Wrocław University of Technology

Heat flux to the helium cryogenic system elements in the case of incidental vacuum vessel ventilation with atmospheric air

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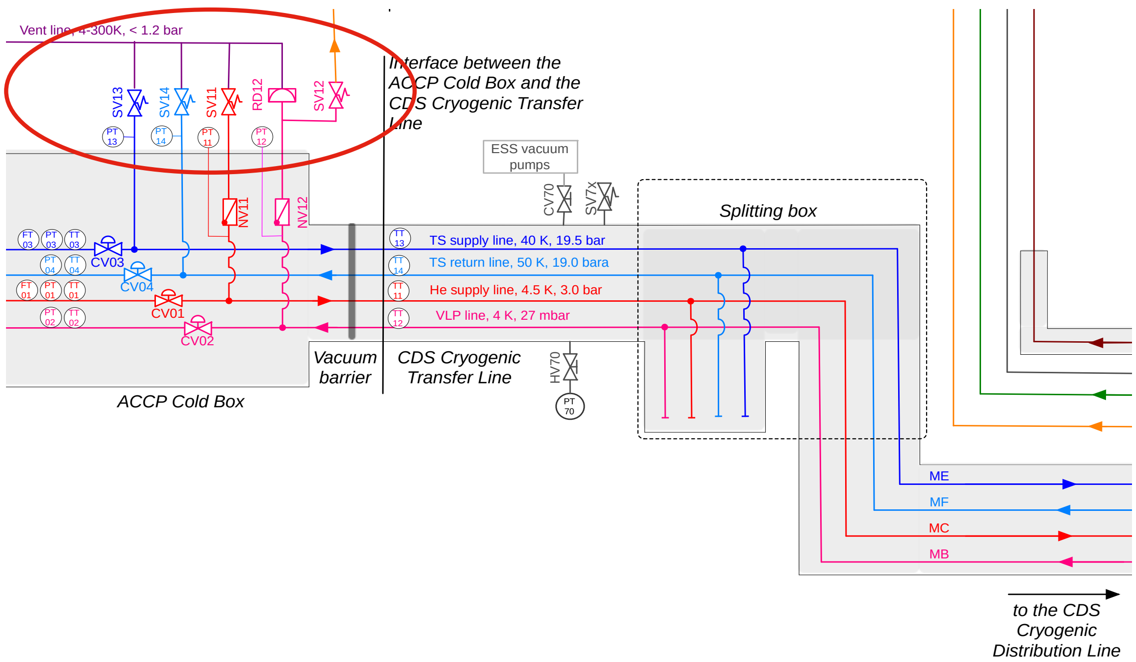
Outline

- Problem's background
- WUST test setup description
- Experiment methodology discussion
- Conclusions

Problem's background

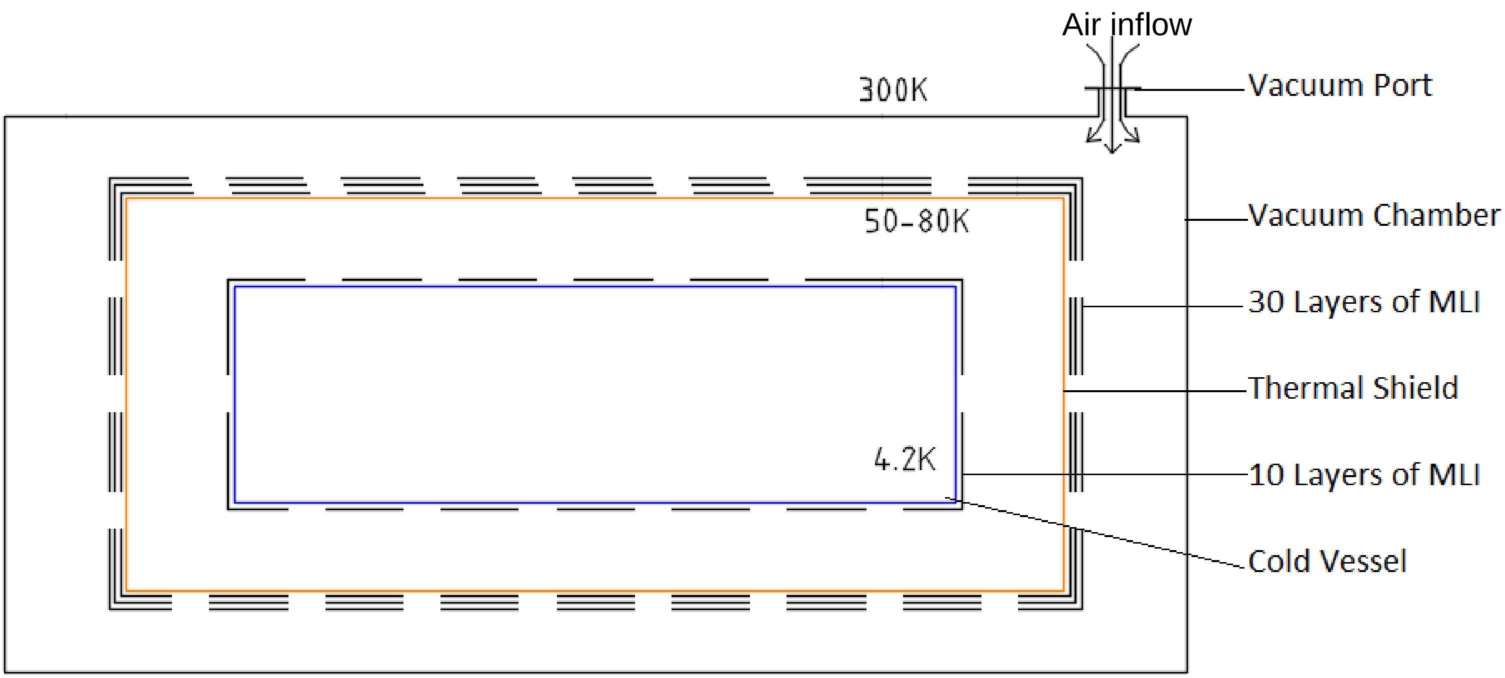
The cryogenic vessels or fluid distribution circuits need to be protected by safety equipments against excessive pressure caused by intensive heat inflow to this elements



