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ANALYSIS OF COOLING SYSTEM FOR SPENT NUCLEAR FUEL CASK

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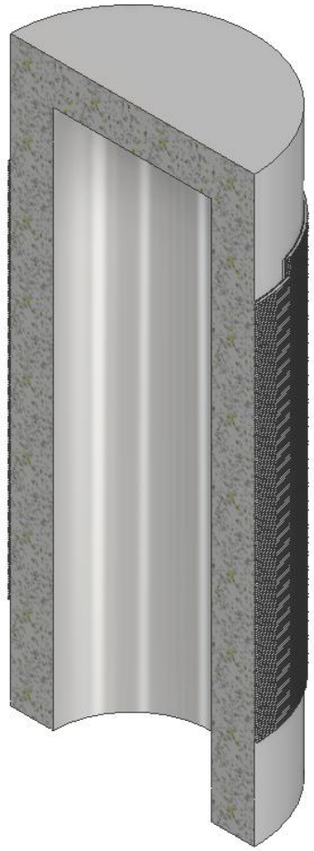
Introduction

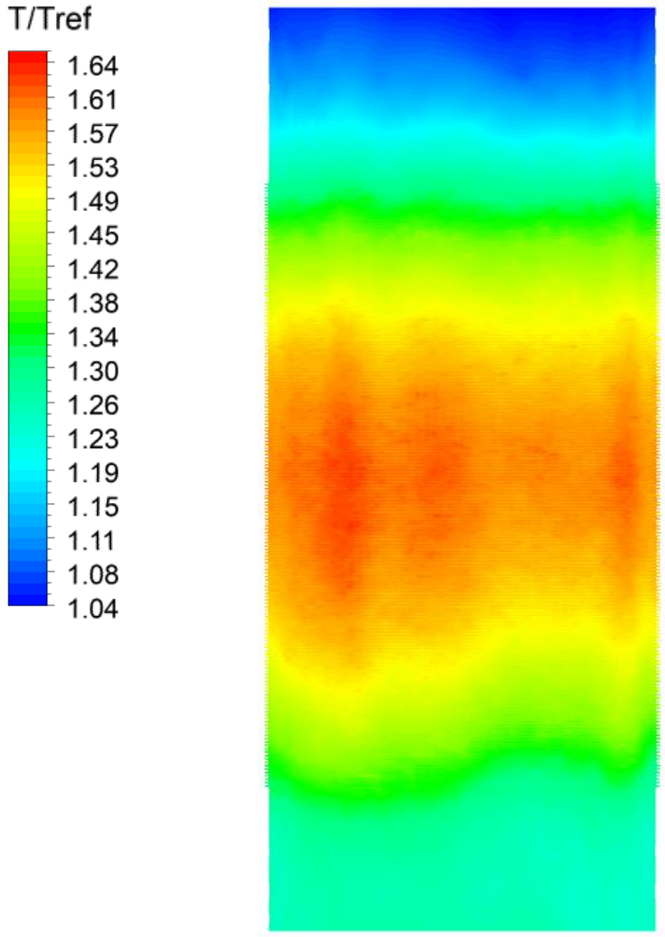
Objective:

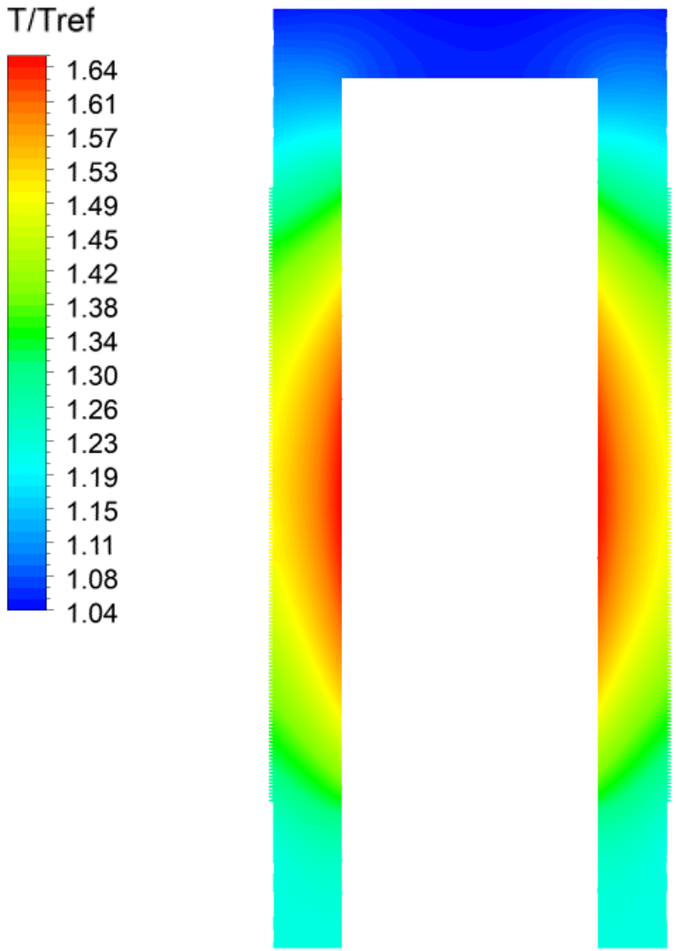
- **Cool down the spent nuclear fuel cask below T_{ref}**
- **Use ambient air with defined temperature as the cooling medium**
- **Easy-to-use and cheap cooling system**

Natural convection (validation) → **Cooling system with tangential air inlet** → **Cooling system with direct air inlet**



