



Experiments on LH₂ transfer facility performance for mobile applications

Final Dissemination Conference

Daniela Lindner, Benjamin Brösicke

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Structure

- 1. Introduction to test facility**
- 2. Test scenarios & goals**
- 3. Integration of Scenario 1 – Schematic & Impressions**
- 4. Integration of Scenario 2 – Schematic & Impressions**
- 5. LH₂ Transfer Activities - Results**
- 6. Summary & Conclusions**

H2 Container Test center (H2CT) from project Zero Emission

- Test field with 4 test positions for 24/7 operation
- Supply with green hydrogen (GH₂)
 - 30 bar and 300 bar
 - max. 150 kg/h
- Supply with LH₂ or LN₂
 - max. 16 bar
 - Designed to 1000 kg/h LH₂
- Supply with secondary media
 - GN₂ (flushing and control pressure)
 - GHe (flushing and Quick discharge)
 - Natural Gas
 - Power up to 1000 kW
 - Water, Ultrapure water, Waste water
- Exhaust system
 - Withdrawal capacity to flare stack 2000 kg/h



Hydrogen Supply at H2CT

Liquid hydrogen (delivered)



- LH₂ supply tank 12m³ for trailer deliveries (until own liquefier available)

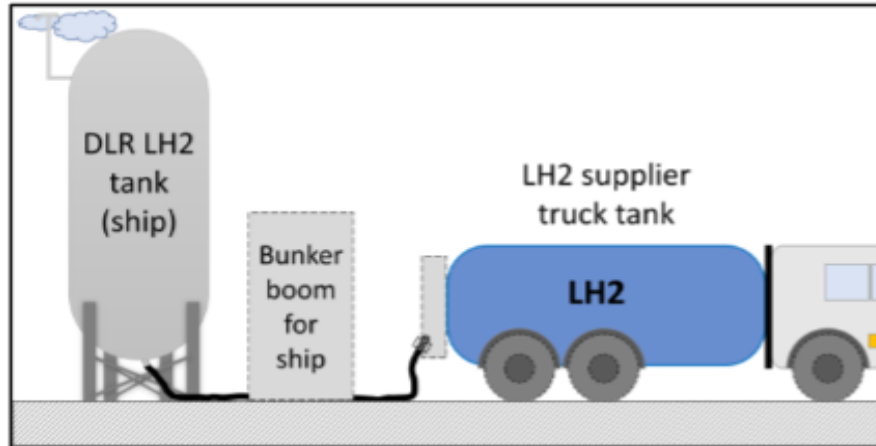
100% green gaseous hydrogen on-site produced



- Primarily via electrolysis (30 bar) (direct line to the wind farm)

Overview on fuelling experiments (WP3)