ESS Cryogenic Distribution System – process lines safety equipment

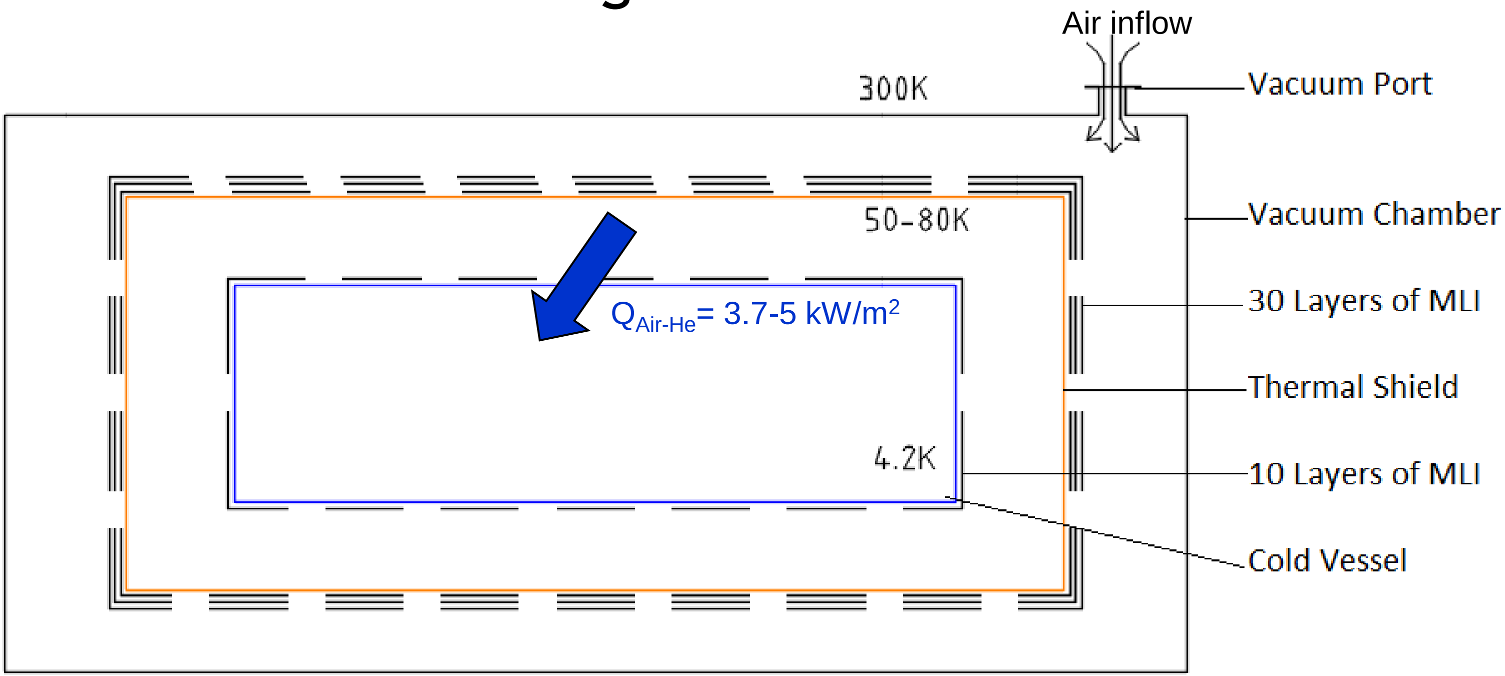
Problem's background

One of the heat inflow source to be considered in the safety equipments sizing is the incidental ventilation of the vacuum vessel with atmospheric air



