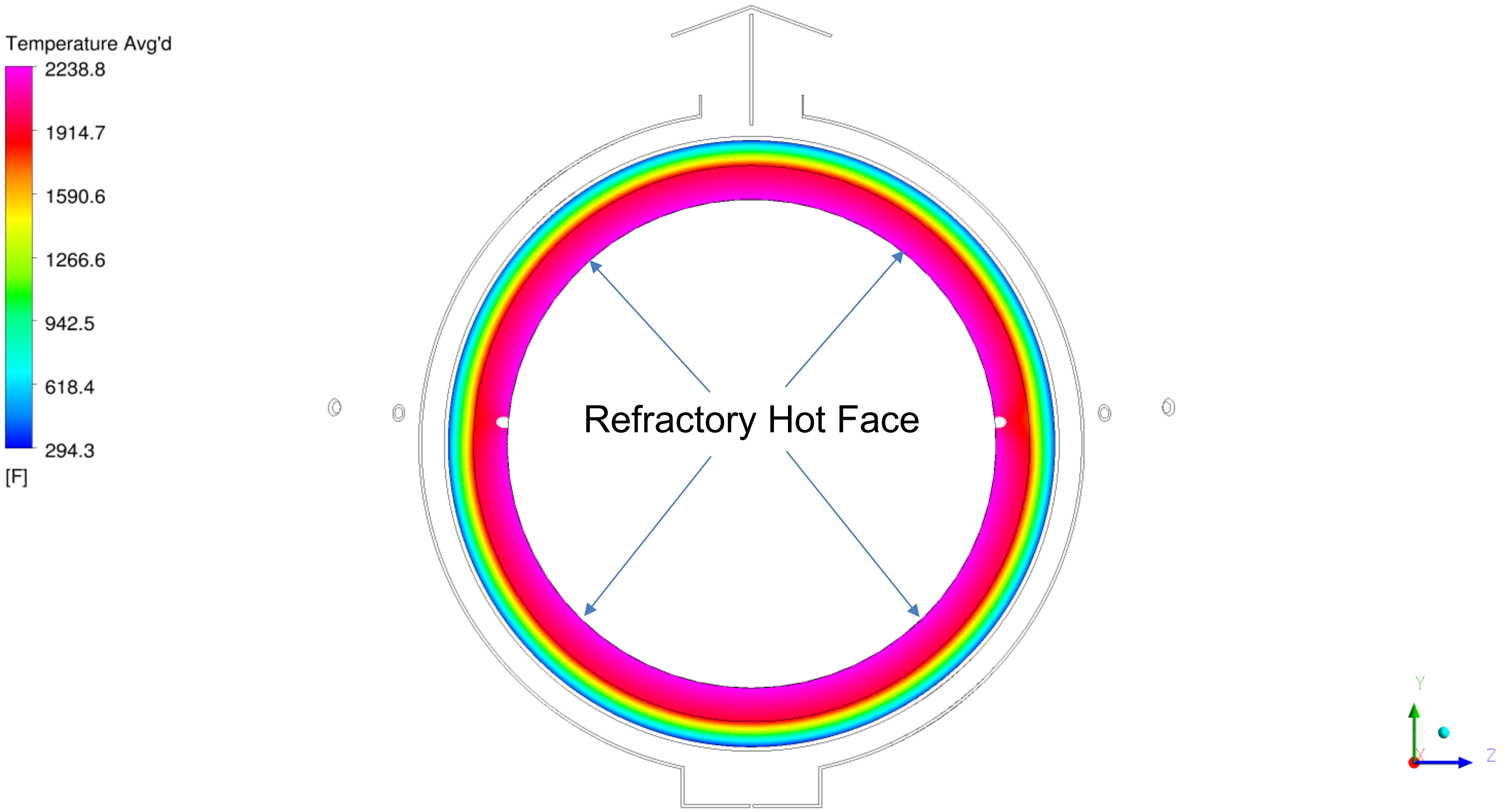
Process Gas Temperature (°F) – Nitrogen Purge Medium



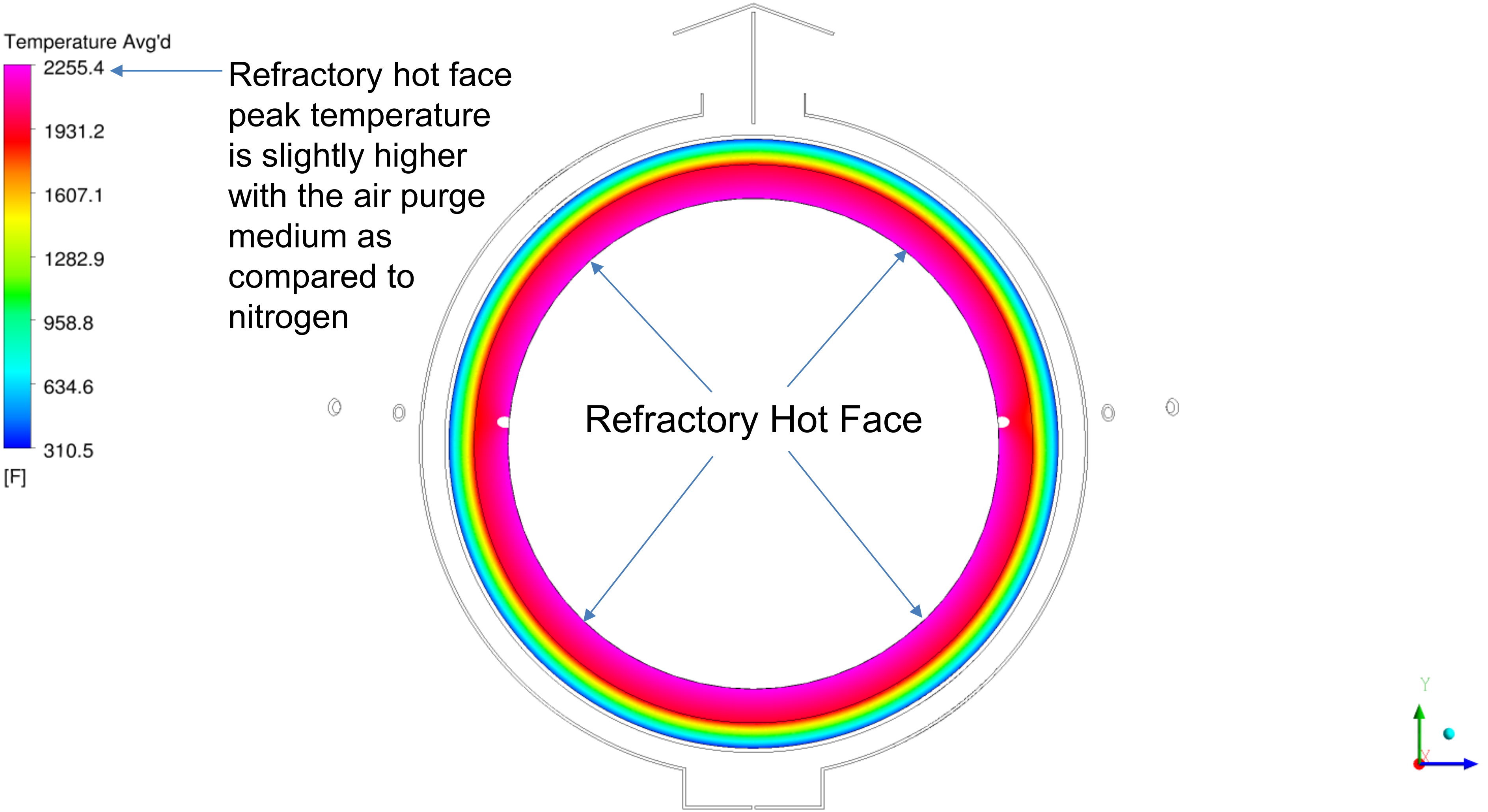
Process Gas Temperature (°F) – Air Purge Medium



