Thermo-Mechanical Behaviour of Polymeric Foam Insulation for Liquid Hydrogen Storage

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Why Liquid Hydrogen?

- High volumetric energy density
- Essential for large-scale storage and transport

Simanullang (2025) [2]

Current LH_2 Storage (4.700 m^3)

Kawasaki Heavy Industries (2025) [4]

Future LH_2 Storage (100.000 m^3)

LH_2 Storage Tanks

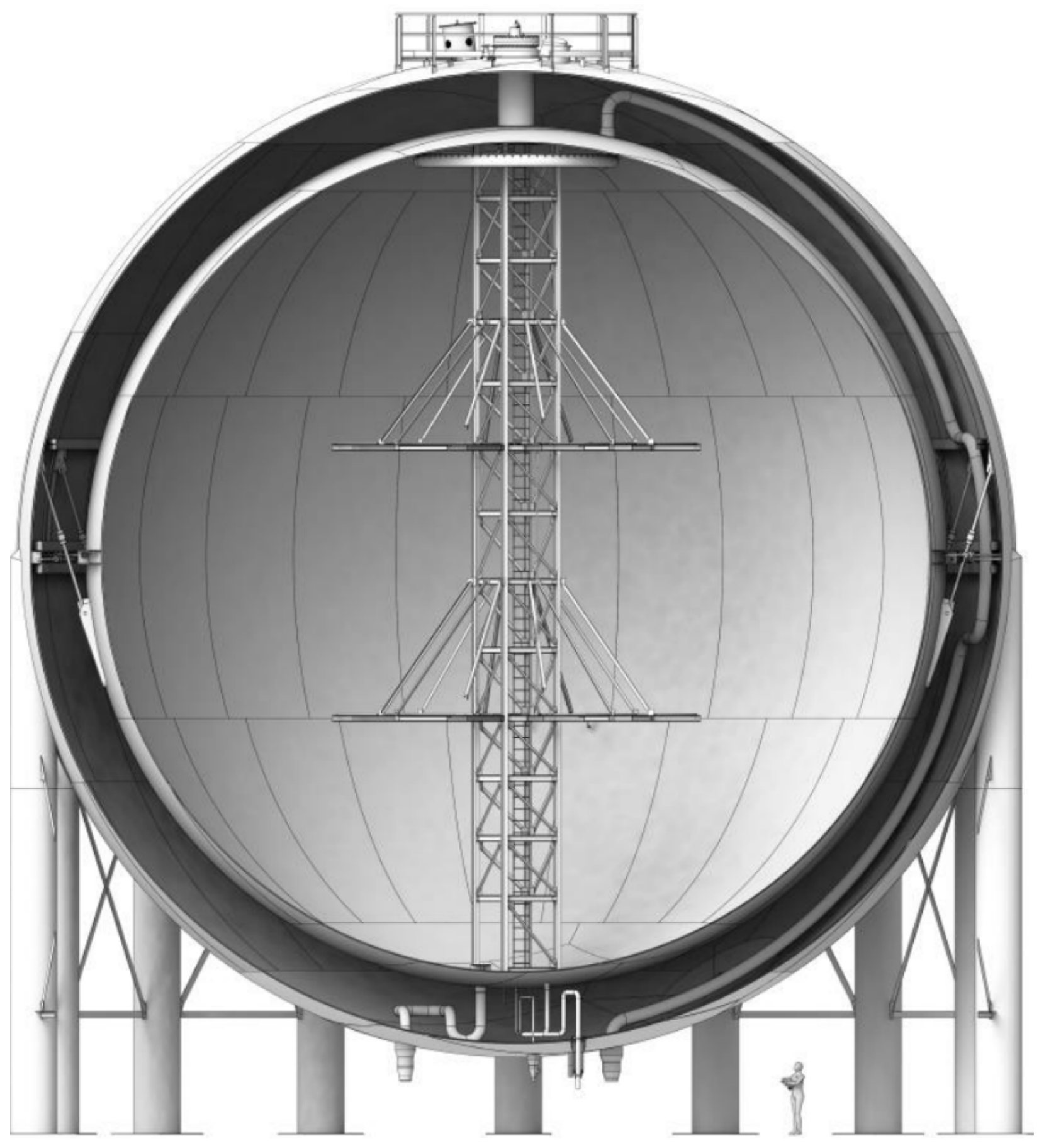
- Cryogenic temperatures (20 K)
- Heat ingress → boil-off losses
- Complex geometry and constraints