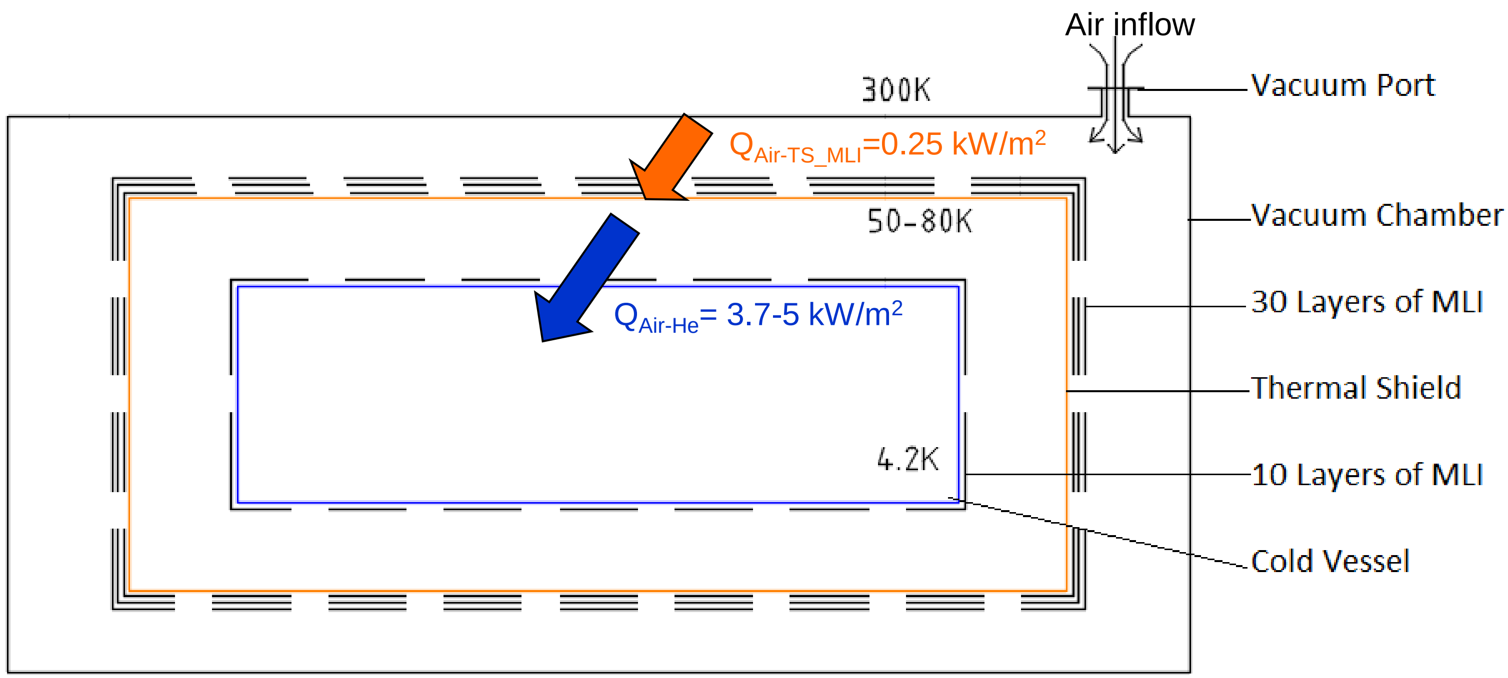
Problem's background

The heat flux with atmospheric air inflow to helium temperature elements has been already experimentally determined as 3.7 – 5.0 kW/m2 [1,2,3], but no heat flux to thermal shields were investigated