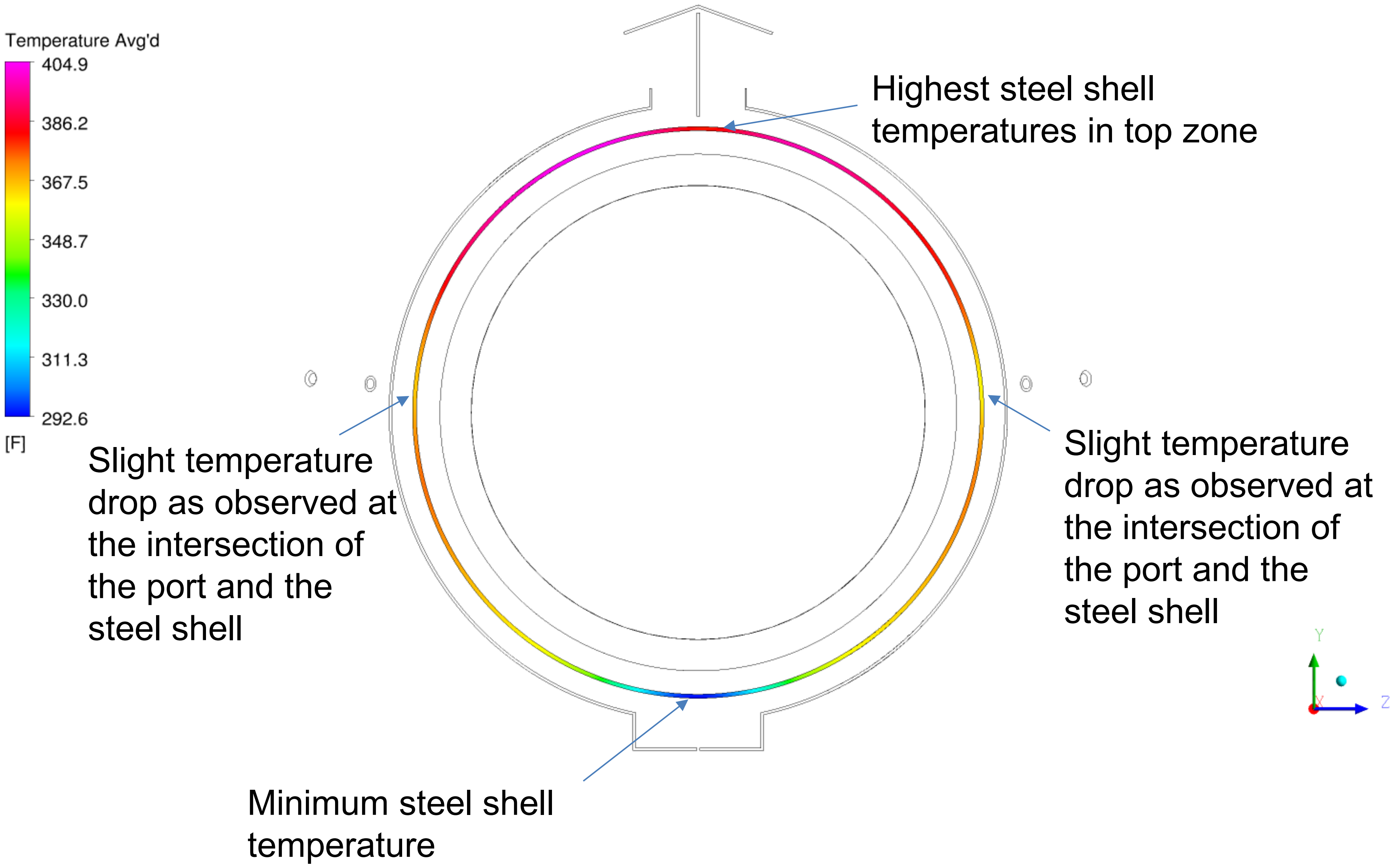
Refractory Hot Face Temperature (°F) – Nitrogen Purge Medium



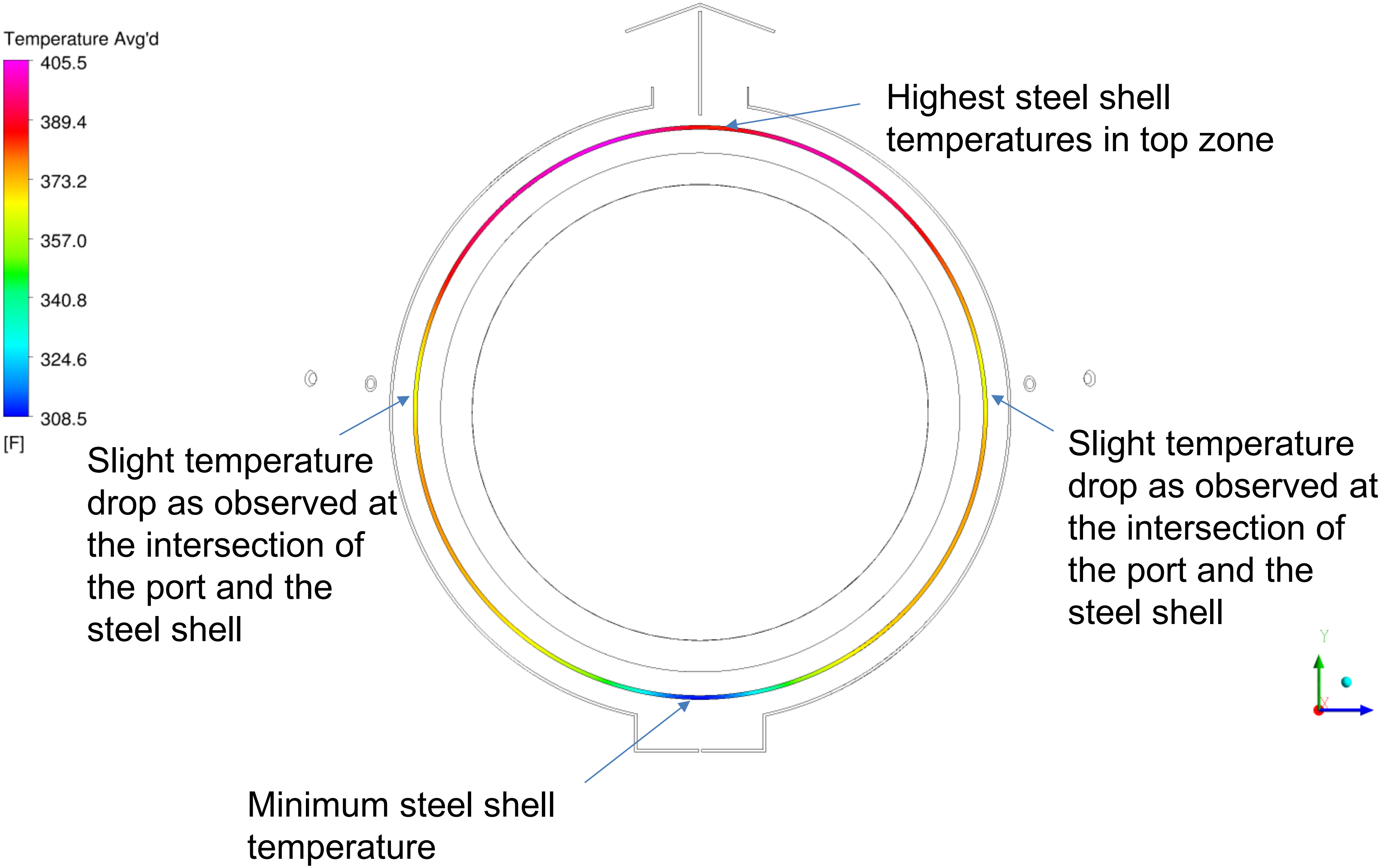
Refractory Hot Face Temperature (°F) – Air Purge Medium



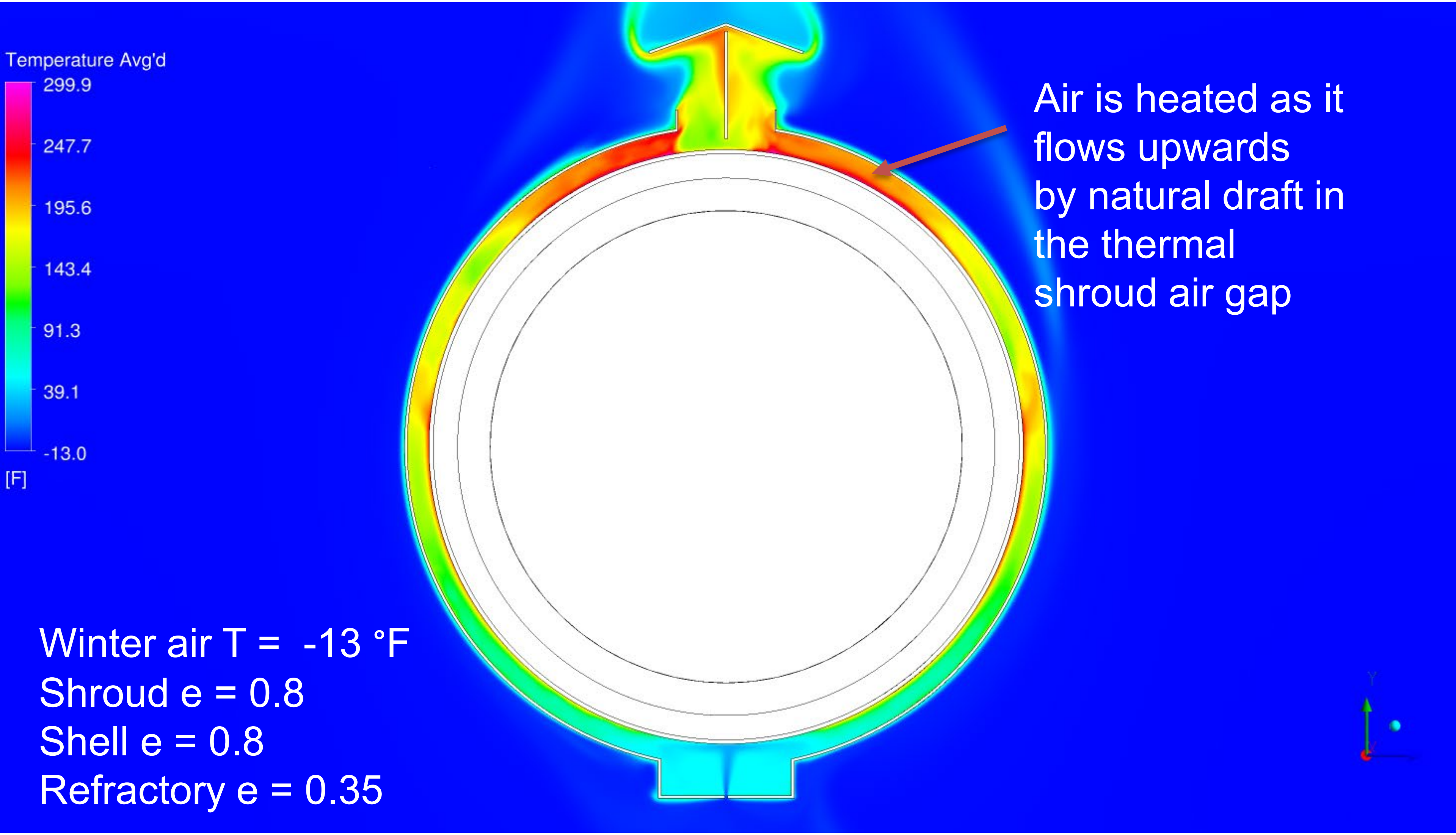
Steel Shell Temperature – Nitrogen Purge Medium