Vacuum Insulation Challenges

- High complexity and capital cost
- Scalability brings challenging

Polymeric Foam Insulation

- Enables scalable flat-bottom tank
- Lower system complexity and cost
- Thermal contraction stresses
- Ageing / Moisture sensitivity

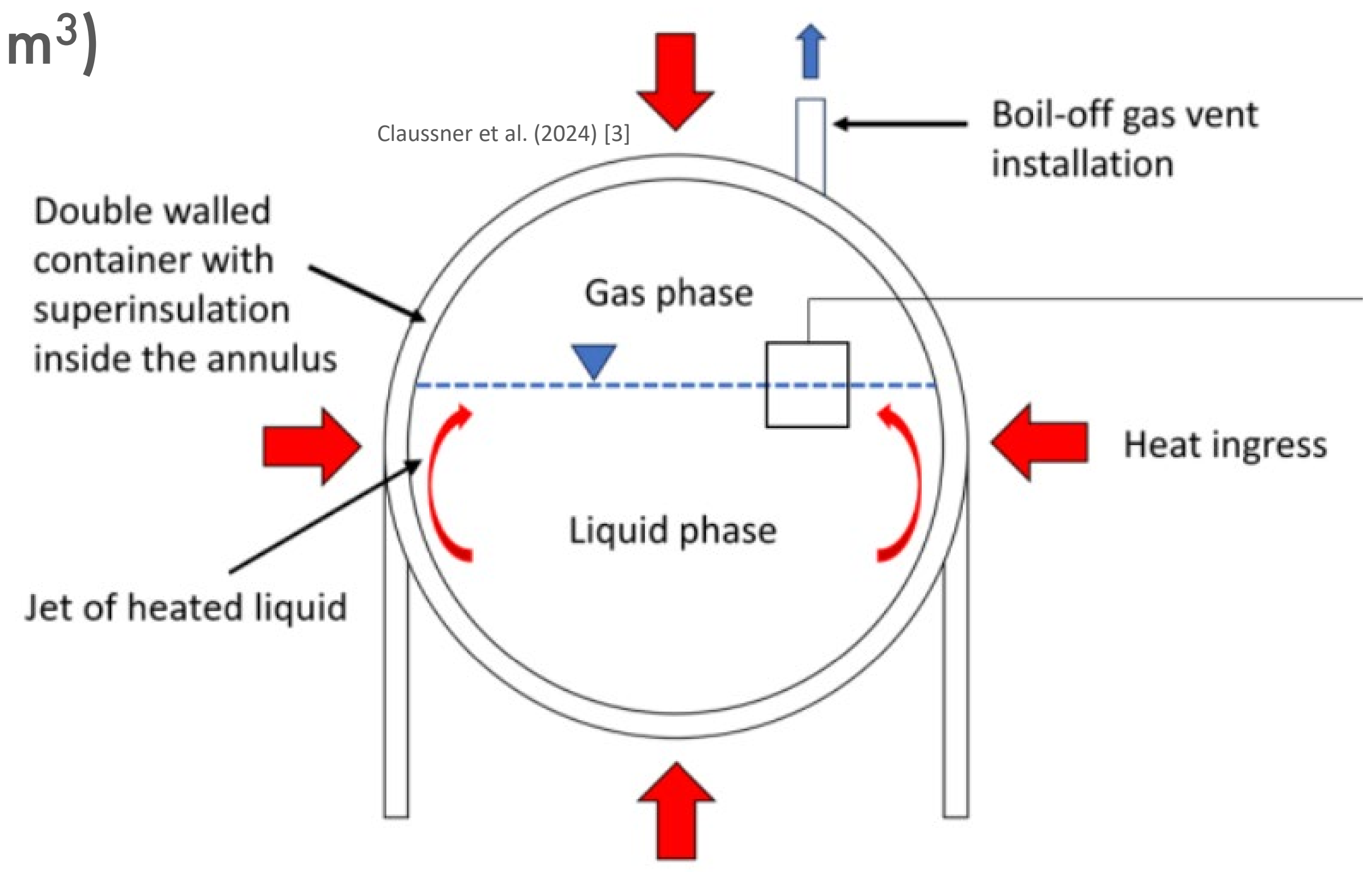


Fesmire et al. (2022) [1]