Scenario 1



Scenario 2

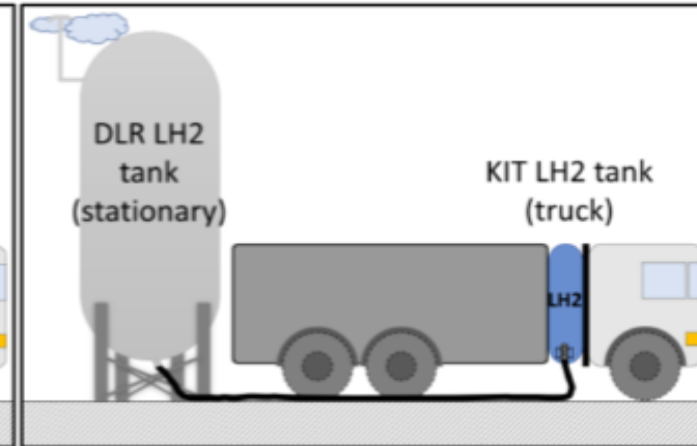
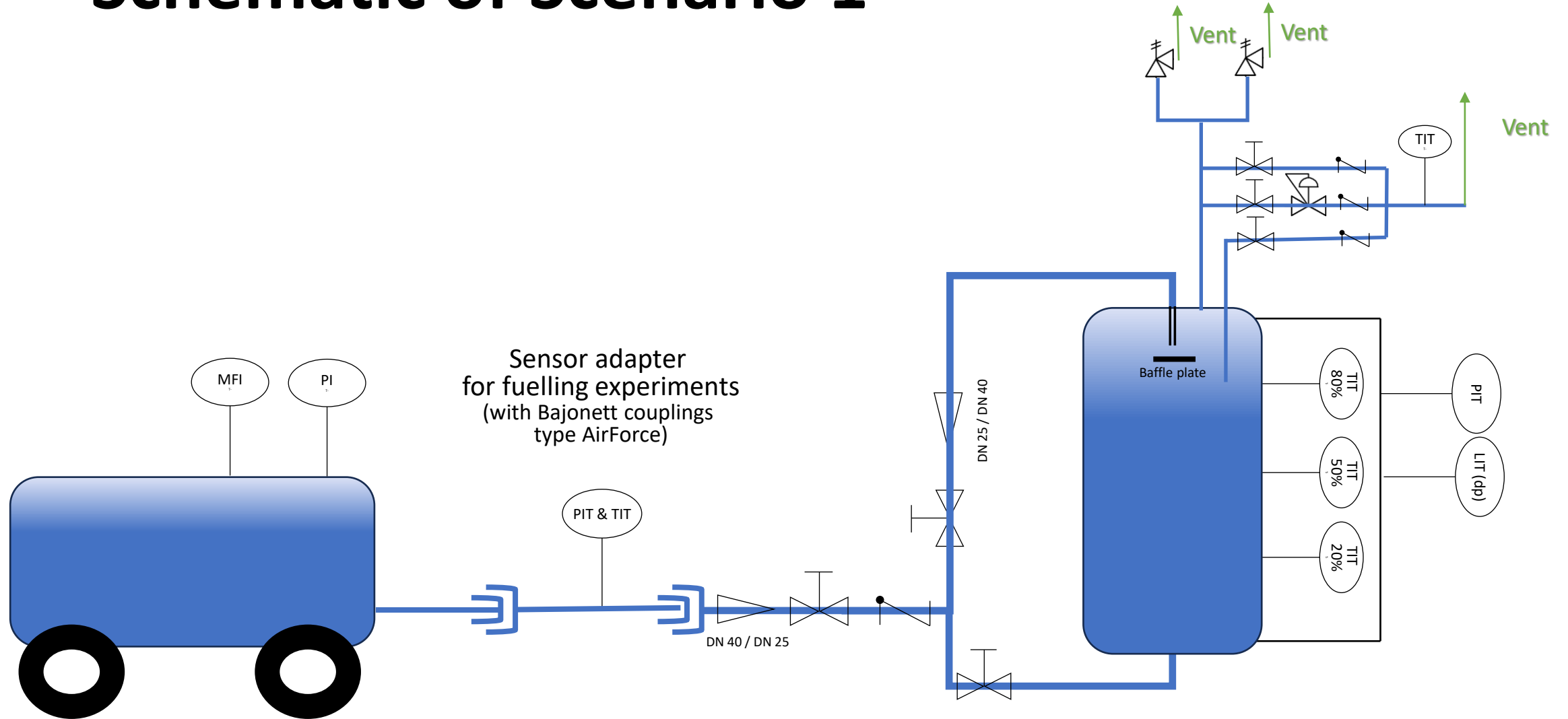


Figure 5: simulation of mobile applications, bunkering of a ship (left) and truck fuelling and defuelling of stationary tank (right)

Goals:

- Optimization of LH₂ fueling procedures
- Investigation on mass flow, temperature and pressure variations
- Investigation of specific phenomenas and points of interest as filling degrees, boil-off losses, heat transfer or thermal-acoustical effects
- Validation of operational safety requirements