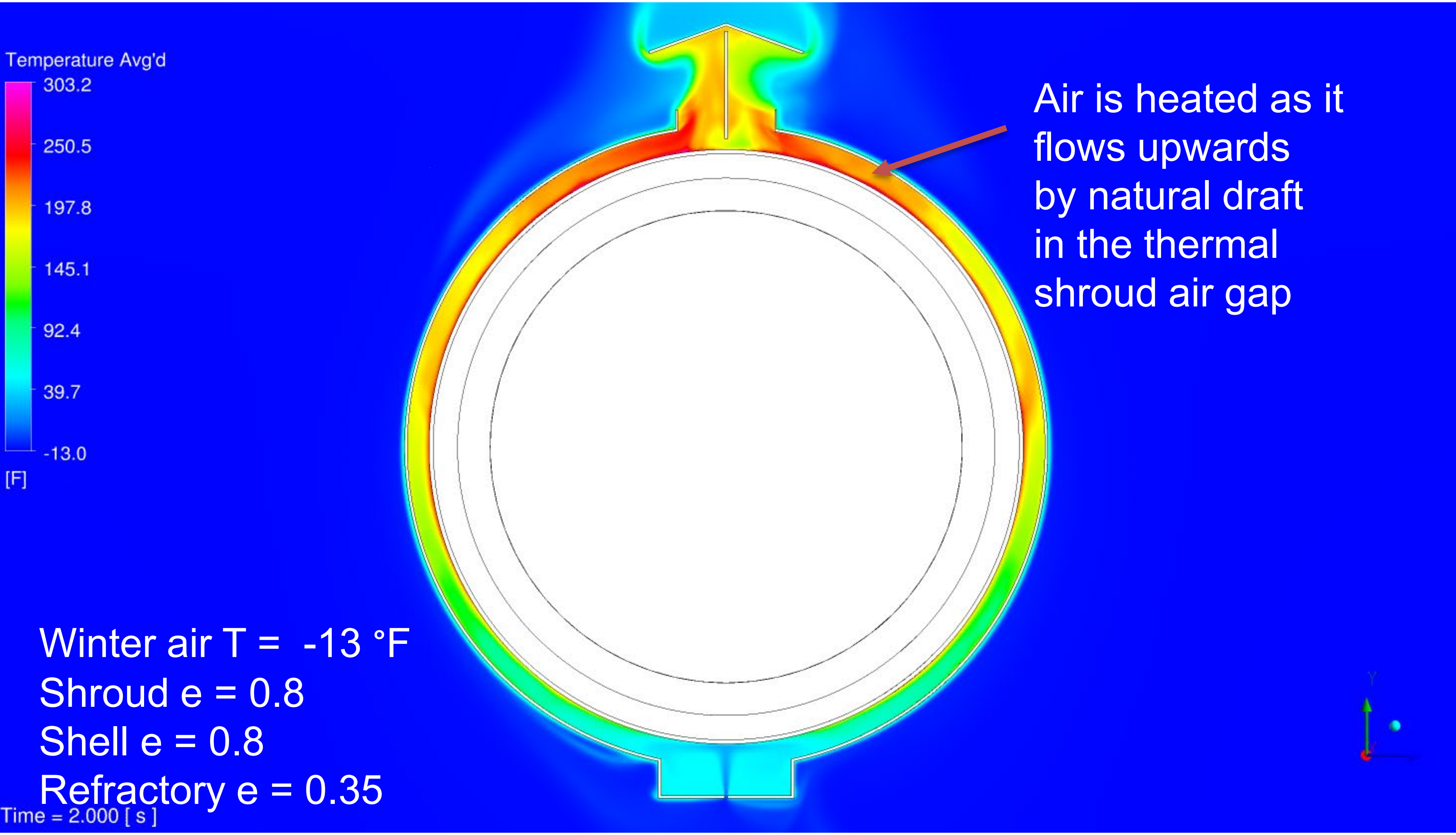
Steel Shell Temperature – Air Purge Medium