Natural convection

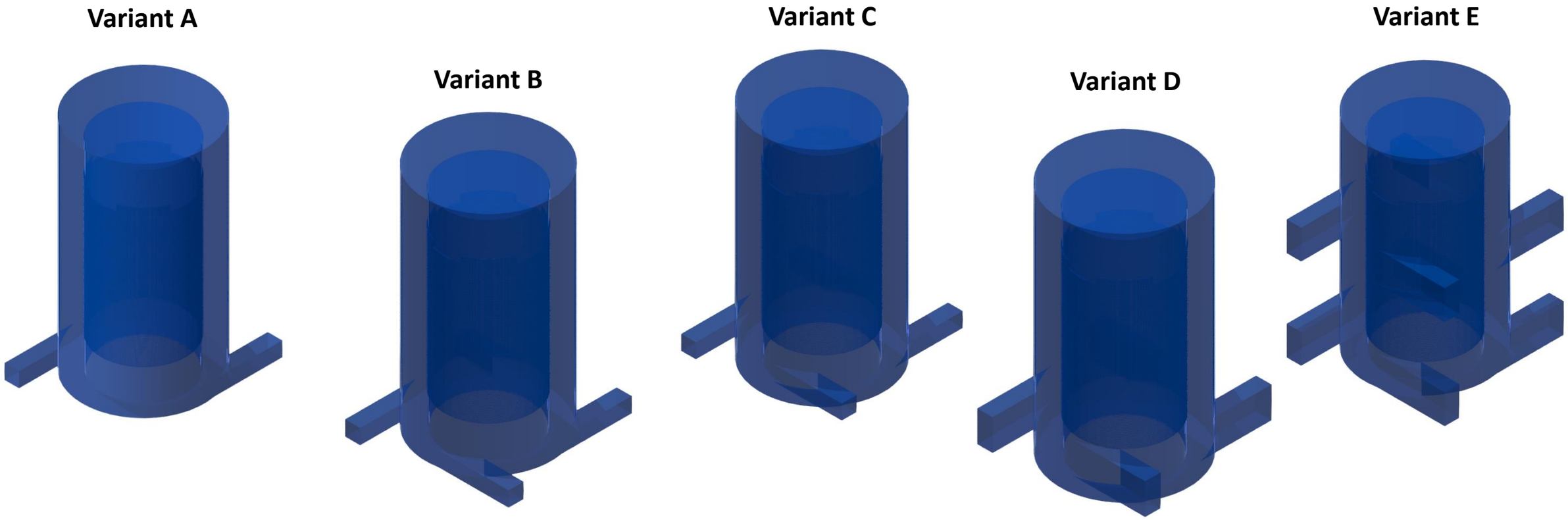




Validation

- **Ideal gas**
- **Reference pressure**
- **Turbulence SST k-ω model with 5% turbulence intensity at the inlet**
- **Gravitation**
- **Thermal radiation**
- **Definition of boundary condition including proper heat source definition**

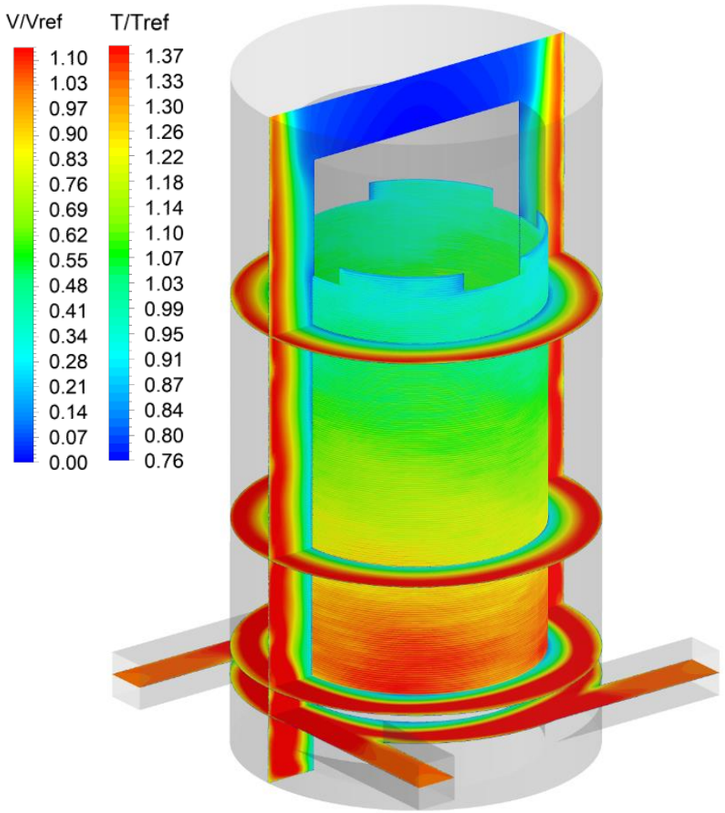
Forced convection – tangential air inlet



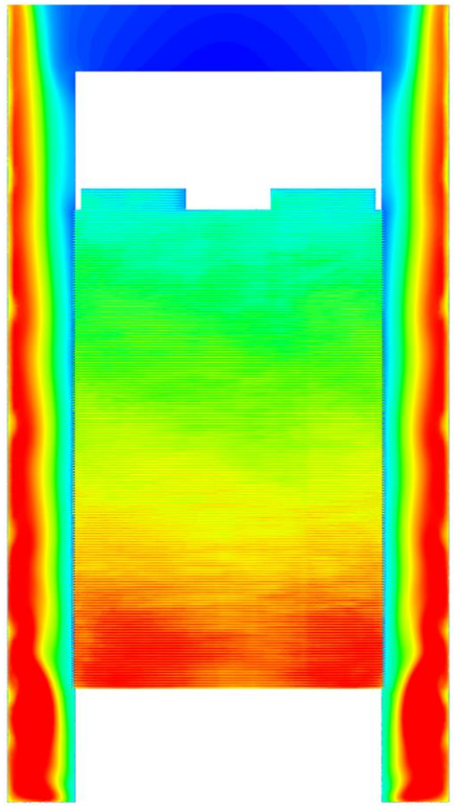
- **Variant A:** 2 tangential square inlets
- **Variant B:** 4 tangential square inlets
- **Variant C:** 4 tangential square inlets closer to the cooling fins
- **Variant D:** 4 tangential rectangular inlets closer to the cooling fins
- **Variant E:** 4 tangential rectangular inlets closer to the cooling fins + 4 tangential rectangular inlets in the upper part of the cask