Schematic of Scenario 1



Scenario 1

First fuelling from trailer with LN₂



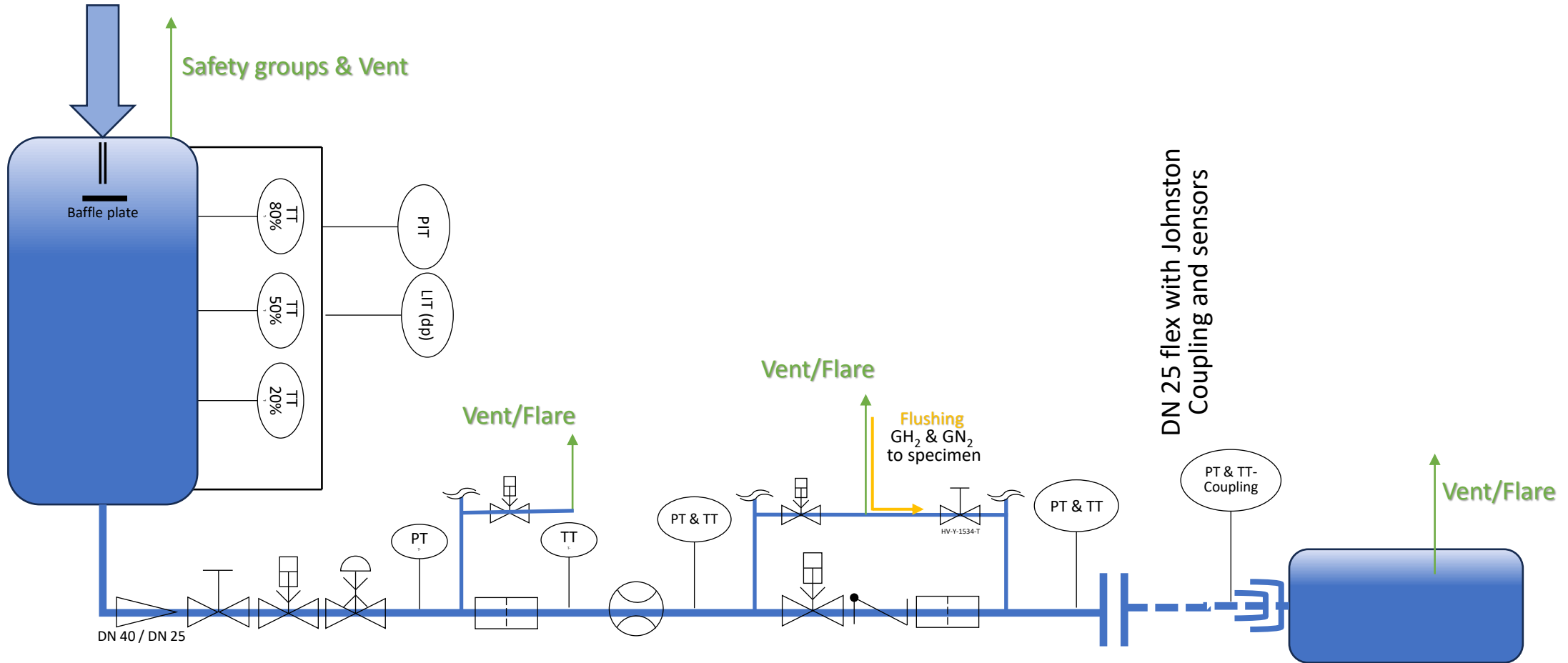
Scenario 1

Fuelling with Sensor Adapter



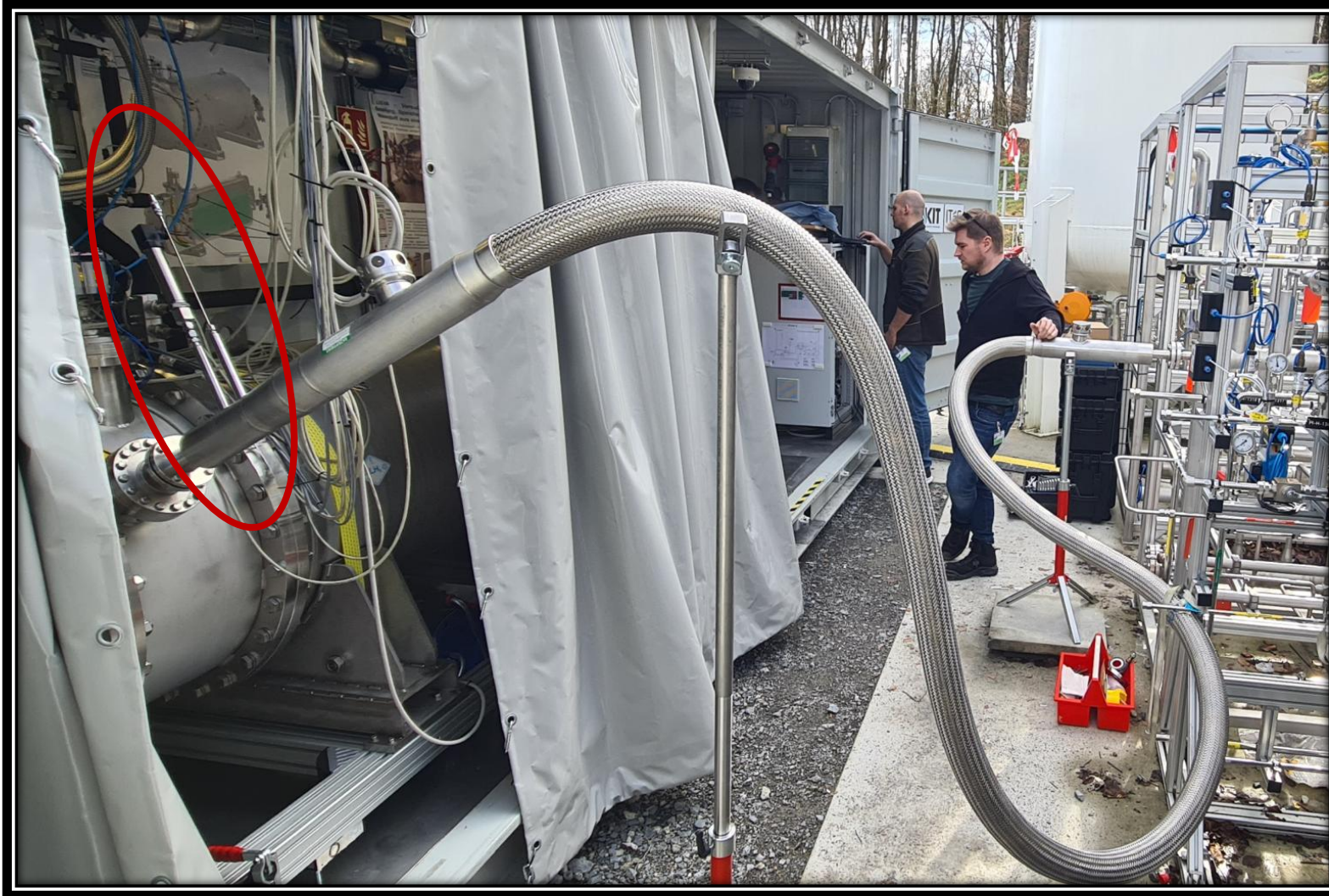
Schematic of Scenario 2

External pressurization system
for high massflow (DN40)