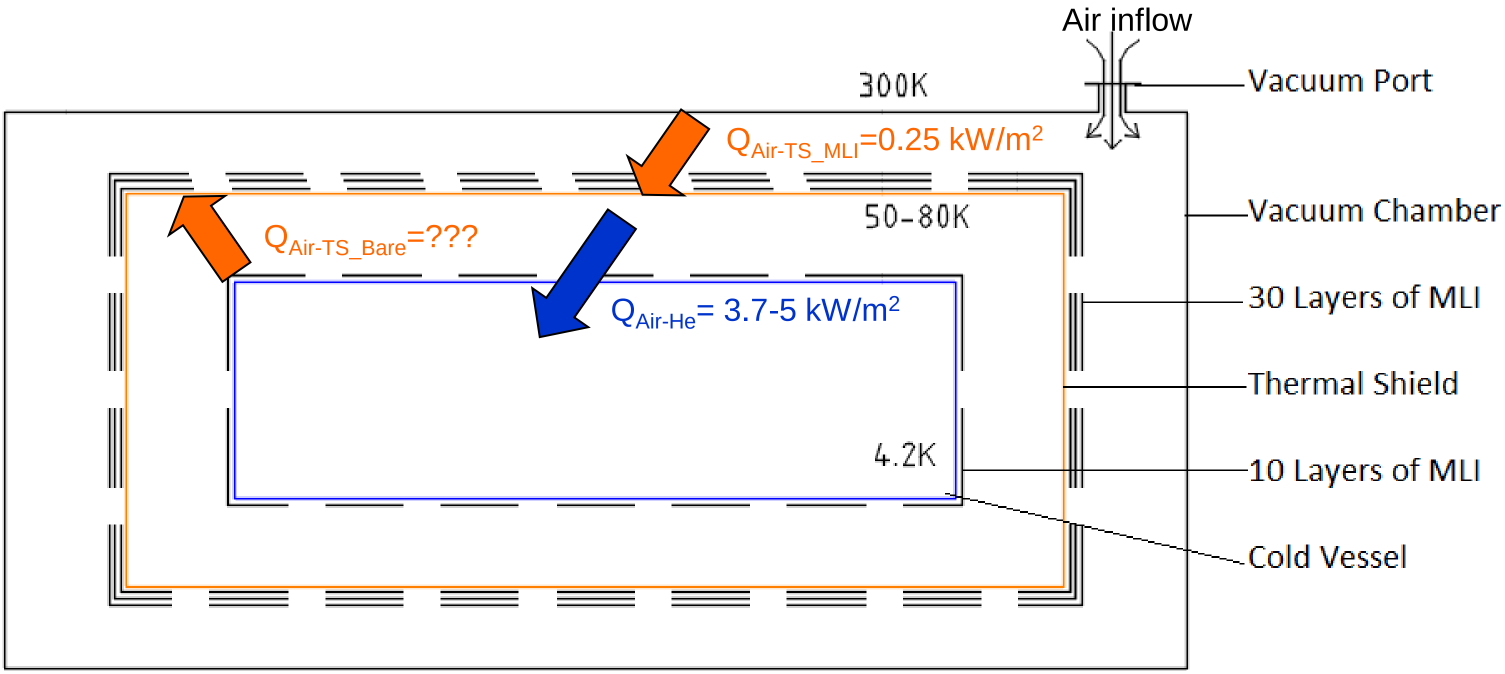
Problem's background

The thermal shields are covered from external side with 30-40 layers of MLI. The heat flux through the MLI side can be expected as 0.25 kW/m^2 [4], but …

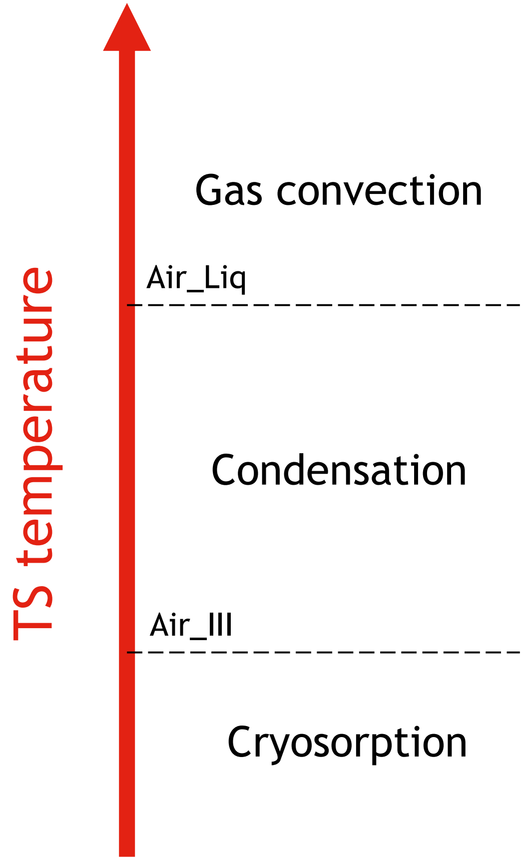


Problem's background

… the heat flux to the bare side of thermals shield is unknown.