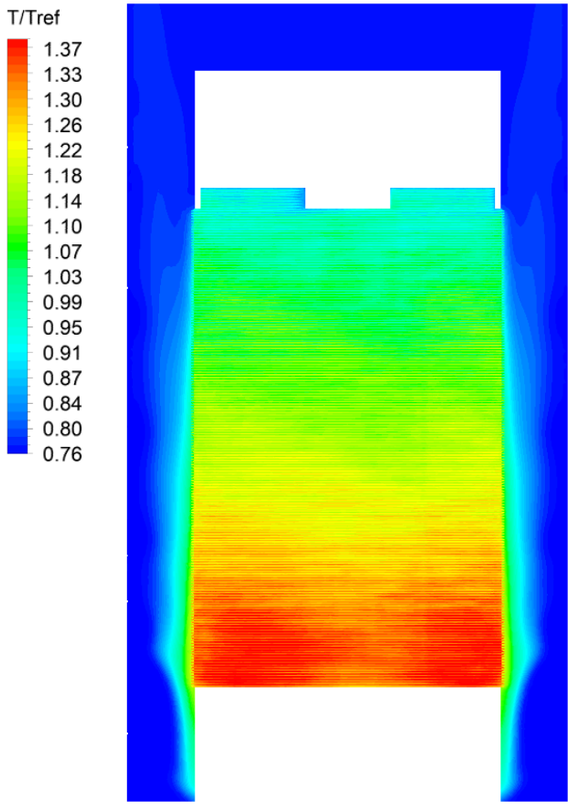
Forced convection – Variant B

Velocity field & temperature field

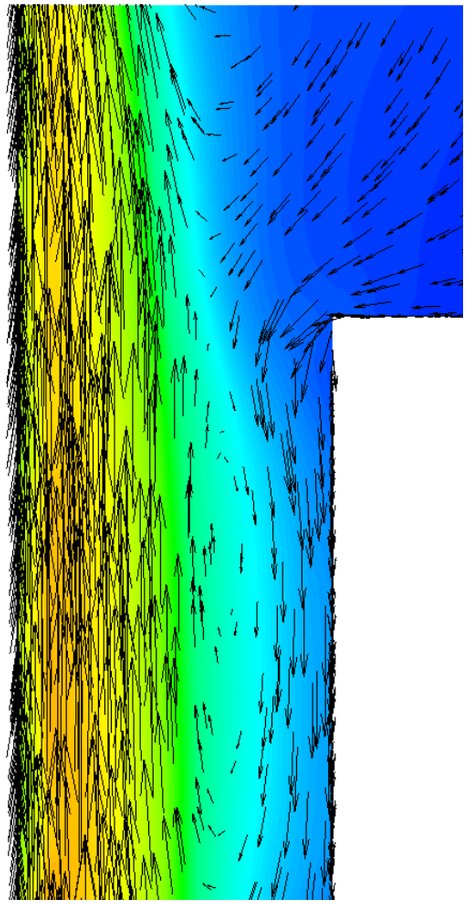


Velocity field & temperature field



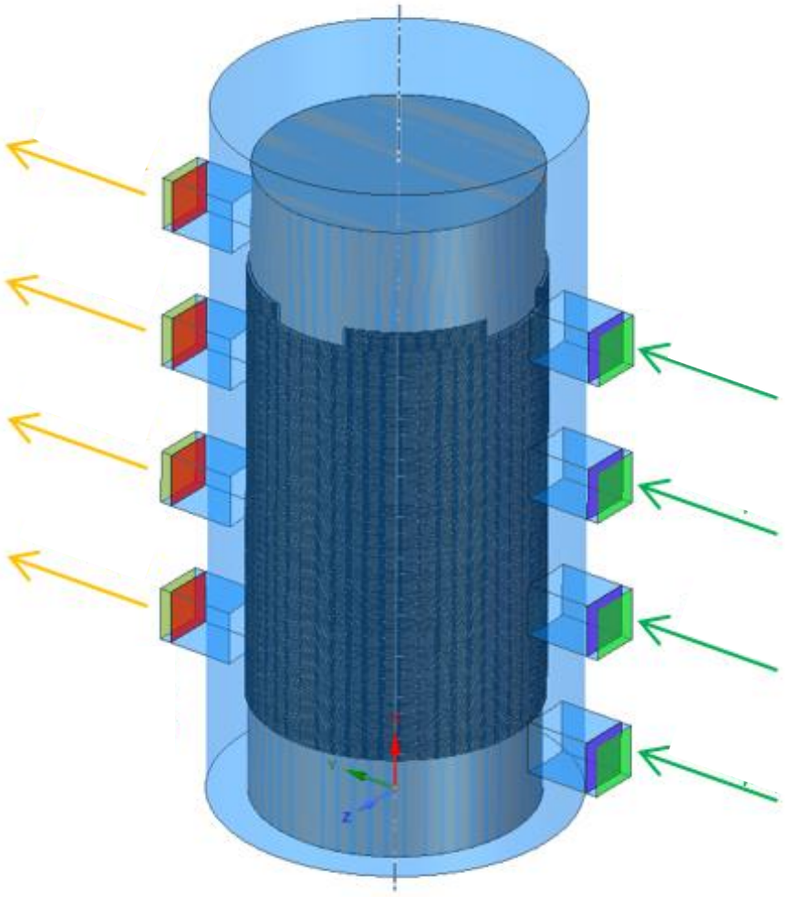


Velocity vectors near the outlet

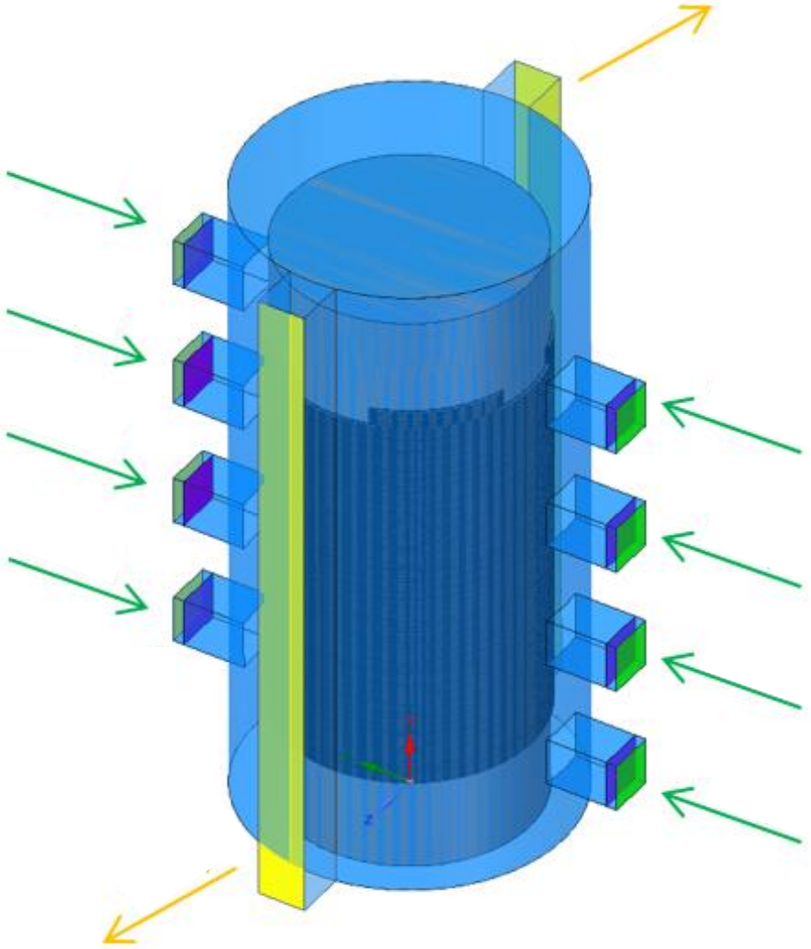


Forced convection – direct air flow cooling system