Scenario 2 Integration

KIT tank connected via Johnston coupling flex line with sensors



Scenario 2

Impressions from the Cryo Test Position



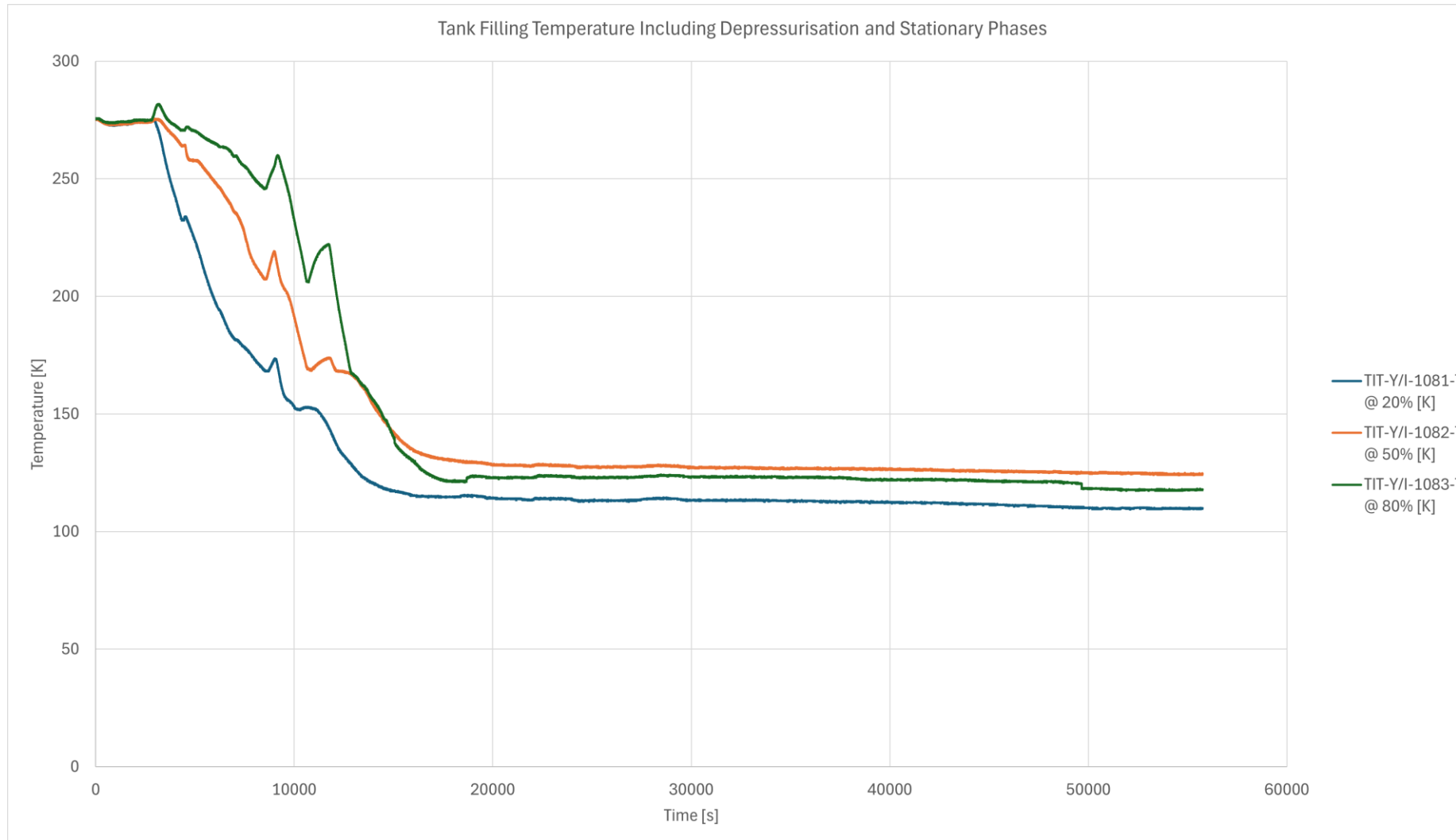
LN₂ / LH₂ Transfer Activities

- Two test campaigns for LN₂ and LH₂
- Two transfer scenarios each
 - From trailer to storage tank (scenario 1)
 - From storage tank to run tank (scenario 2) → see KIT presentation
- Tests conducted with varying (initial) parameters, e. g.:
 - Filling level → temperature
 - Pressure level → mass flow
 - Filling type / procedure

LN₂ / LH₂ Transfer Activities

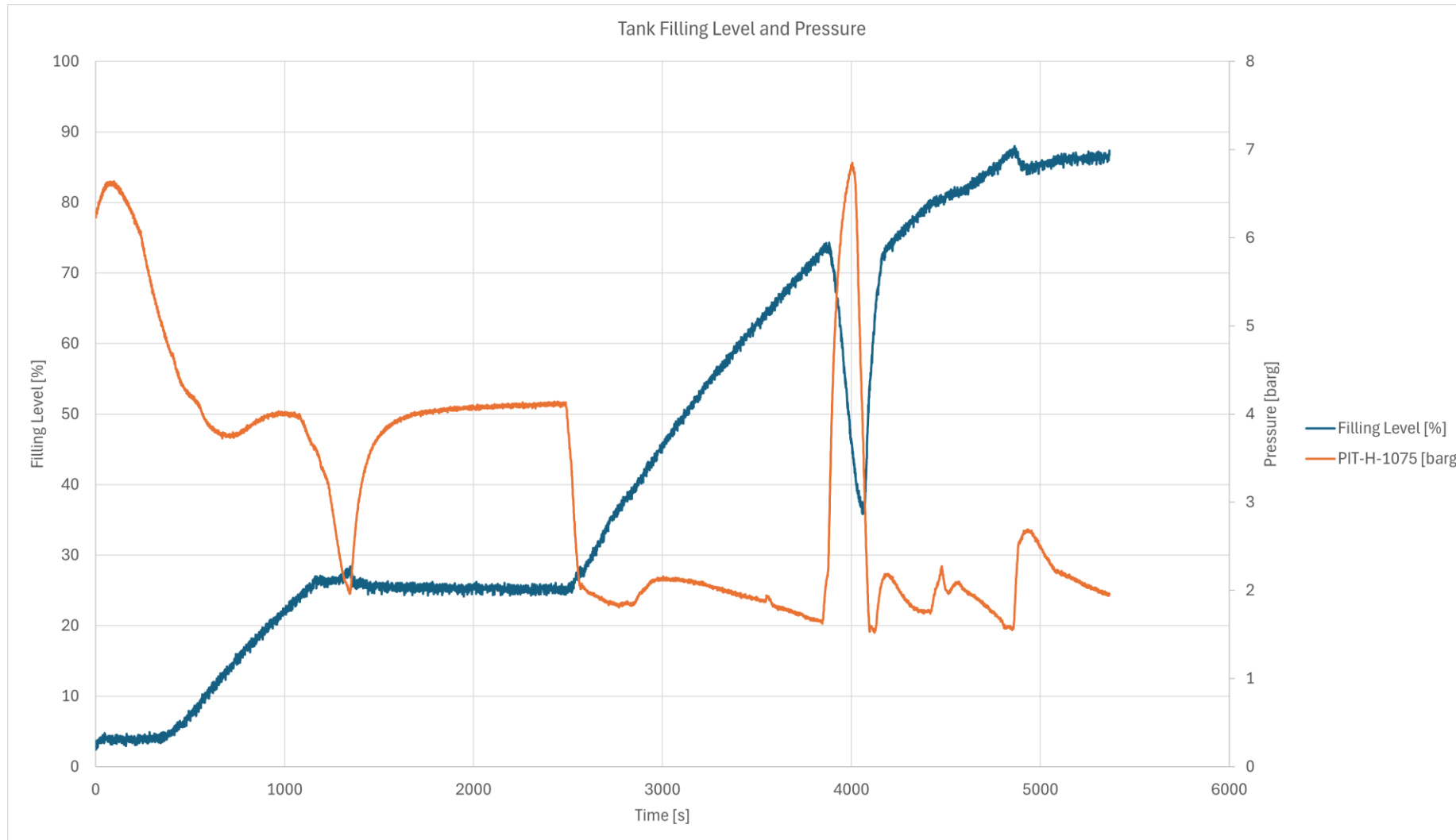
Parameter	LN ₂	LH ₂	Remarks
Trailer pressure level	8 - 10 bars with pump	5 - 8 (10) bars without pump	Without pump, trailer needs to pause filling and re-pressurise
Tank pressure level	Ambient to 8 bars	Ambient to 2 bars	All transfer tests conducted with open boil-off valve.
Tank filling level	Empty to 10 %	Empty / almost empty (2 % - 7 %)	Empty and thus “warm” tank is not recommended.
Tank temperature level	Ambient to „cold conditions“	Ambient to „warm conditions“ (80 K - 90 K)	Wall temperatures at 20 %, 50 % and 80 % filling level. Sensors have off-set.
Filling type	Bottom or top only, simultaneously or alternating*	Bottom or top only, simultaneously or alternating*	*Bottom and top filling lines are opened/closed via hand valves.