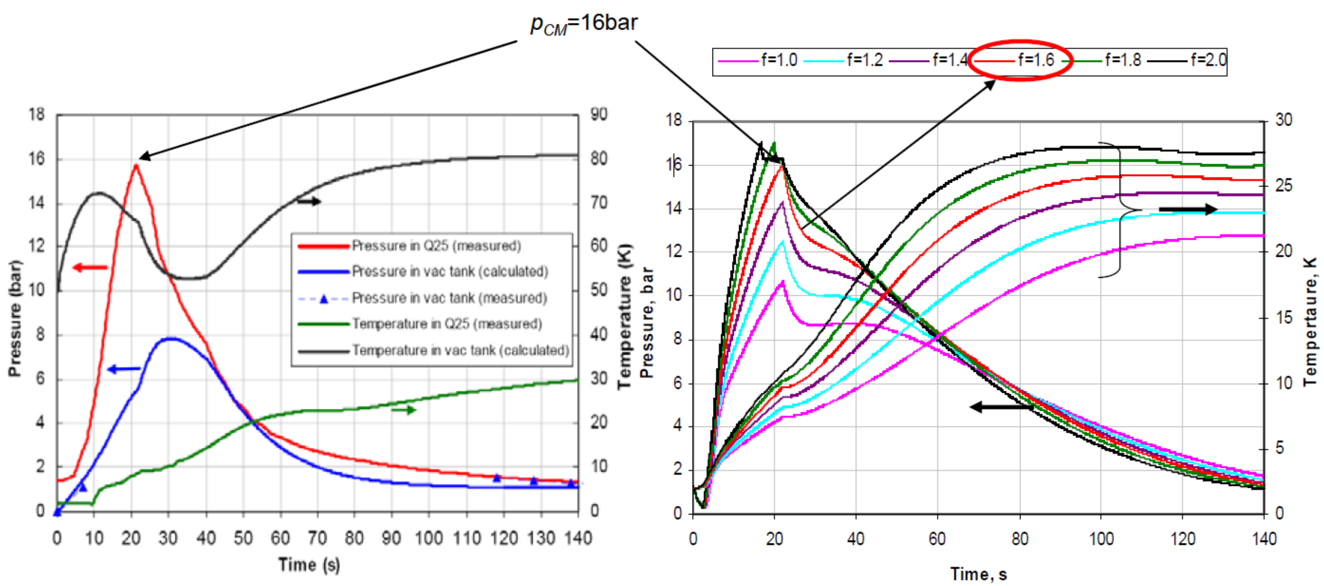
Problem's background



Problem’s background

The heat flux to the bare side of thermals shield:

- for $T_{TS}>T_{Air\_Liq}$ - gas convection, but it is not clear if convetion is forced, natural or „mix” type



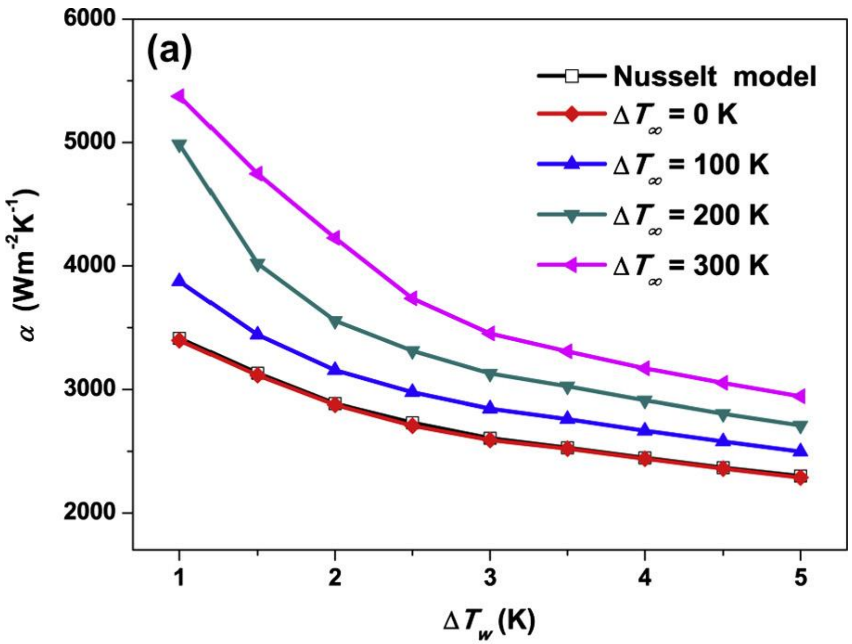
Measured and calculated data for 080919 LHC failure

Evolution of the helium temperature and pressure in Cold Mass

Model tuning by adjusting a natural convection heat transfer coefficient [5]

Problem's background

The heat flux to the bare side of thermals shield for $T_{Air\_Liq}>T_{TS}>T_{Air\_III}$ can be estimated with Nusselt model.