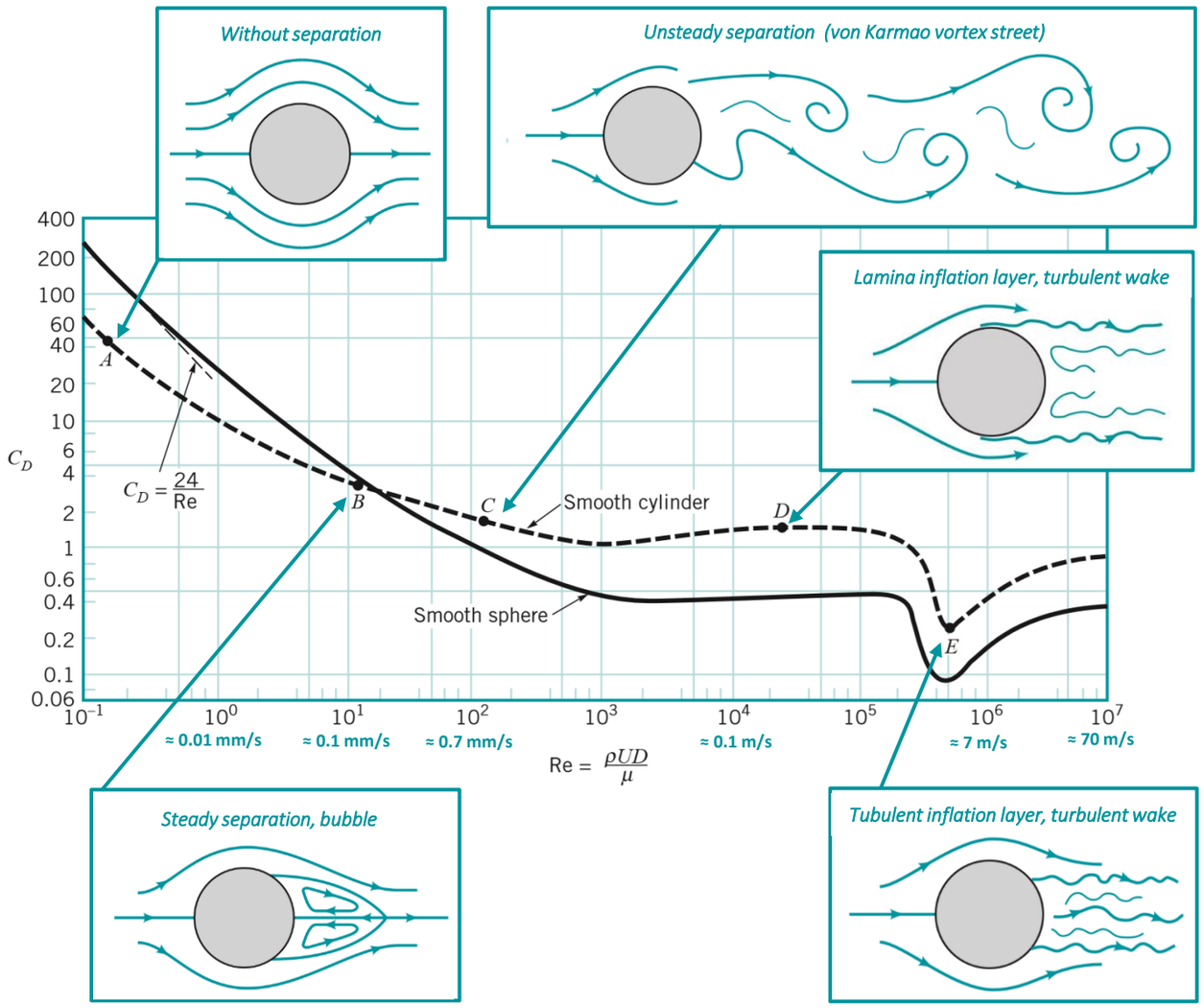
Inlet/Outlet vents



Inlet vents / Free outlets



Drawback of direct air flow cooling system



Size of the wake influences the heat transfer (cooling effect)

It is necessary to minimize the size of the wake

Cannot be modified:

- **Outer surface of the cask**

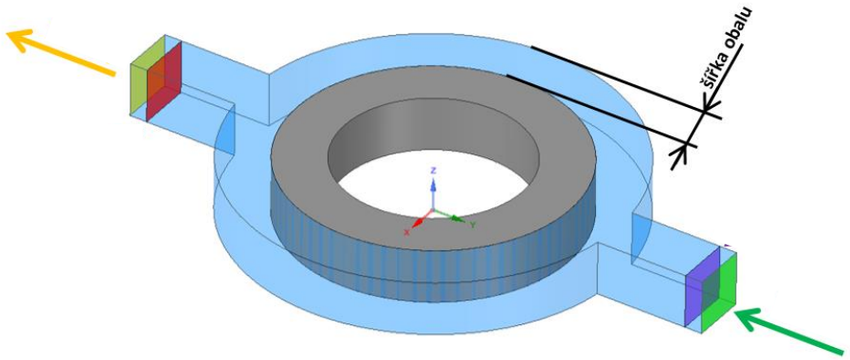
Can be modified:

- **Dimensions and geometry of the cooling system**
- **Mass flow of cooling air**
- **Number and position of vents**

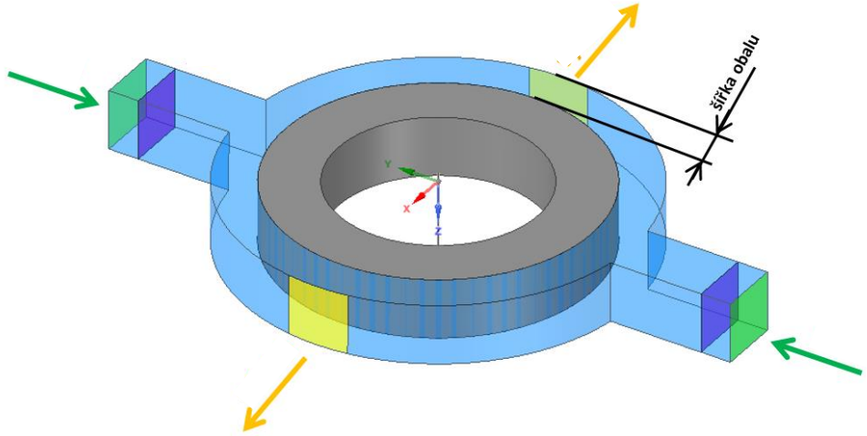
2D ANALYSIS

2D Analysis – computational domains

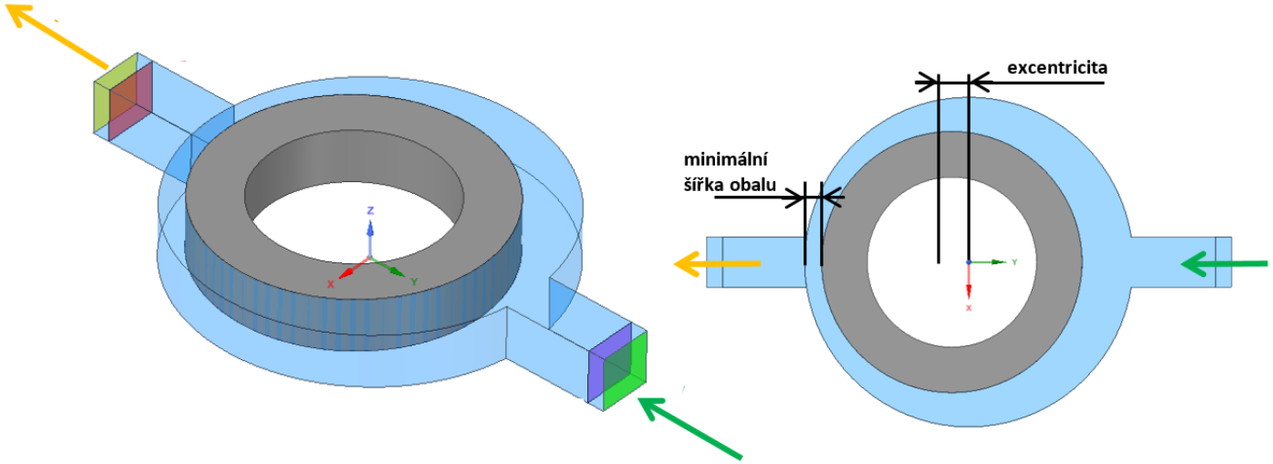
Inlet/Outlet vent, concentric cask



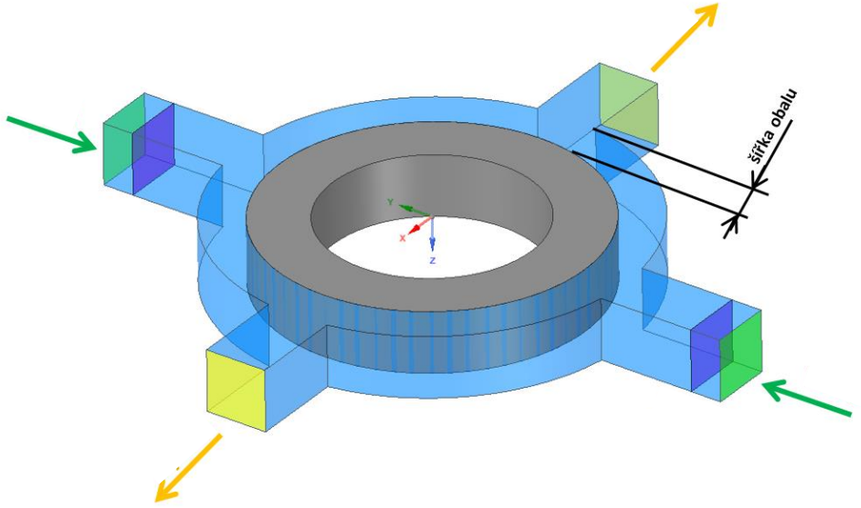
Inlet vents, free outlet, concentric cask