Air Temperature – Nitrogen Purge Medium



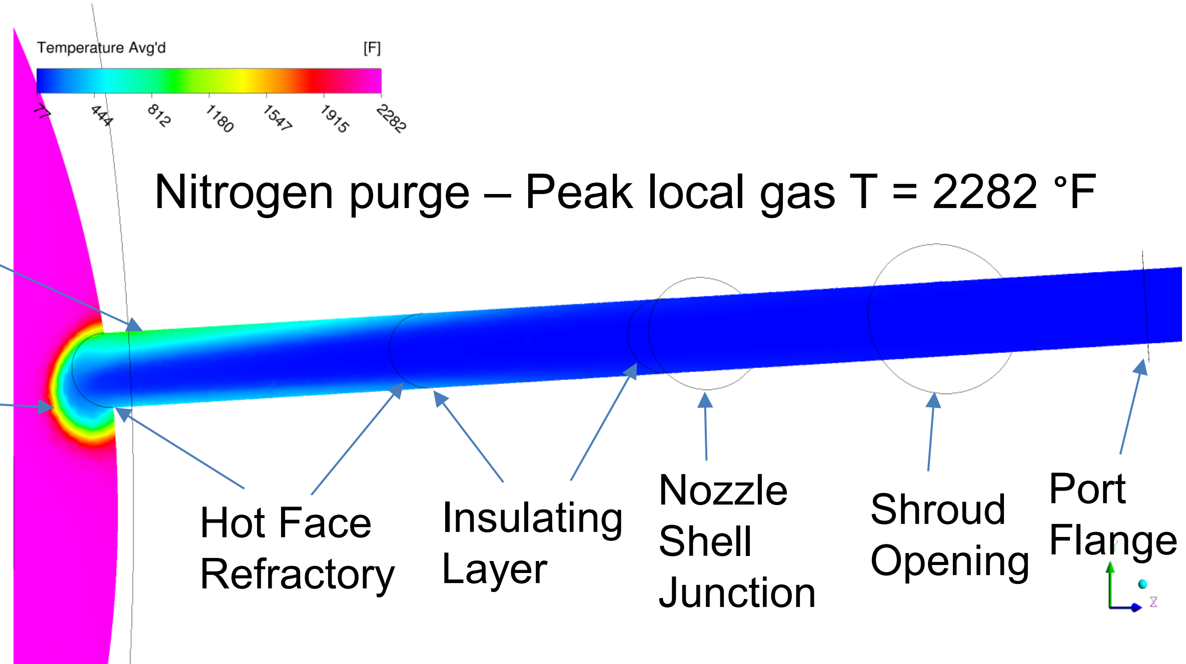
Air Temperature – Air Purge Medium

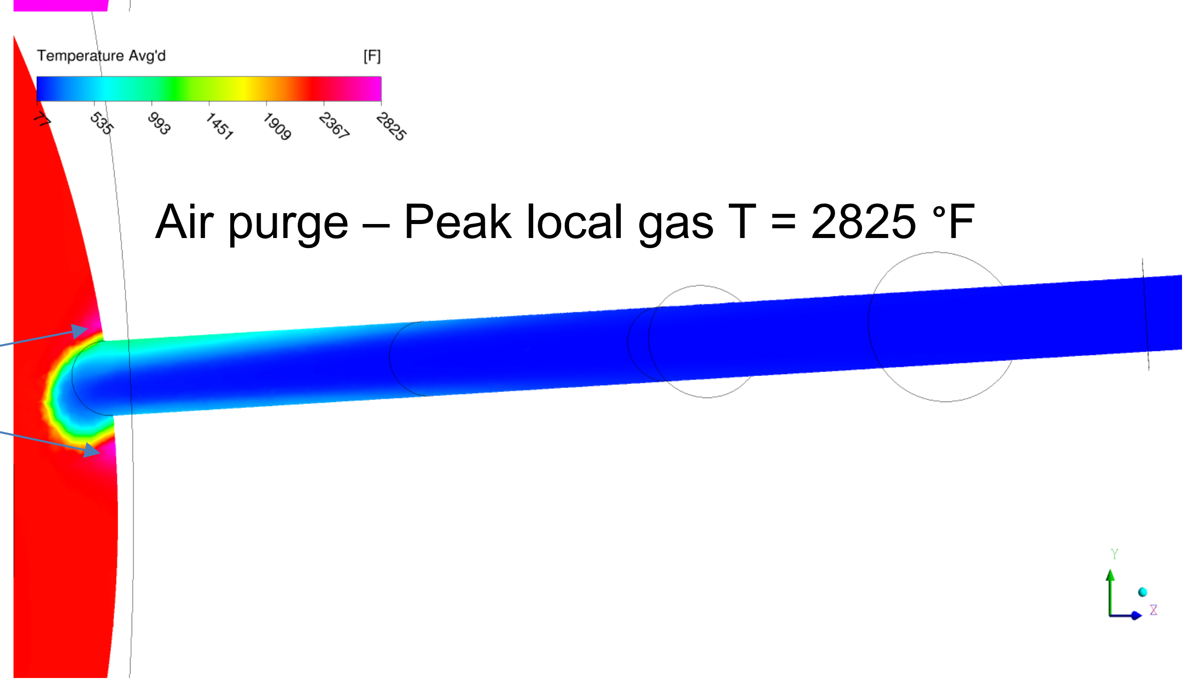


Peak Local Gas T – 4 ft/s

Purge gas heated by conduction/convection from refractory

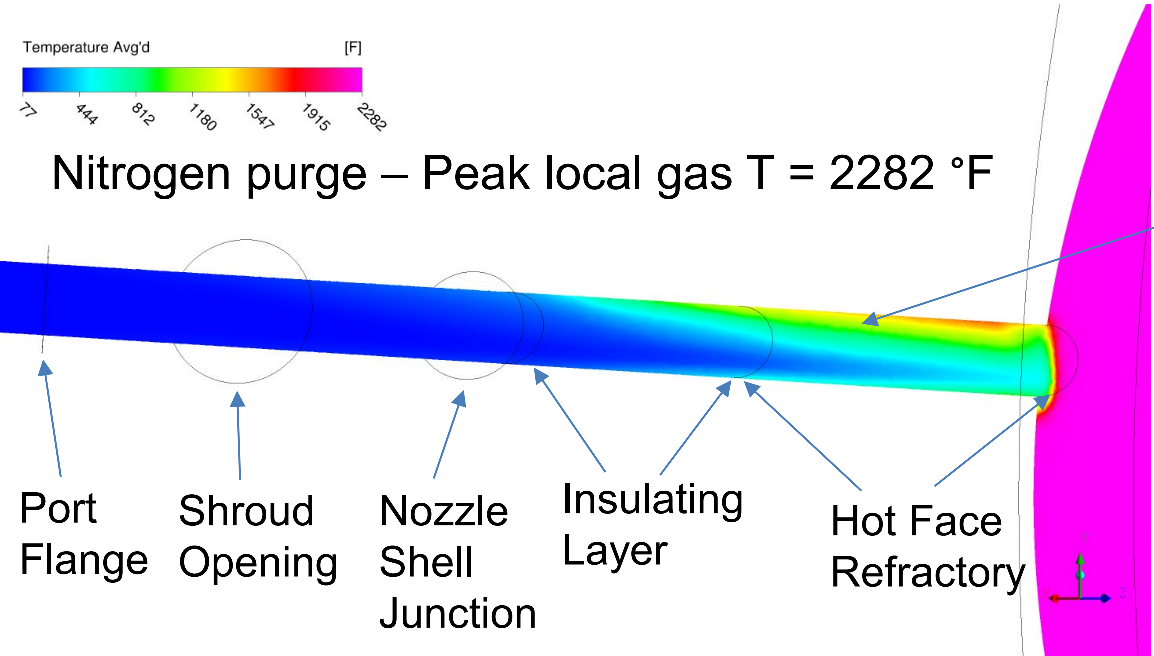
Slight cooling from nitrogen purge.



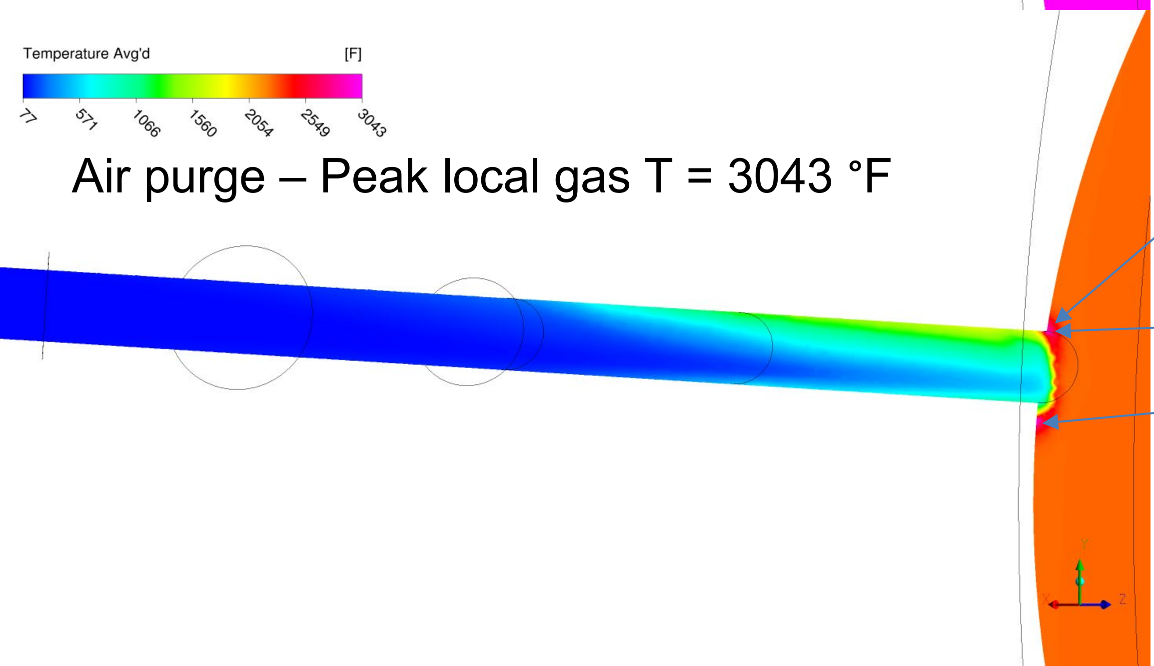


Hot gas impinging on refractory hot face due to secondary combustion from air purge.

Peak Local Gas T – 1 ft/s



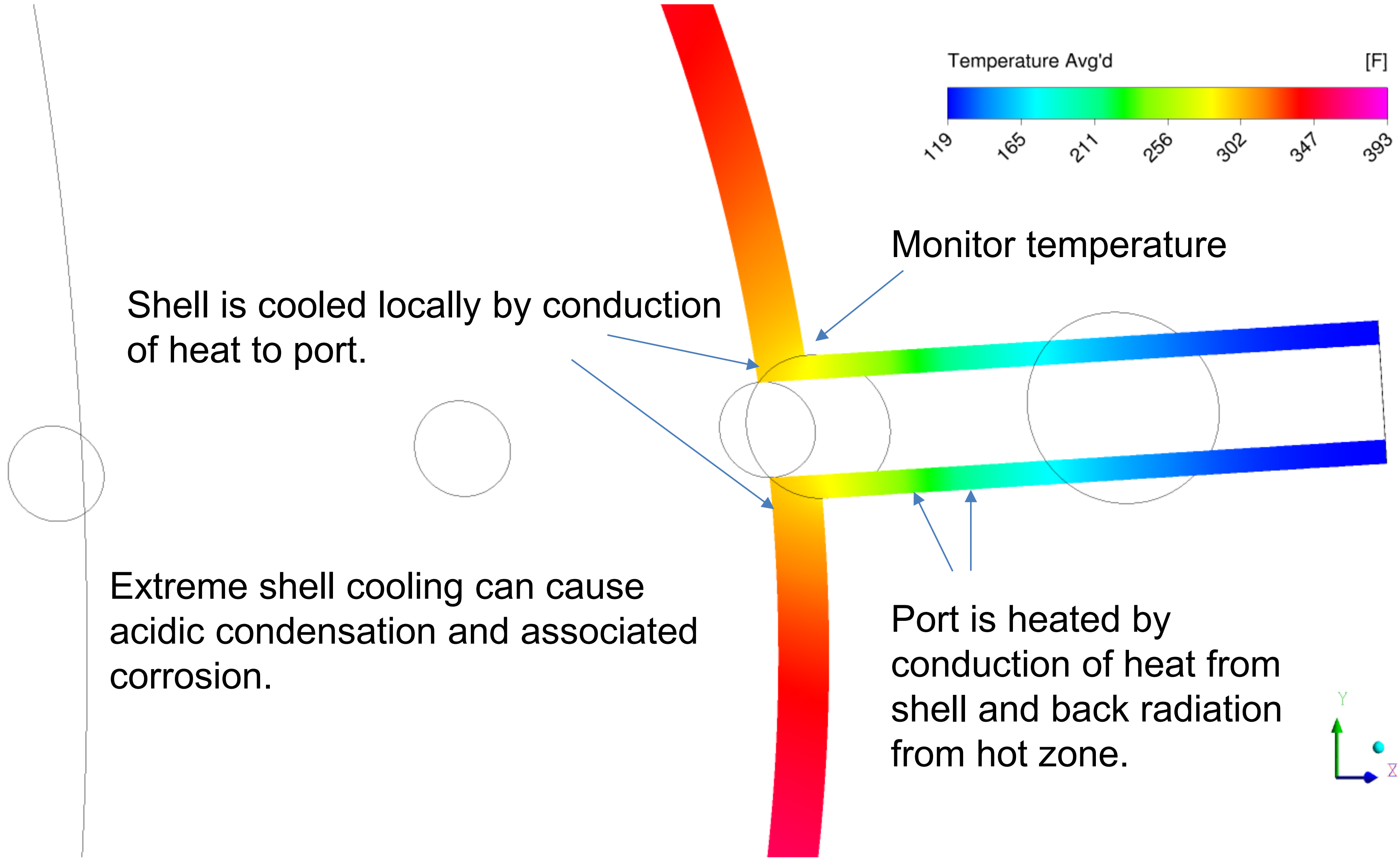
Purge gas heated by conduction/convection from refractory