Modelling results of ambient air condensation on a cryogenic horizontal tube.
Variation of mean heat transfer coefficient for superheating ΔT1 = 0, 100, 200 and 300 K [6]

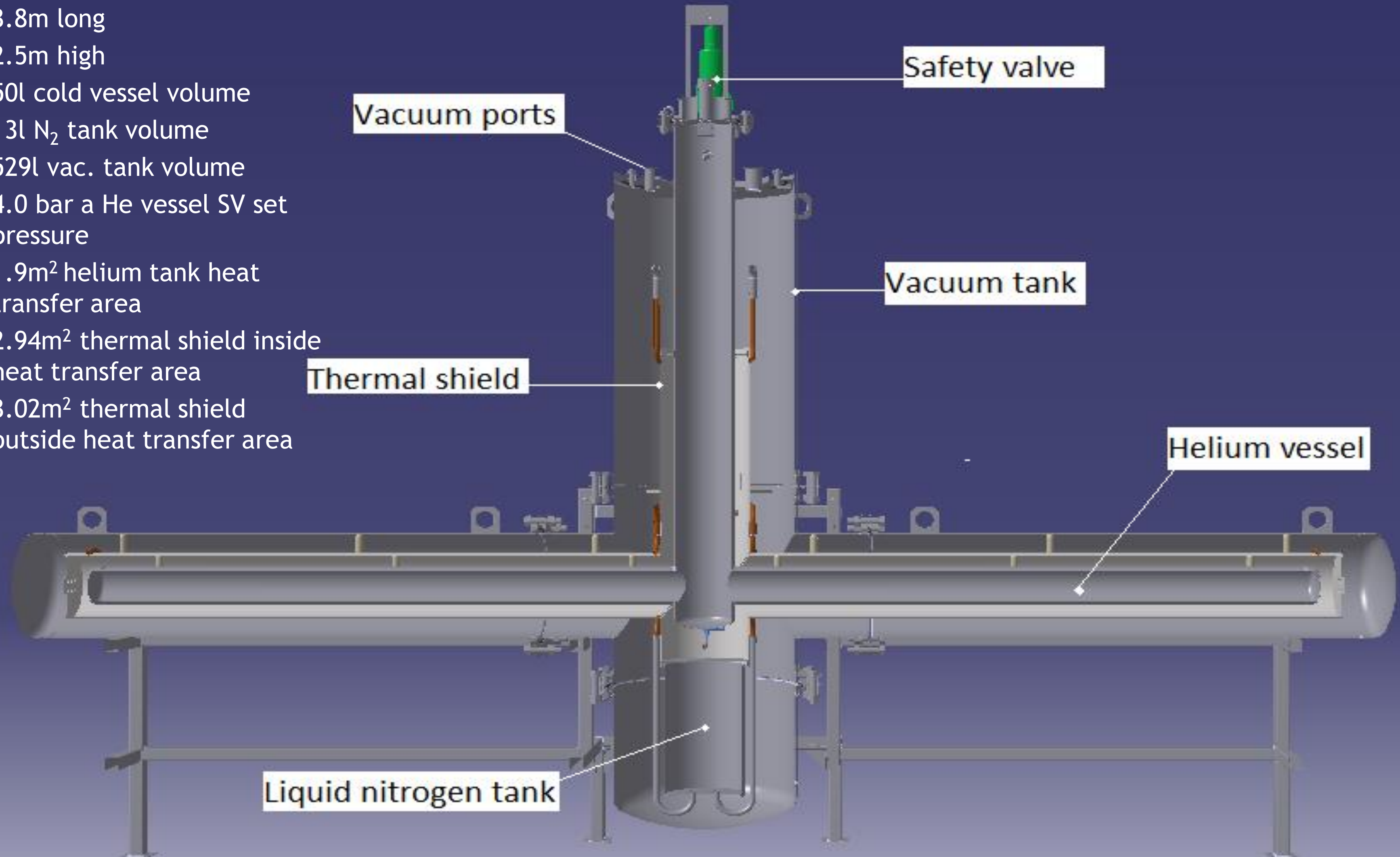
Problem's background

The heat flux to the bare side of thermals shield for $T_{TS}<T_{Air\_III}$ can be estimated with cryopumping effect.