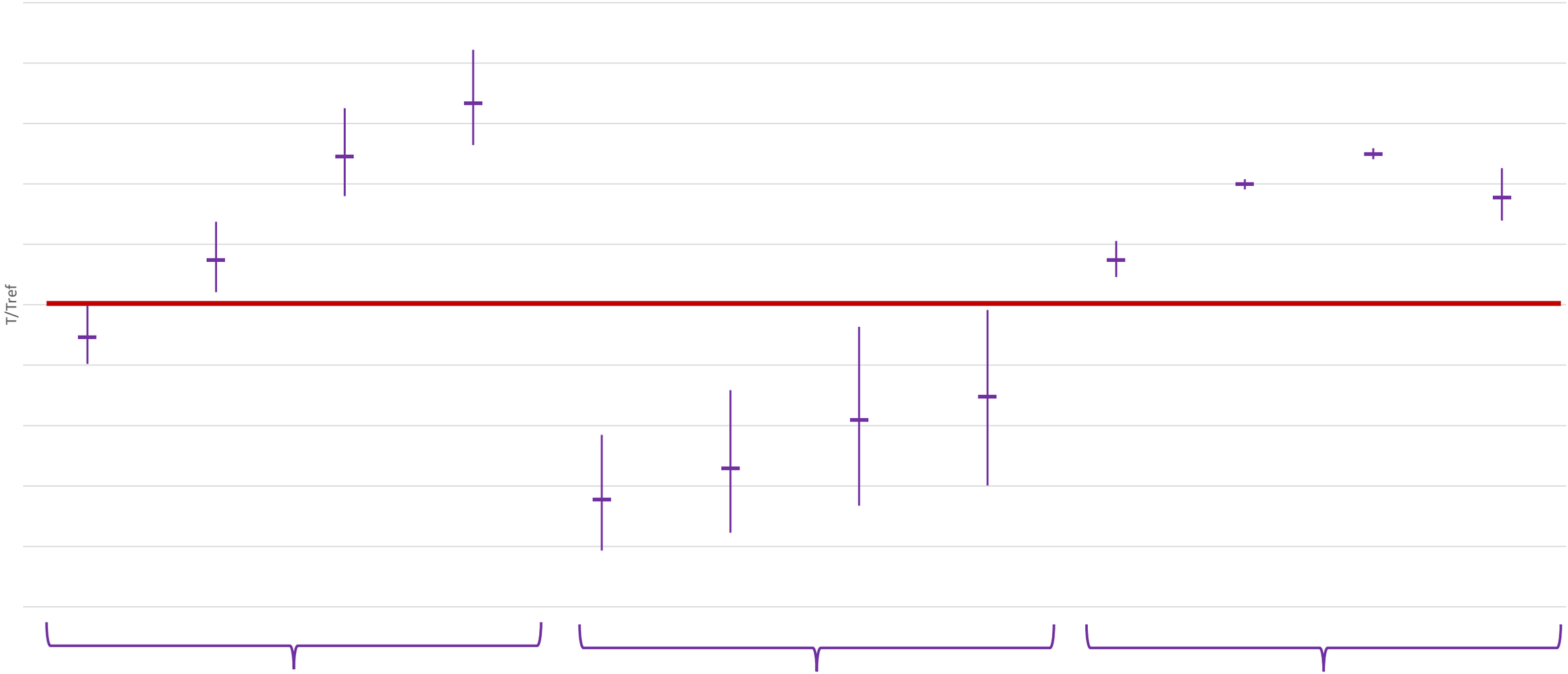
Inlet/Outlet vent, eccentric cask



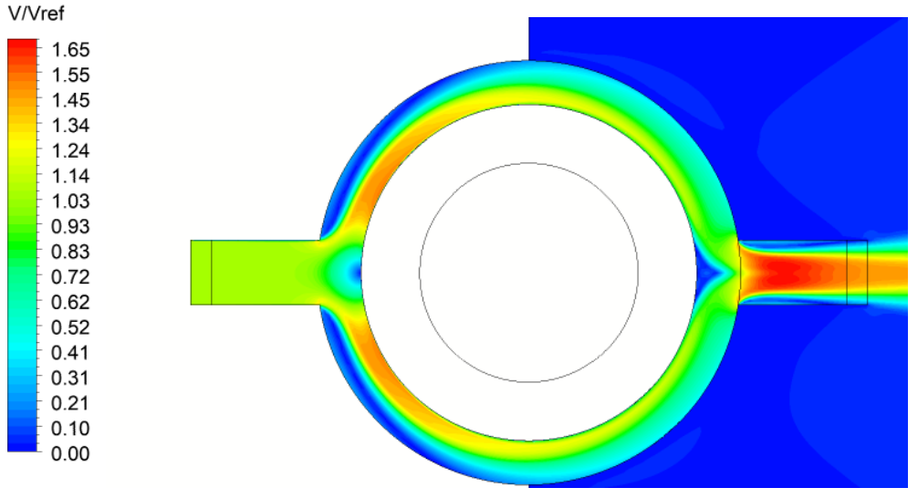
Inlet vents, free extended outlet, concentric cask