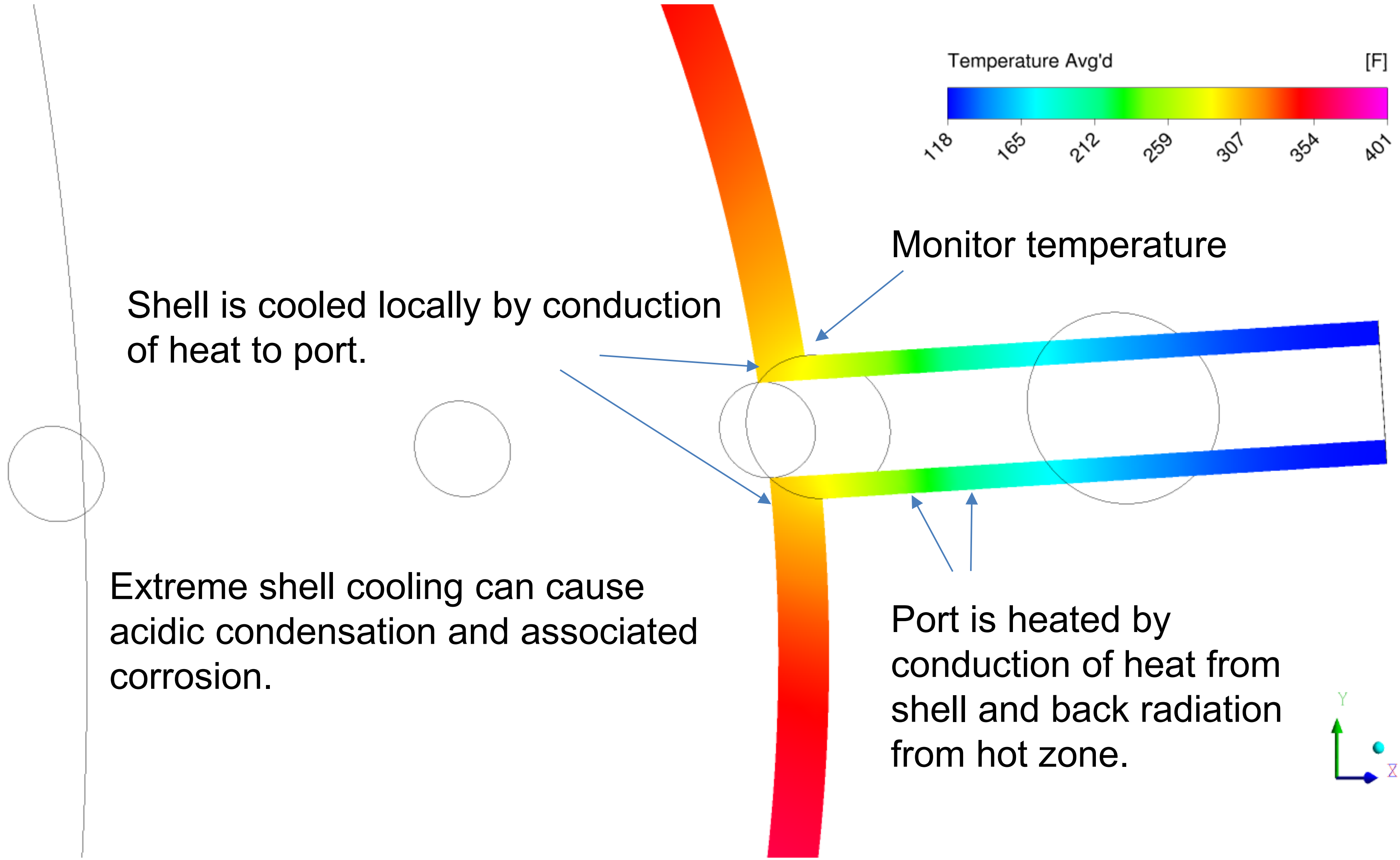
Higher gas temperatures at 1 ft/s purge velocity as compared with 4 ft/s.

Hot gas impinging on refractory hot face due to secondary combustion from air purge.

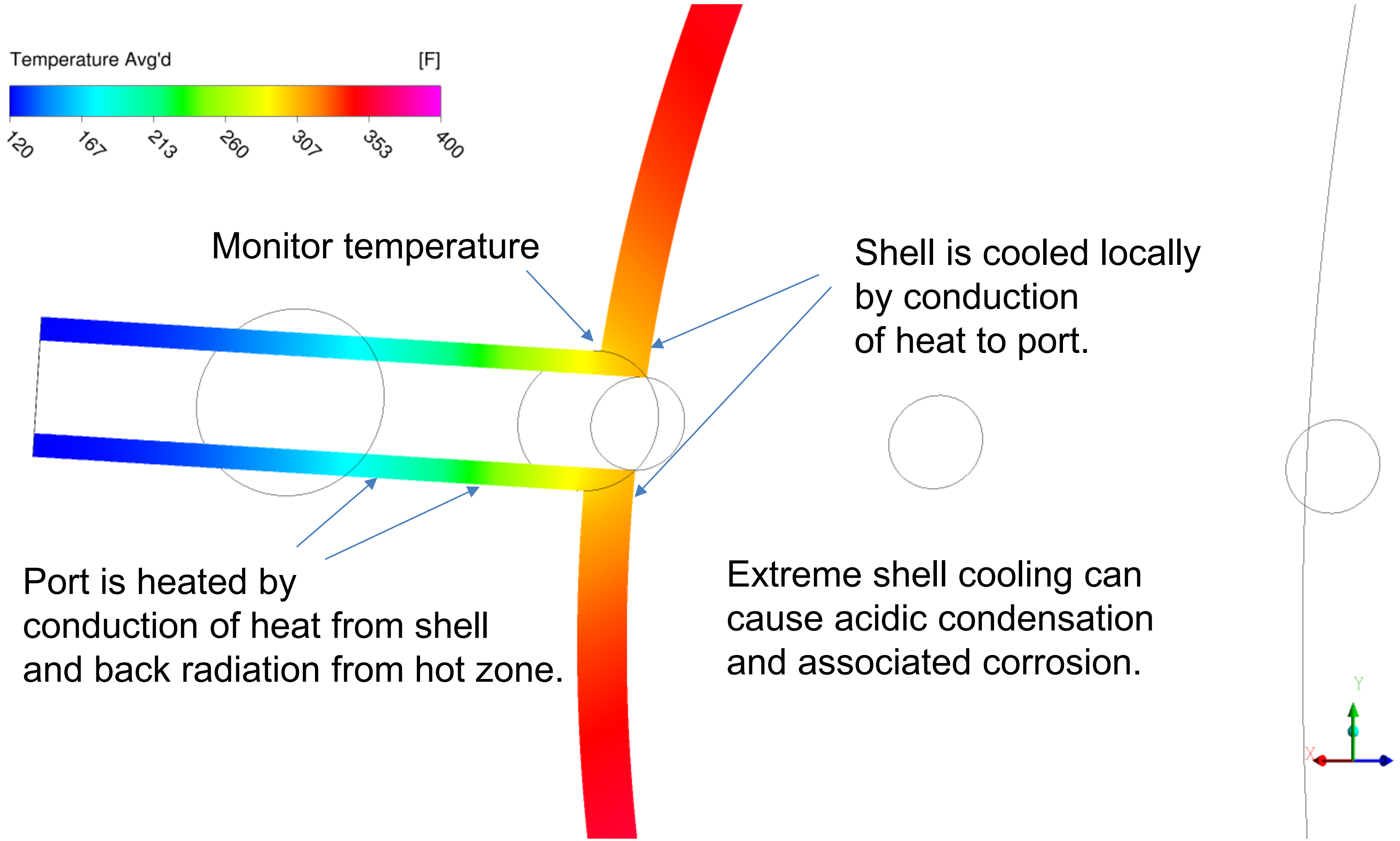
Shell & Port Steel T – Nitrogen Purge Medium (4 ft/s)



Shell & Port Steel T – Air Purge Medium (4 ft/s)



Shell & Port Steel T – Nitrogen Purge Medium (1 ft/s)