Task 3.2 LH₂ Transfer Activities - Results



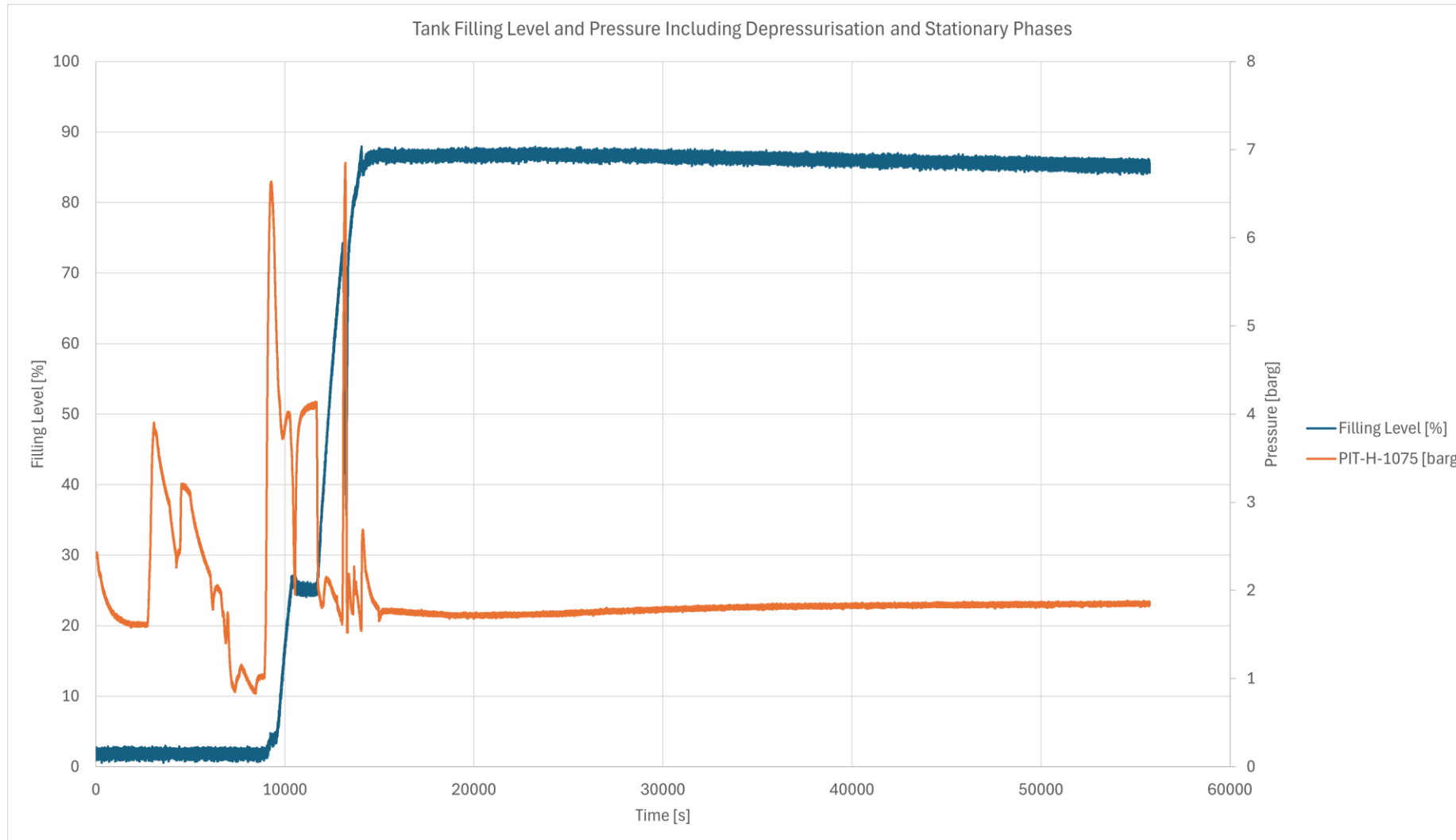
- Bottom filling only
- Temperature sensors show values too high.
- Problem with off-set seems to be the cause.
- Middle of the tank becomes warmest region.