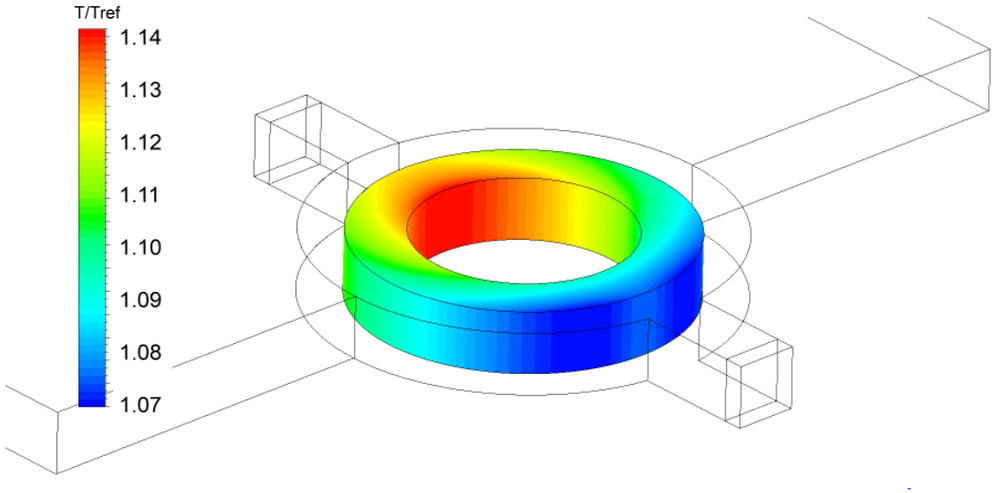


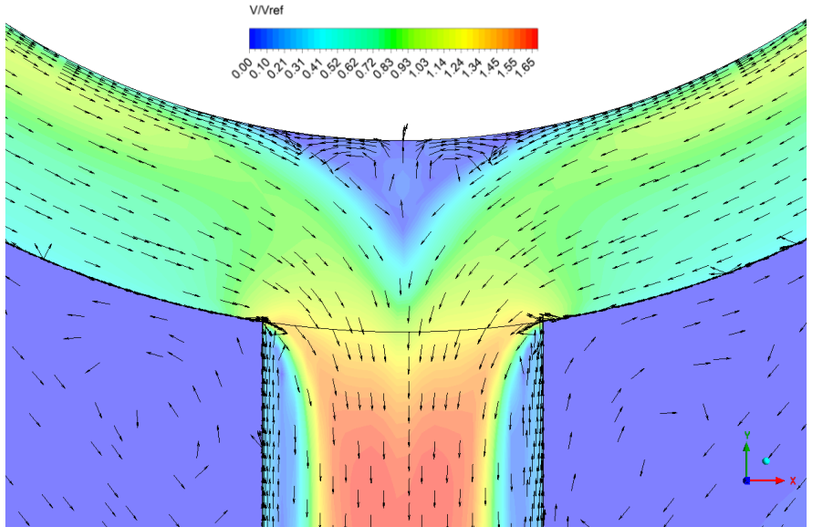
2D Analysis – results



2D Analysis – wake

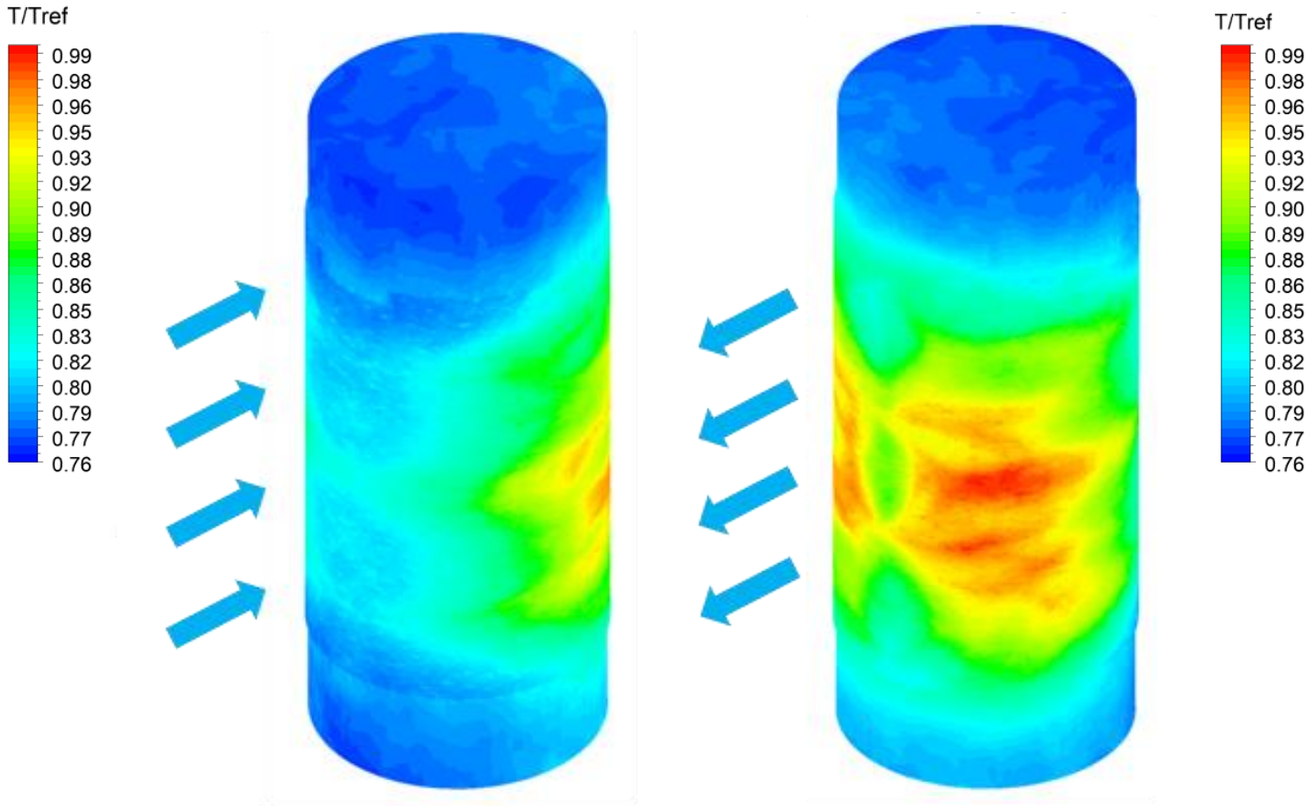




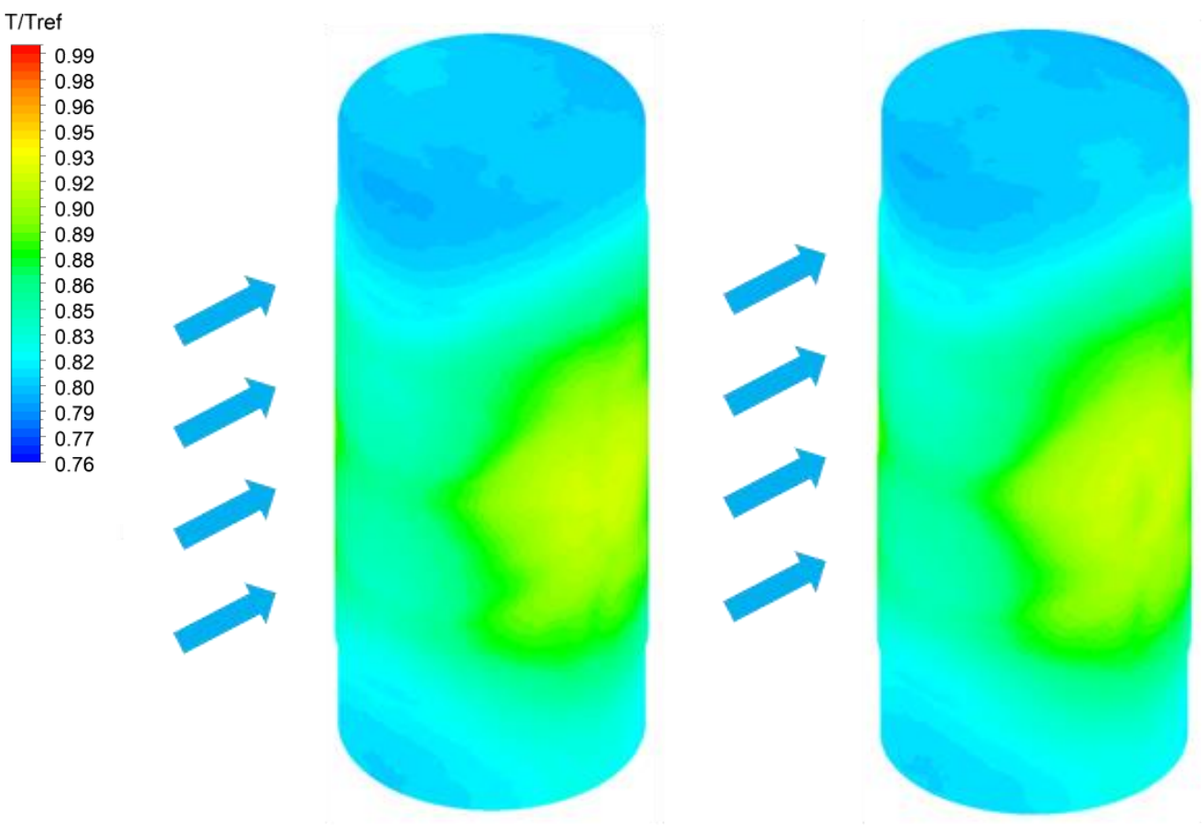


3D Analysis – temperature field

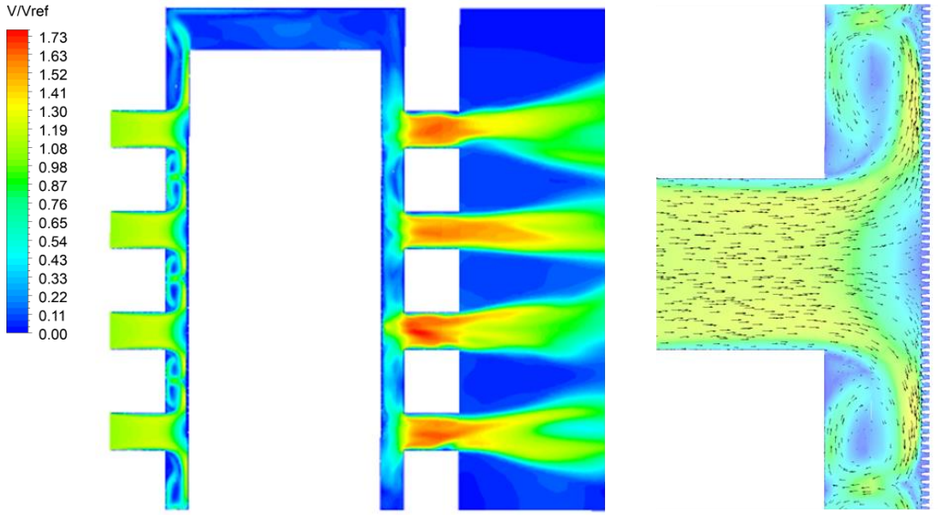
Inlet/Outlet vents, concentric cask

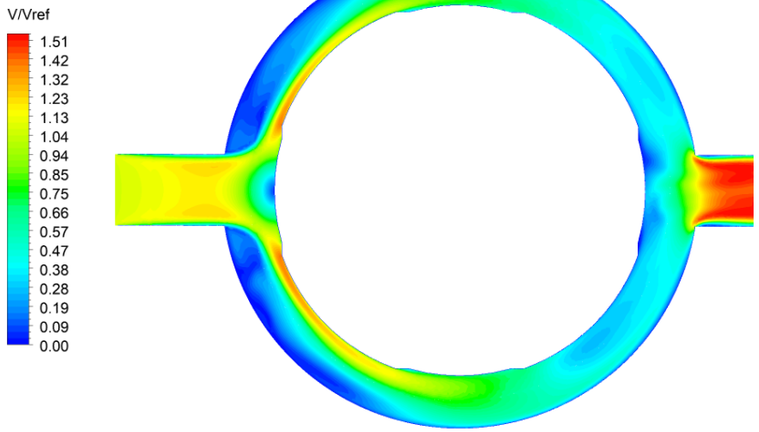


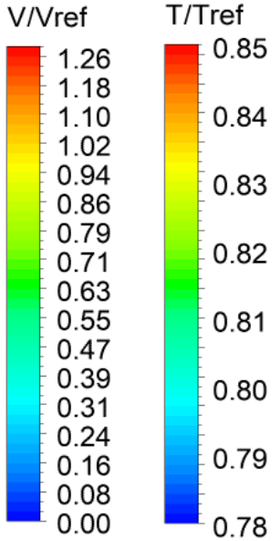
Inlet vents, free extended outlets, concentric cask