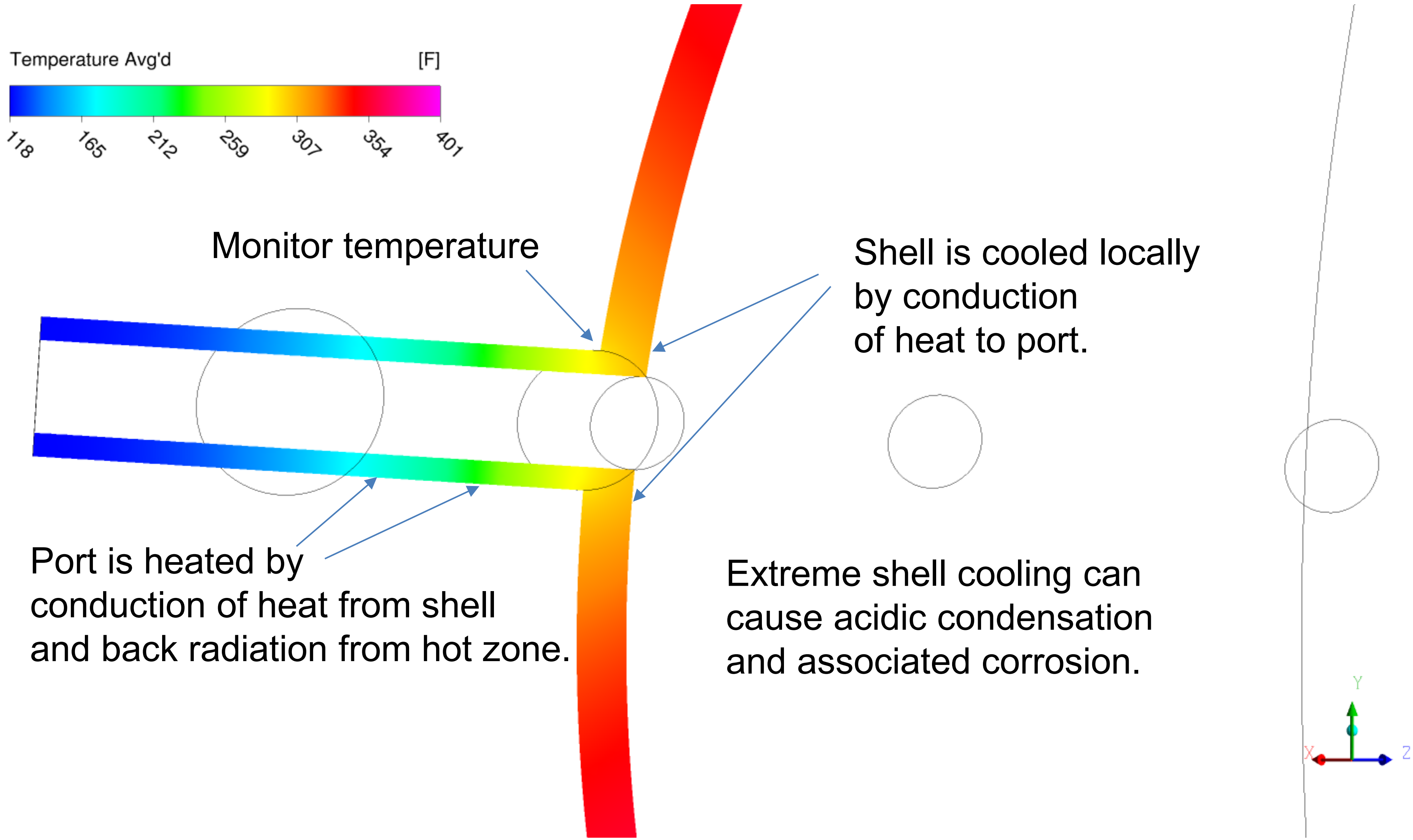
Monitor temperature

Shell is cooled locally by conduction of heat to port.

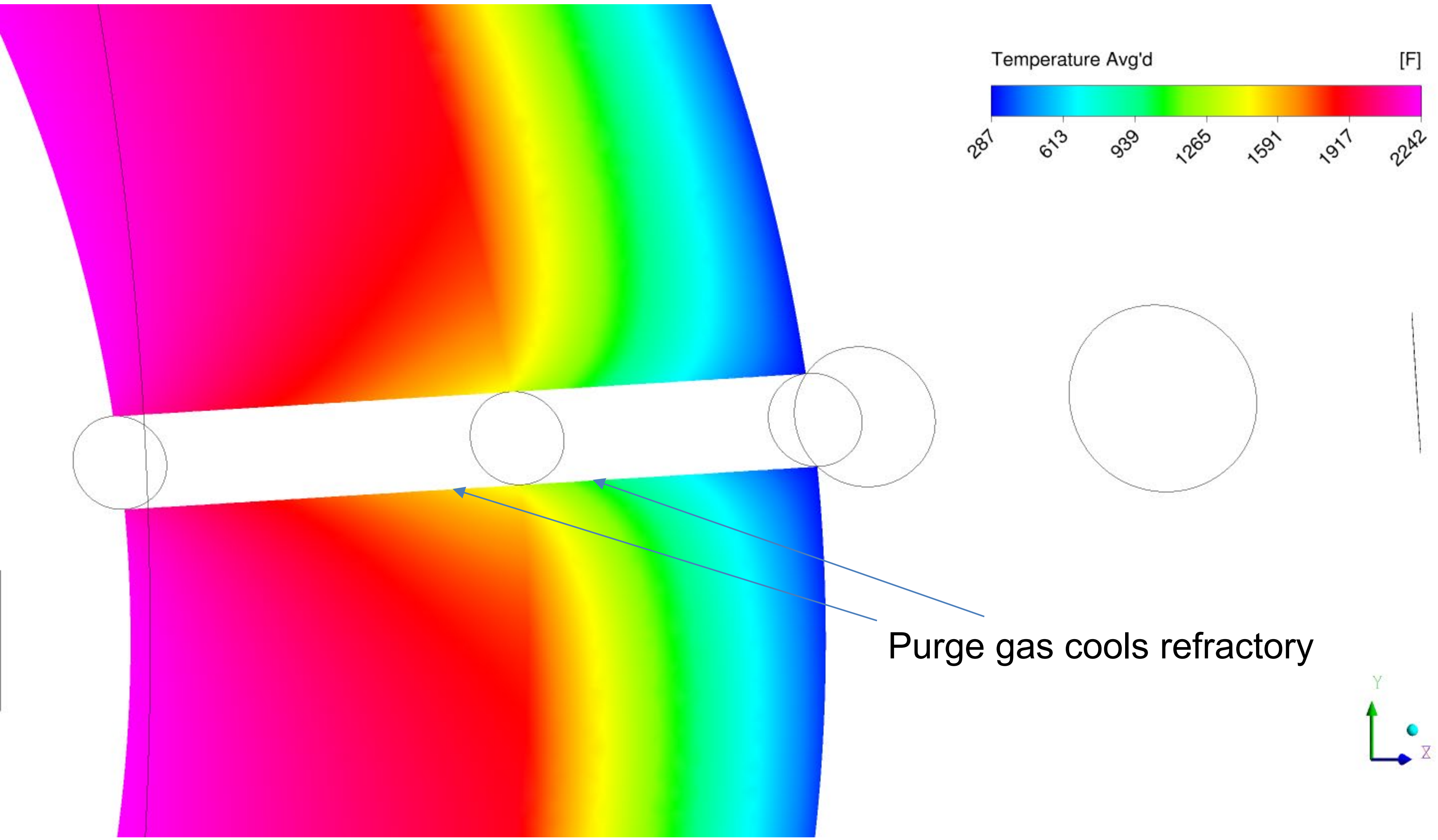
Port is heated by conduction of heat from shell and back radiation from hot zone.

Extreme shell cooling can cause acidic condensation and associated corrosion.

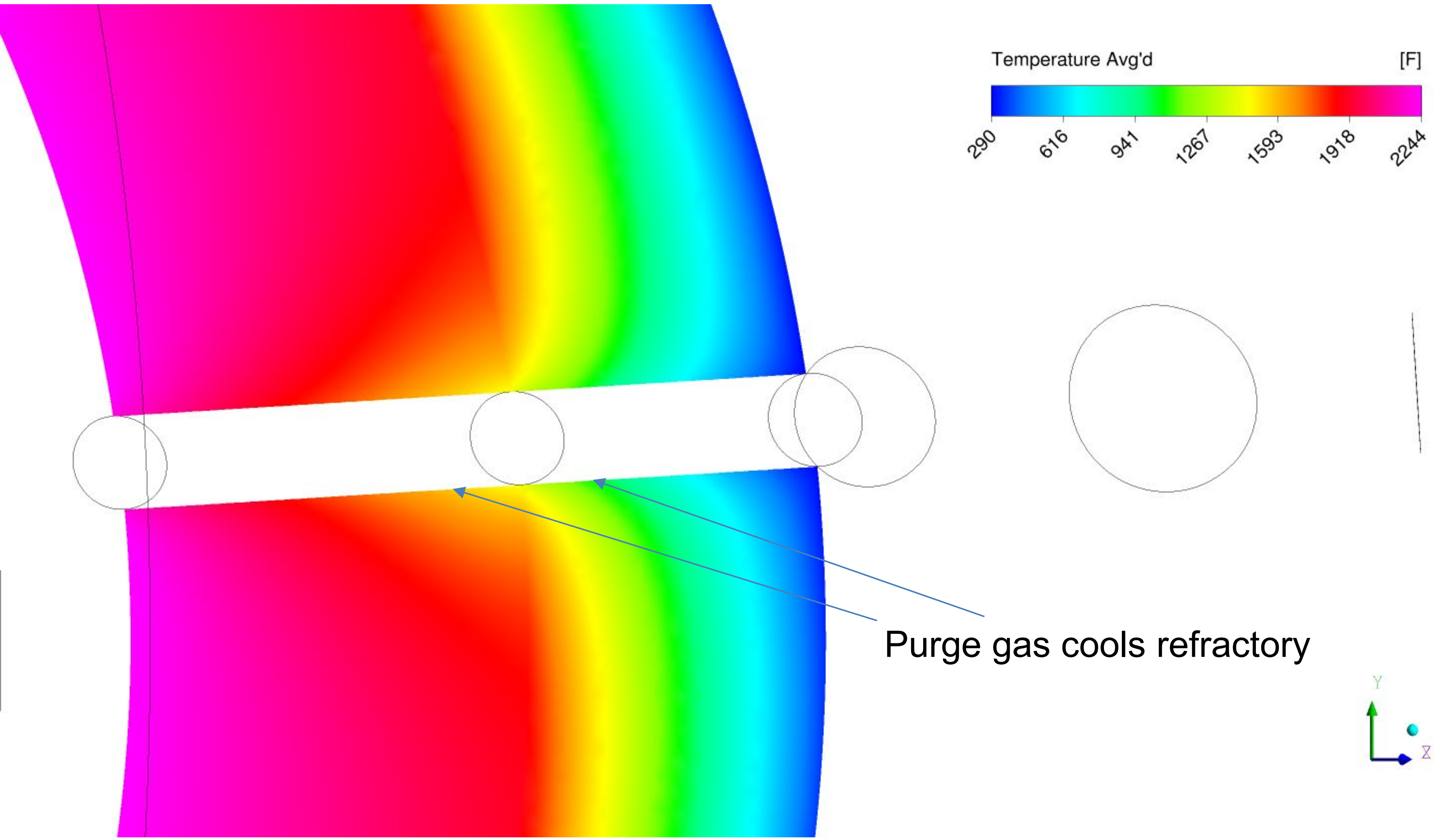
Shell & Port Steel T – Air Purge Medium (1 ft/s)