Task 3.2 LH₂ Transfer Activities - Results



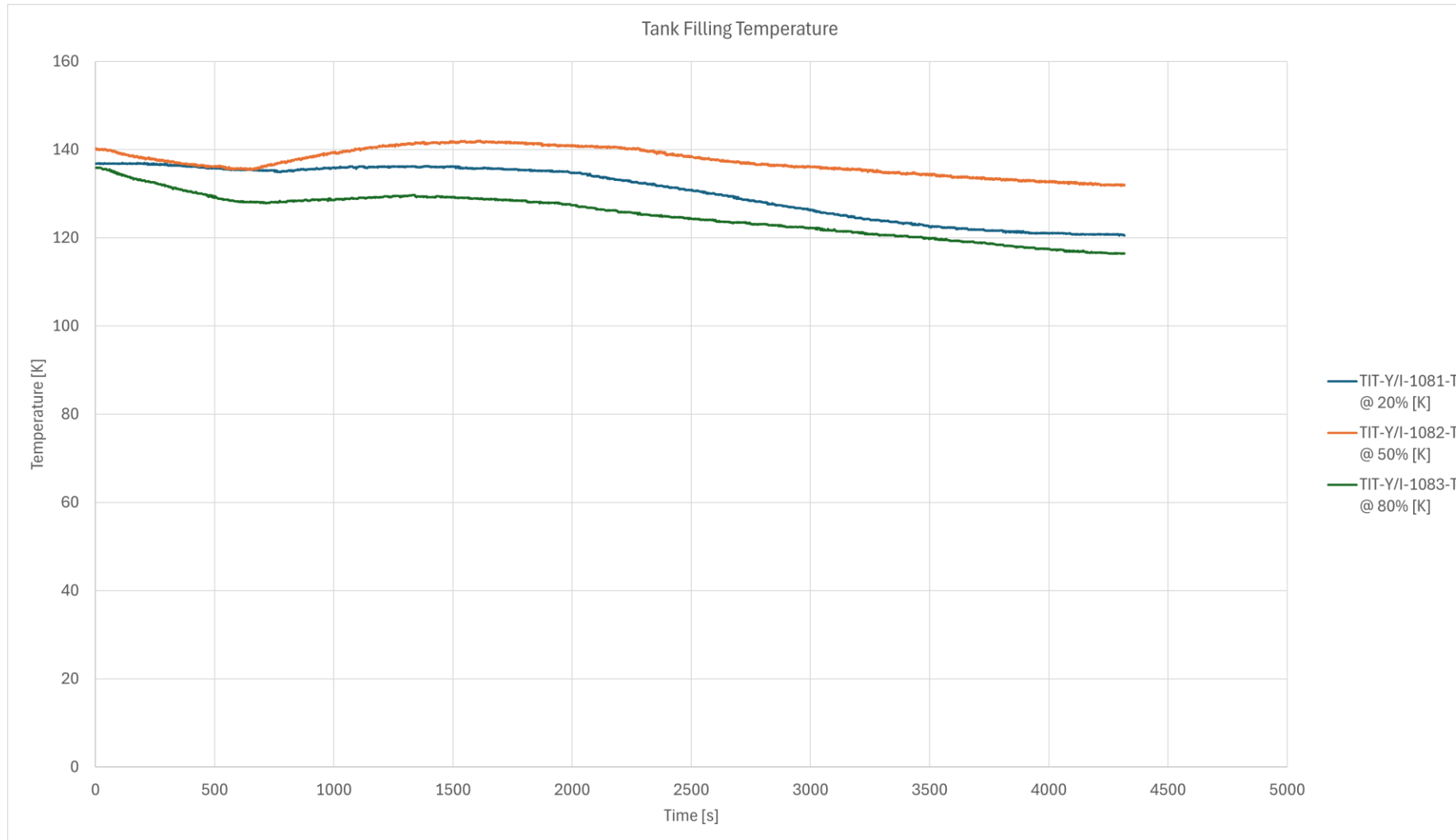
- LH₂ introduced in warm tank.
- Pressure release through boil-off by-pass to reduce Δp to trailer.
- Filling paused. Trailer had to re-pressurise. Pressure increase due to evaporation.
- Filling restarted, pressure drop.
- Near top, pressure spike (low ullage volume).
- By-pass opened for topping up.