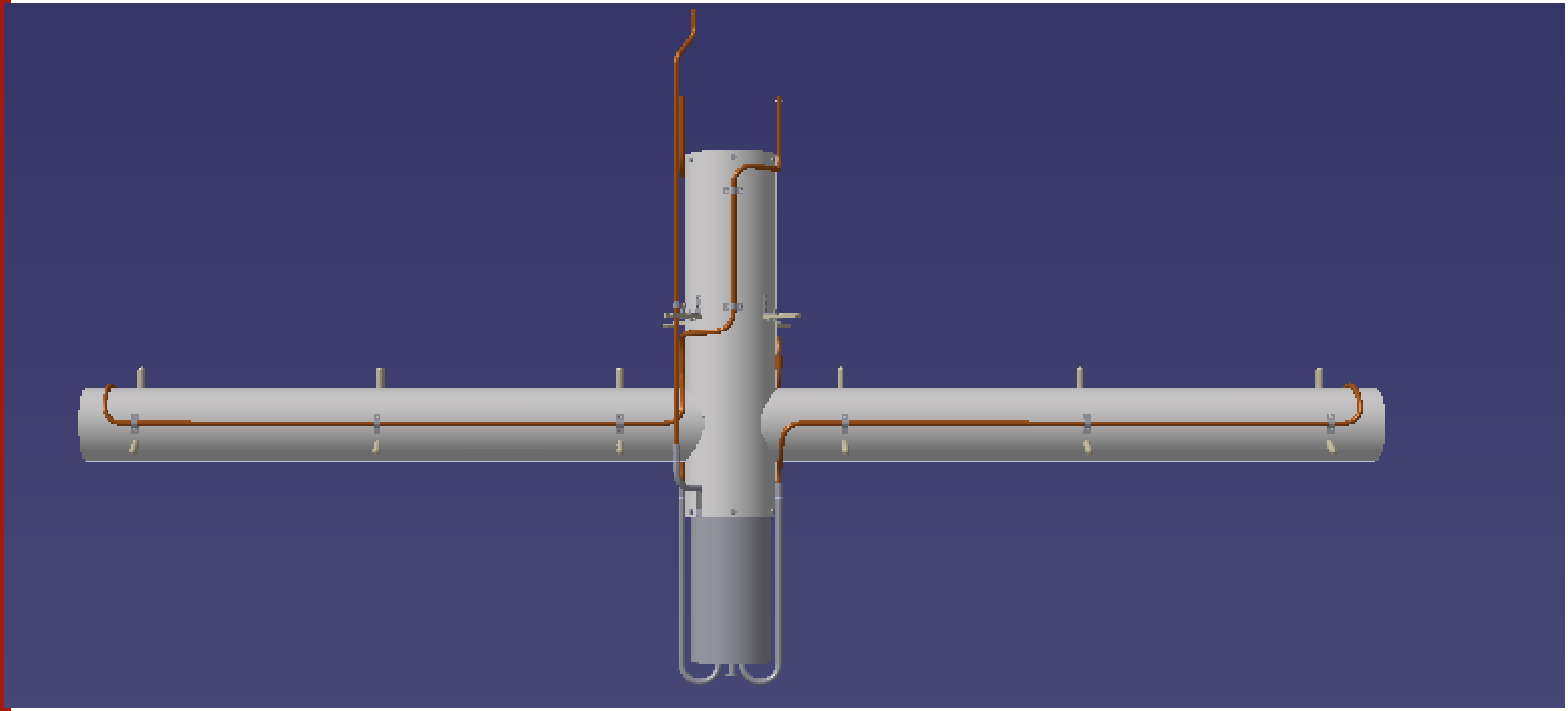
Gas velocity	$v = \dot{V} / A = \sqrt{\frac{kT}{2\pi M}}$
For nitrogen	$v_{N2} = 11.9\, l/s \; per \; cm^2$
Mass stream	$\dot{m} = \rho \cdot \dot{V}$
For nitrogen	$\dot{m}_{N2} / A = 1.25 \cdot 11.9 \cdot 10^{-3} \cdot 1/10^{-4} = 148\, kg/s \; per \; m^2$
Enthalpy difference	$h_{N2}(300K \rightarrow 50K) \approx 480\, kJ/kg$
Heat load with nitrogen	$\dot{q}_{N2} = \dot{m}_{N2} / A \cdot h_{N2} = 148 \cdot 480 = \boxed{71\, MJ/m^2}$!!!

WUST cryostat

- 3.8m long
- 2.5m high
- 50l cold vessel volume
- 13l N_2 tank volume
- 529l vac. tank volume
- 4.0 bar a He vessel SV set pressure
- 1.9m^2 helium tank heat transfer area
- 2.94m^2 thermal shield inside heat transfer area
- 3.02m^2 thermal shield outside heat transfer area