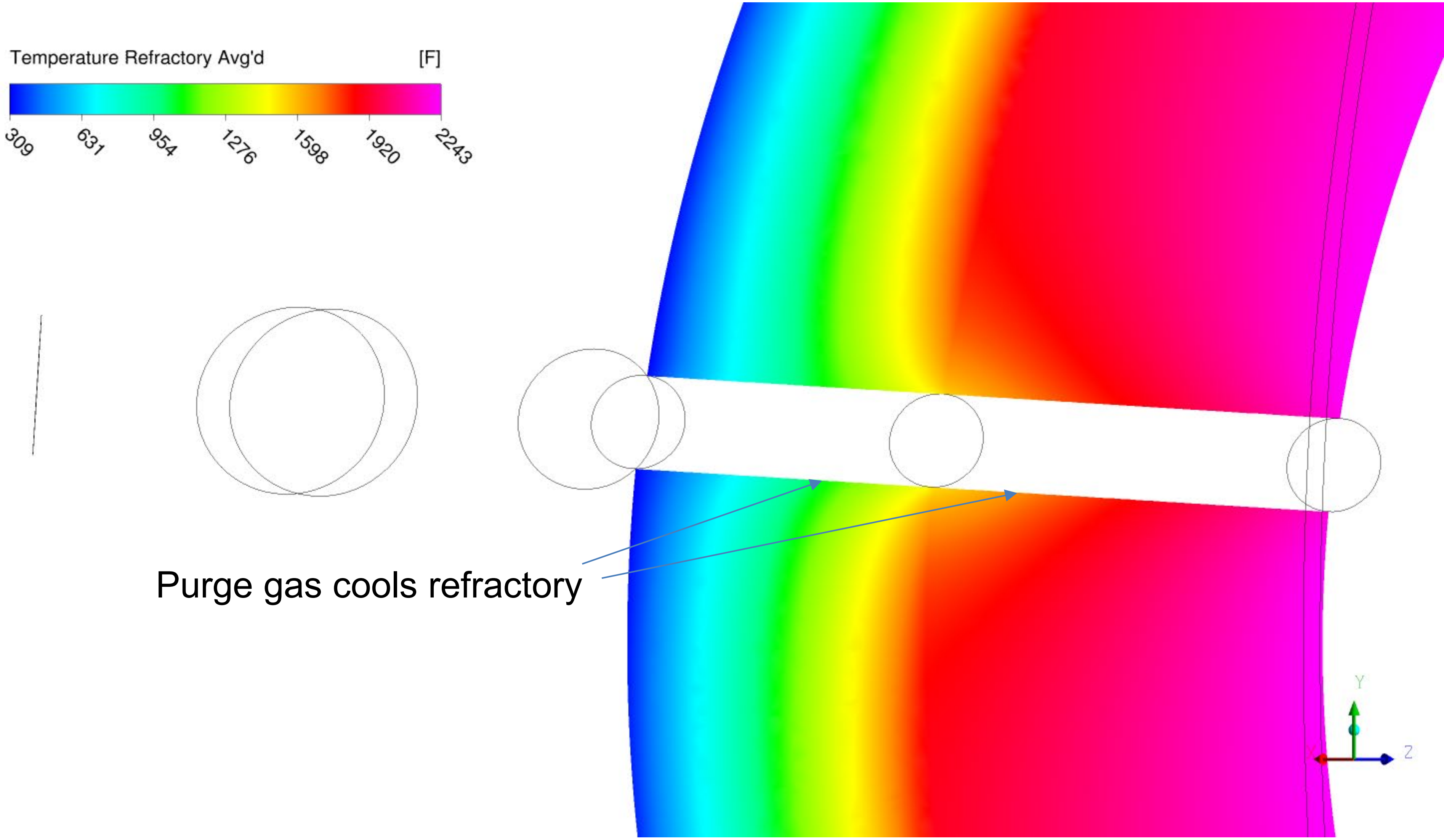
Refractory T – Nitrogen Purge Medium (4 ft/s)



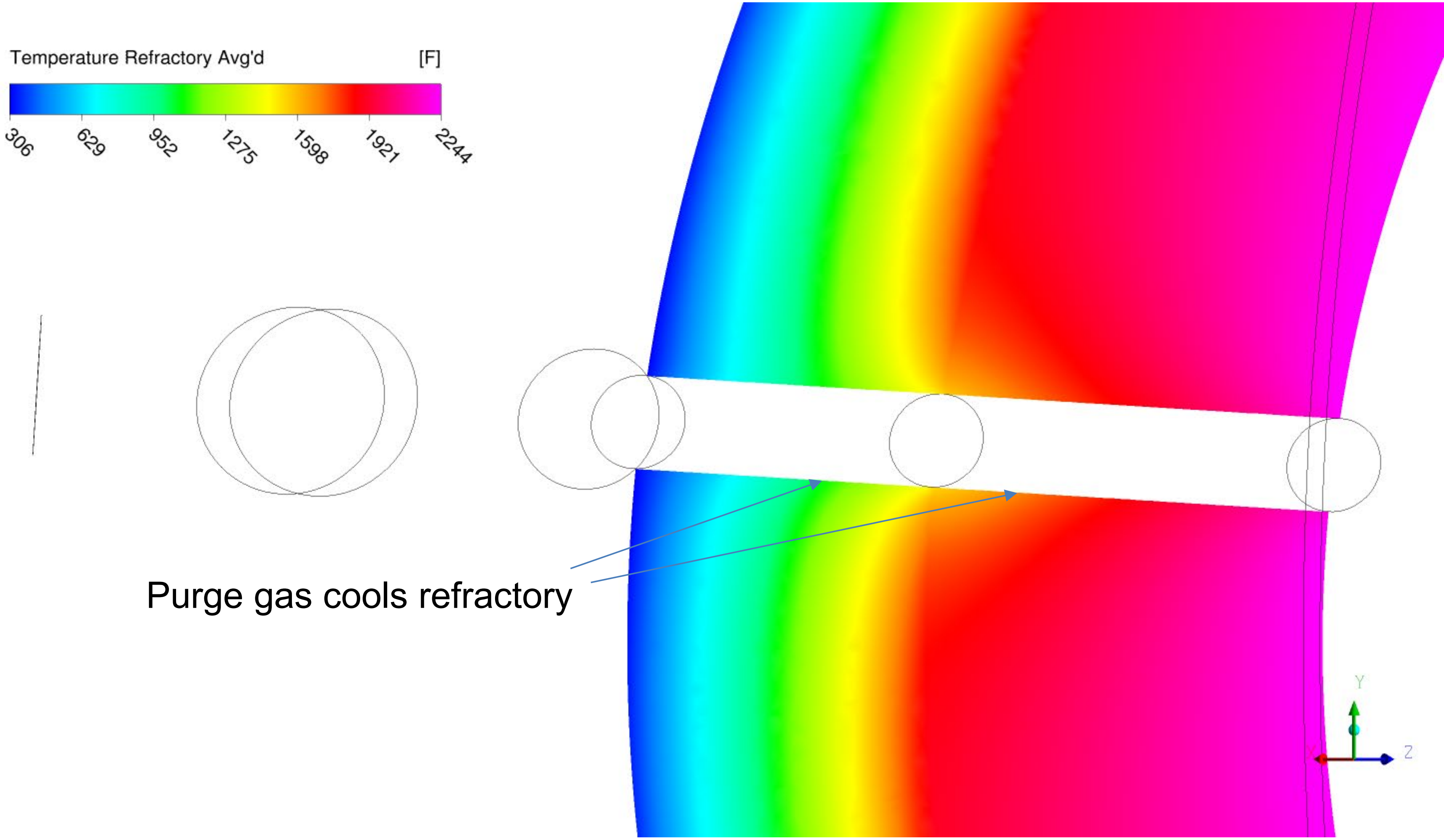
Refractory T – Air Purge Medium (4 ft/s)



Refractory T – Nitrogen Purge Medium (1 ft/s)