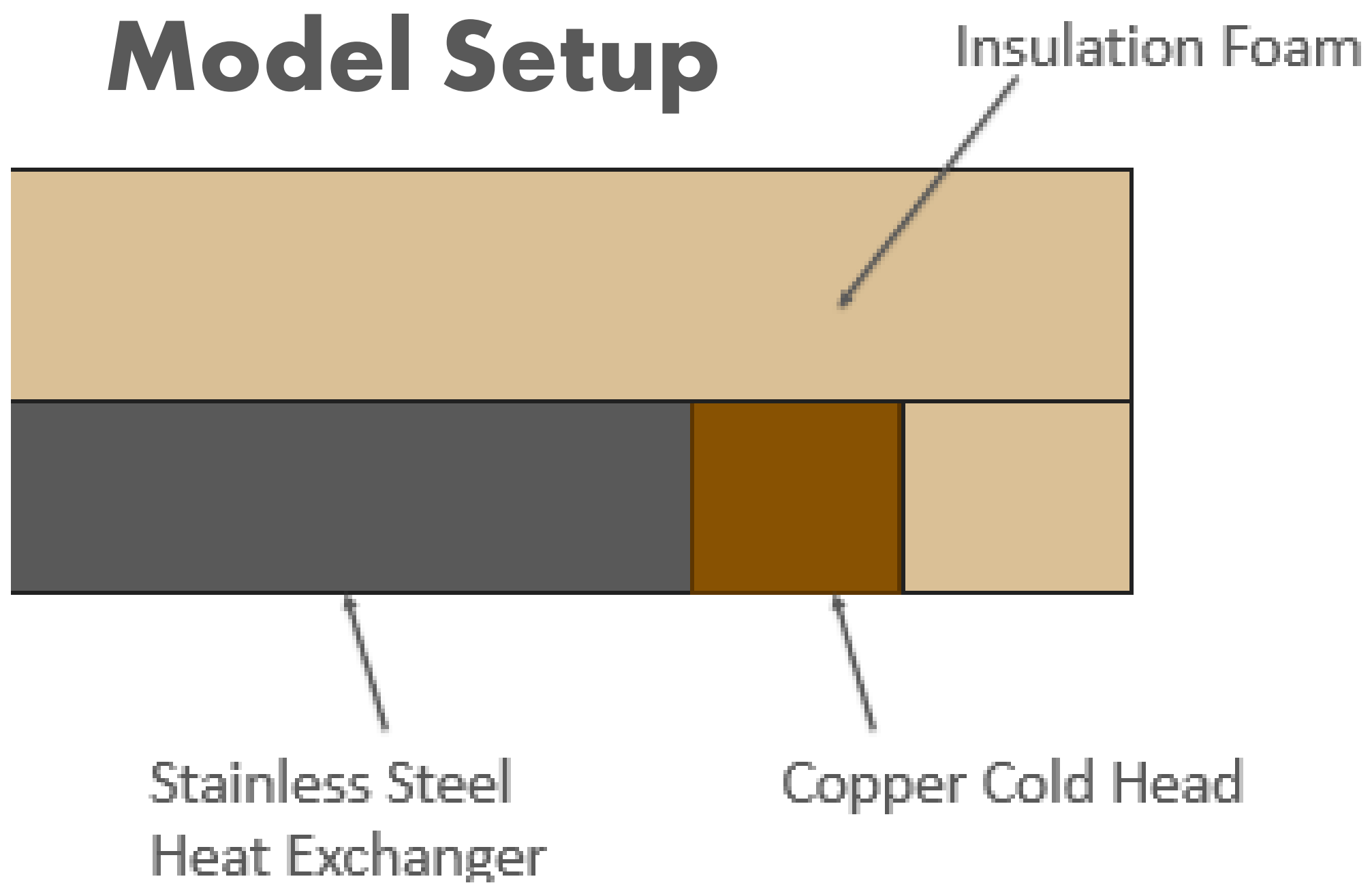
Thermal-Mechanical Behaviour of Foam

- Gas conduction dominates at moderate temperatures
- Solid conduction dominates at cryogenic temperatures
- Strong dependence on temperature and density
- Foam stiffens at low temperatures
- Reduced ductility at low T → brittle behaviour
- Local defects dominate failure

Claussner et al. (2024) [3]