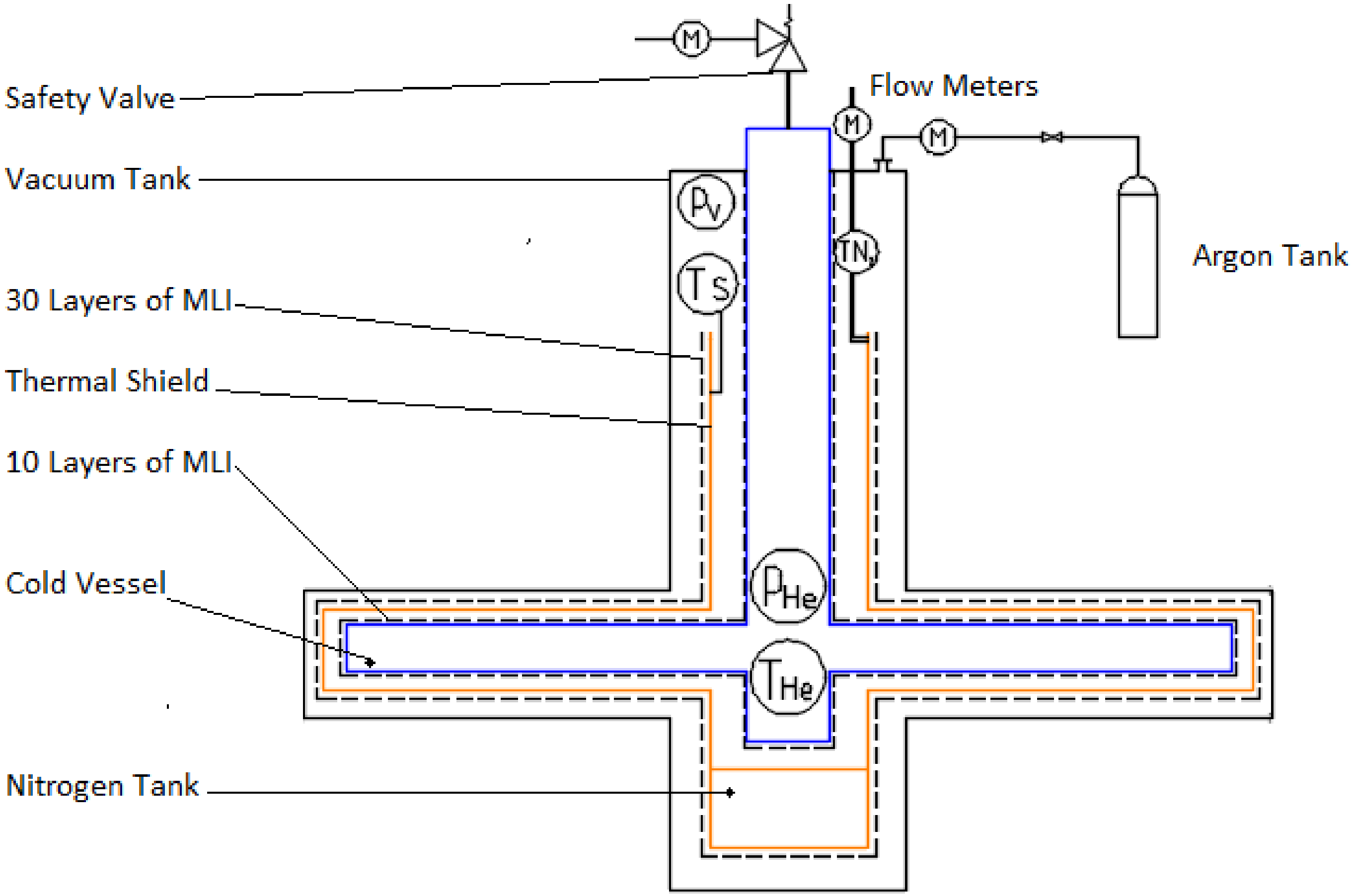
WUST cryostat Thermal Shield



Physical properties of air components

Gas	Normal boiling temperature, K	Triple point temperature, K	Heat of evaporation, kJ/kg	Heat of melting, kJ/kg
Air	78.8	58	205.1	23
Nitrogen	77.36	63.2	199	25.6
Argon	87.29	83.85	163	29.6

Experiment methodology



Experiment methodology

WUST set-up allowing:

- Measurement of the heat flux to He vessel – measurement of p, T or evaporation mass stream for SV open
- Measurement of the heat flux to the Thermal Shield bare side – measurement of the Shield temperature
- Measurement of the heat flux to LN2 vessel - evaporation mass stream

Conclusions

- Heat flux to Thermal Shield of large cryogenic helium distribution systems is less interested in both, theoretical and experimental investigations, but is of high importance in TS SV sizing
- WUST has designed a dedicated cryostat that allowing measurements of the heat flux to different elements of the helium distribution systems in case of the vacuum vessel ventilation with atmospheric air as well as with process gas (cold helium)

Reference

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2. Will Francis, Mike Tupper, Stephen Harrison, *Conformable tile method of applying CRYOCOAT™ UL79 insulation to cryogenic tanks.*
3. Harrison, S. M., "*Loss of Vacuum Experiments on a Superfluid Helium Vessel*" in IEEE Transactions on Applied Superconductivity, IEEE, 2002, pp. 1343-1346
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5. M. Chorowski, J. Fydrych, Z. Modlinski, J. Polinski, L. Tavian, J. Wach, Upgrade on risk analysis following the 080919 incident in the LHC sector 3-4, CERN/ATS/Note/2010/033 (TECH), 2010-07-01
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Thank you for the attention!