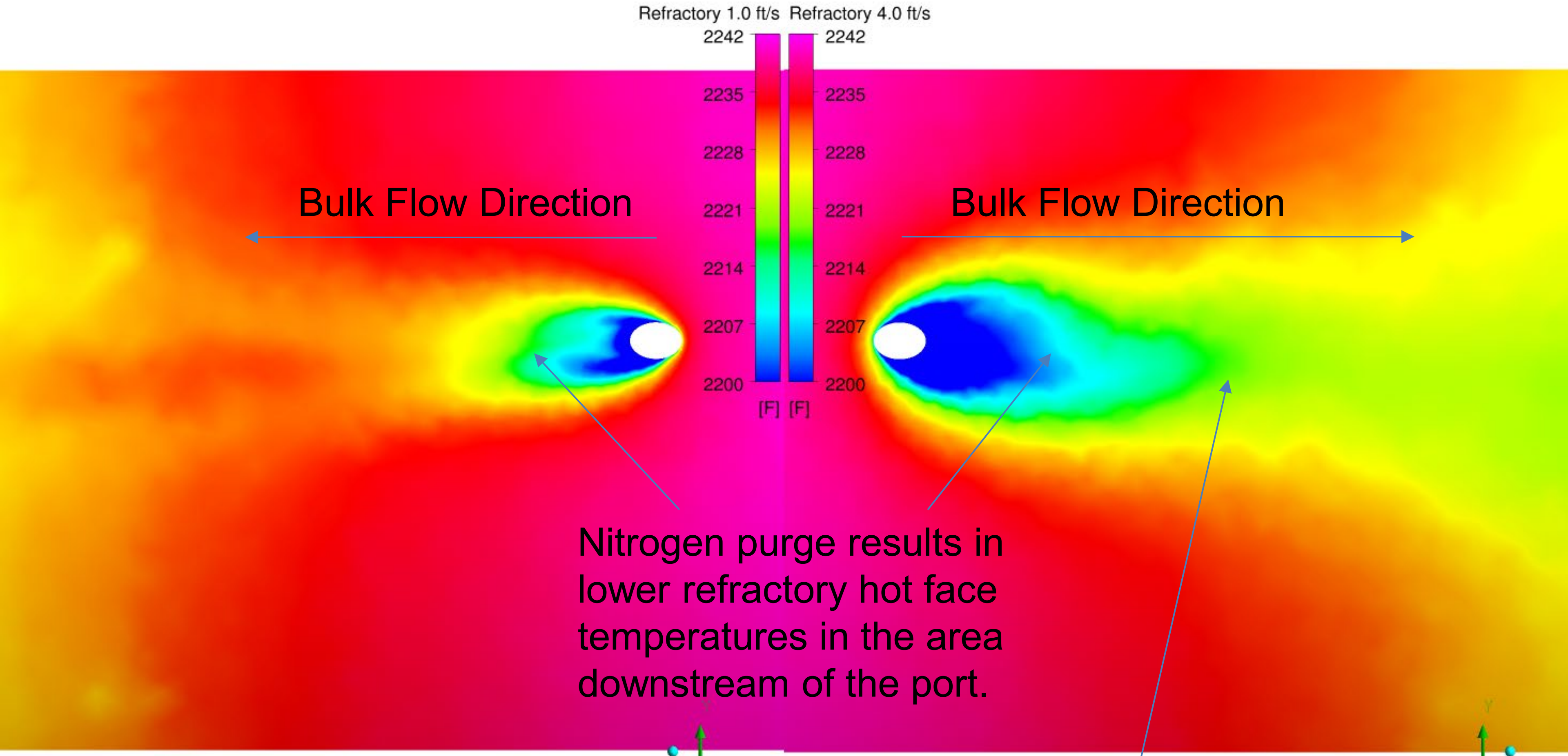


Refractory T – Air Purge Medium (1 ft/s)



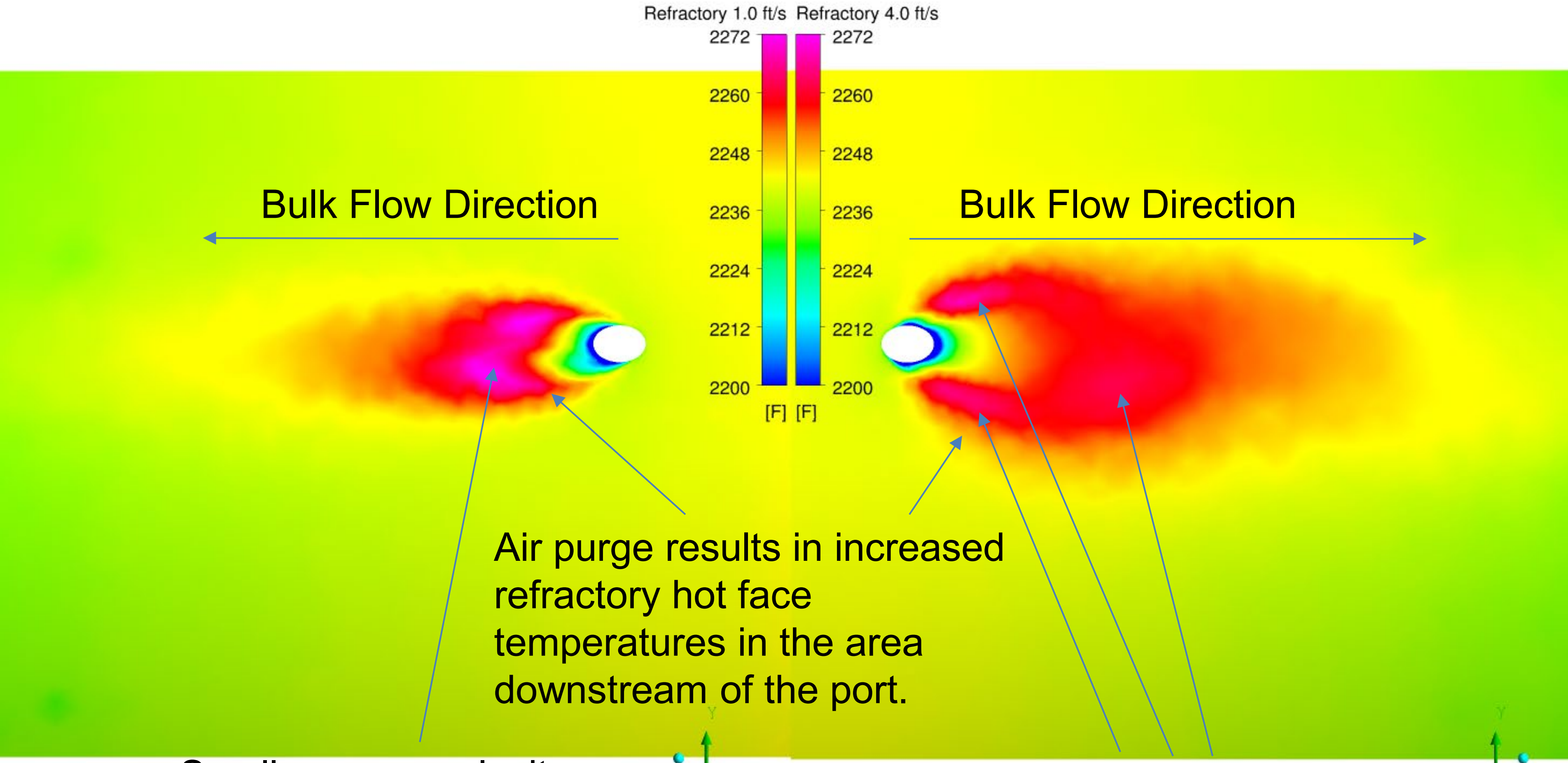
Purge gas cools refractory

Refractory Hot Face T – Nitrogen Purge Medium



Larger purge gas mass flow results in a greater area of the refractory hot face being cooled.

Refractory Hot Face T – Air Purge Medium



Smaller purge velocity results in more concentrated hot spots just downstream of the port.

Larger purge velocity results in smaller hot spots distributed over a larger area.

Summary

	Nitrogen 4 ft/s	Nitrogen 1 ft/s	Air 4 ft/s	Air 1 ft/s
Peak Local Gas T (°F)	2282	2282	2825	3043
Peak Local Refractory Hot Face T (°F)	2242	2242	~2260	2272
Cooling Effect on Nozzle/Shell Junction	Highest	Lower	High	Lower
Cooling Effect Through Refractory	Highest	Low	High	Lowest

These results pertain to idealized system simulations and are intended only to illustrate qualitative trends.

Summary

- Specific simulation showed a local refractory hot face temperature increase downstream of the port when using air as a purge medium, and a local refractory hot face temperature decrease when using nitrogen as a purge medium.
- Higher purge rates keep ports cooler.
- Secondary combustion from air purge causes higher local refractory temperature.
- For these specific simulations, the secondary combustion associated with the use of air as the purge medium did not indicate unacceptably high refractory temperatures. However, depending on the conditions, it could lead to much higher local refractory temperatures.

Recommendations

- Purging with nitrogen removes the risks associated with secondary combustion when purging with air.
- If air is used for purging nozzles going through refractory, the local refractory should be inspected for any signs of overheating that may be caused by secondary combustion.
- Frequently monitor the temperature of the nozzle/shell junction area to ensure the steel temperature lies within the acceptable range for avoiding acidic condensation or overheating.
- The flow to each purge connection should be individually metered using a dedicated flow meter. This allows for quick visual verification of the flow rate to each point. ***Low air purge rates can result in secondary combustion of reaction furnace gas within the steel port nozzles and cause thermal failure.***