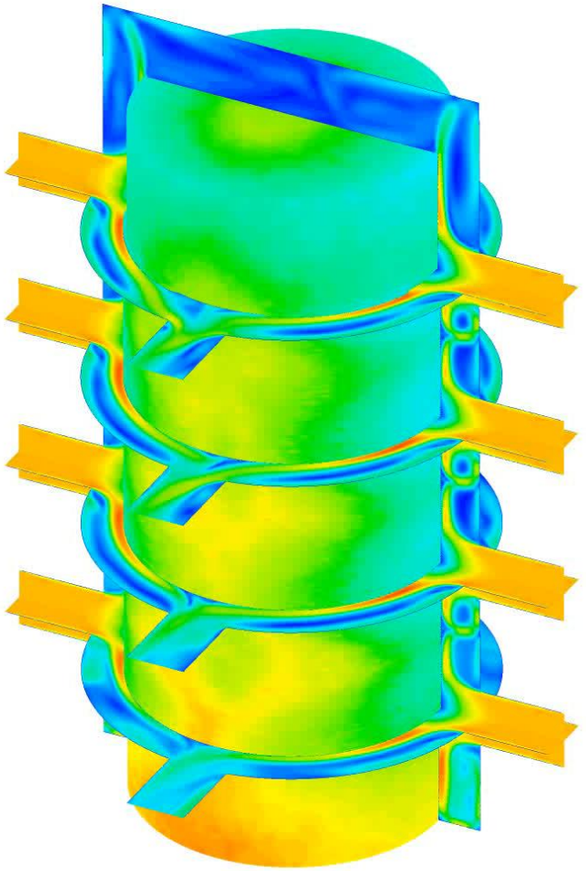


3D Analysis – velocity & temperature field









Conclusion

- **CFD simulation validated (natural convection)**
- **Cooling system with tangential air inlets does not cool down the cask below T_{ref}**
- **2D analysis of factors influencing wake behind cask when it is cooled down by direct air flow cooling system**
- **Direct air flow cooling system can cool down the cask below T_{ref}**

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