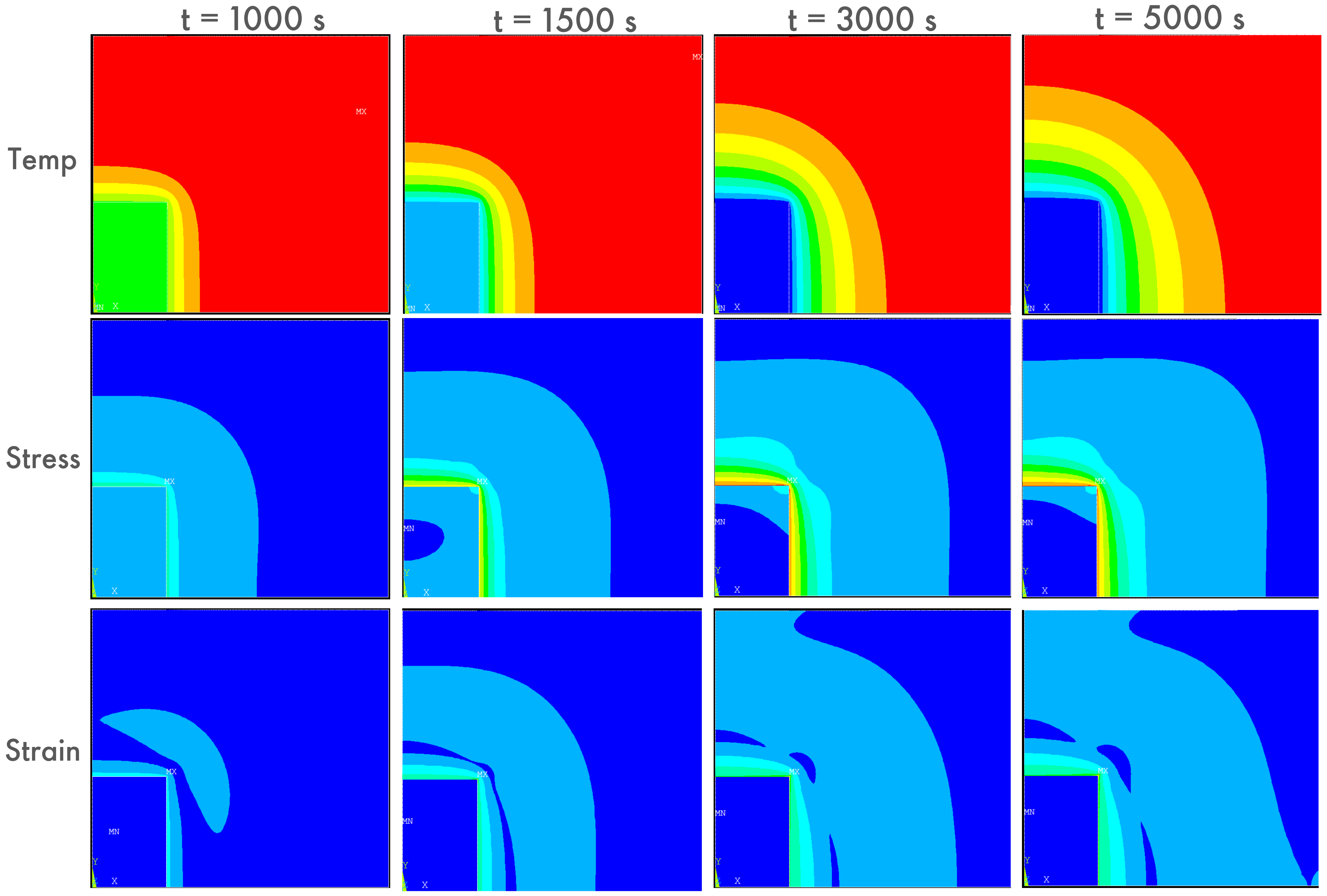
Model Setup



Modelling Approach and Results

Objective: Predict stress and strain development during cryogenic cool-down with a thermo-mechanical FEM model (ANSYS)

Validation Strategy: Exact foam failure criteria at cryogenic temp remains uncertain, therefore, stress and strain are evaluated as functions of temperature for comparison with experimental behaviour



Key Findings

- Stress and strain fields do not directly follow the temperature contours
- Foam–metal interface acts as the dominant stress concentration zone
- Constrained thermal contraction alone generates significant local stress

Next Steps

- Rounded corner geometry: investigate stress concentration effect
- Refined boundary conditions and extending the model
- Glass transition and plasticity incorporation
- Sensitivity analysis

Energy Transition Campus Amsterdam
Together with Shell

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4. Kawasaki Heavy Industries, Ltd. (2025). *Kawasaki delivers spherical liquefied hydrogen storage tank for the world's first 160,000 m^3-class LH_2 tank project*. News release, August 7, 2025. https://global.kawasaki.com/en/corp/newsroom/news/detail/?f=20250807_3407