Task 3.2 LH₂ Transfer Activities - Results



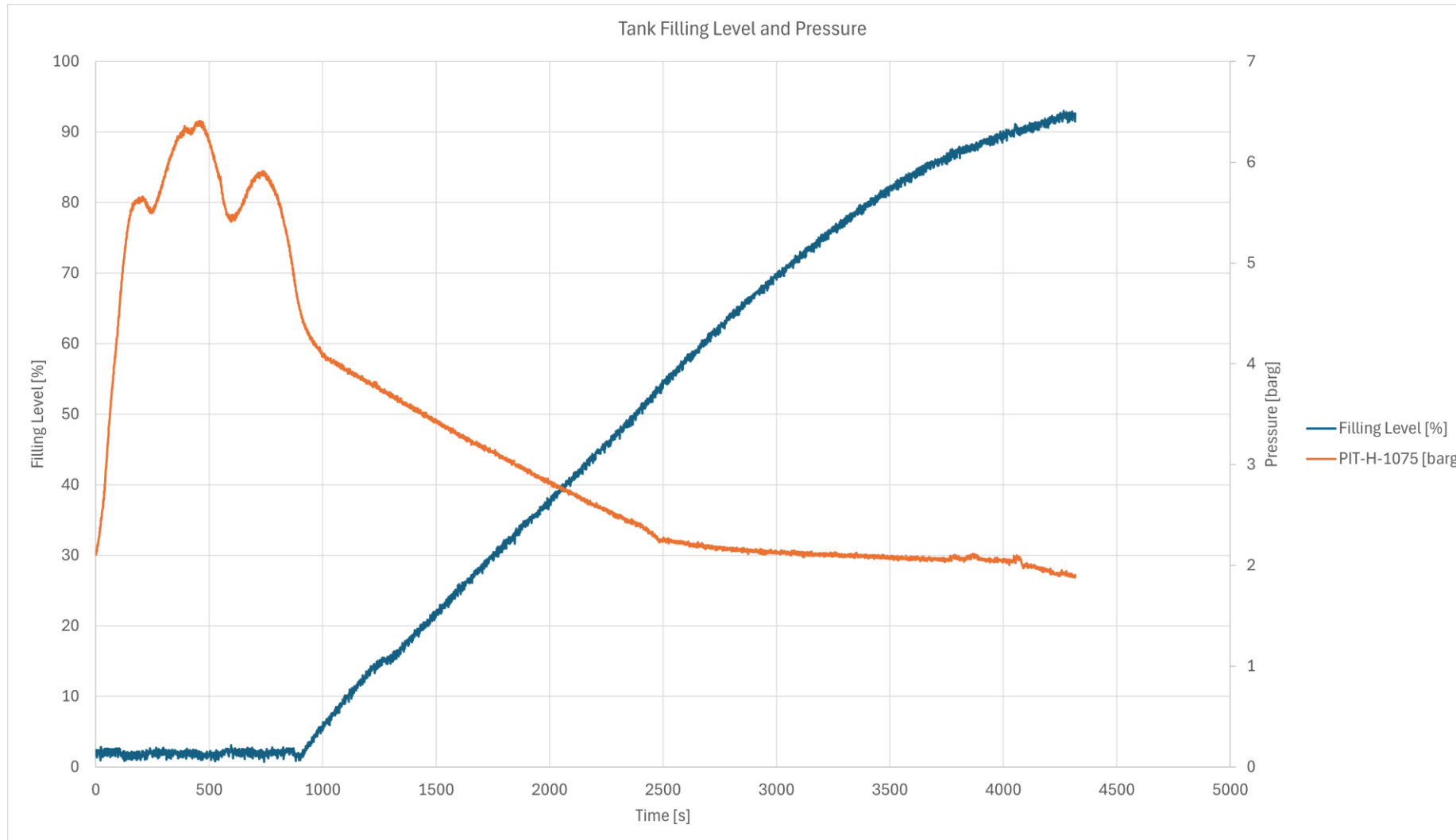
- Boil-off behaviour indicates bad vacuum insulation:
- Over the course of 12 h, from noon to midnight, the filling level drops from 87 % to at 85 %.
- Boil-off losses approx. at 4 % per day.

Task 3.2 LH₂ Transfer Activities - Results



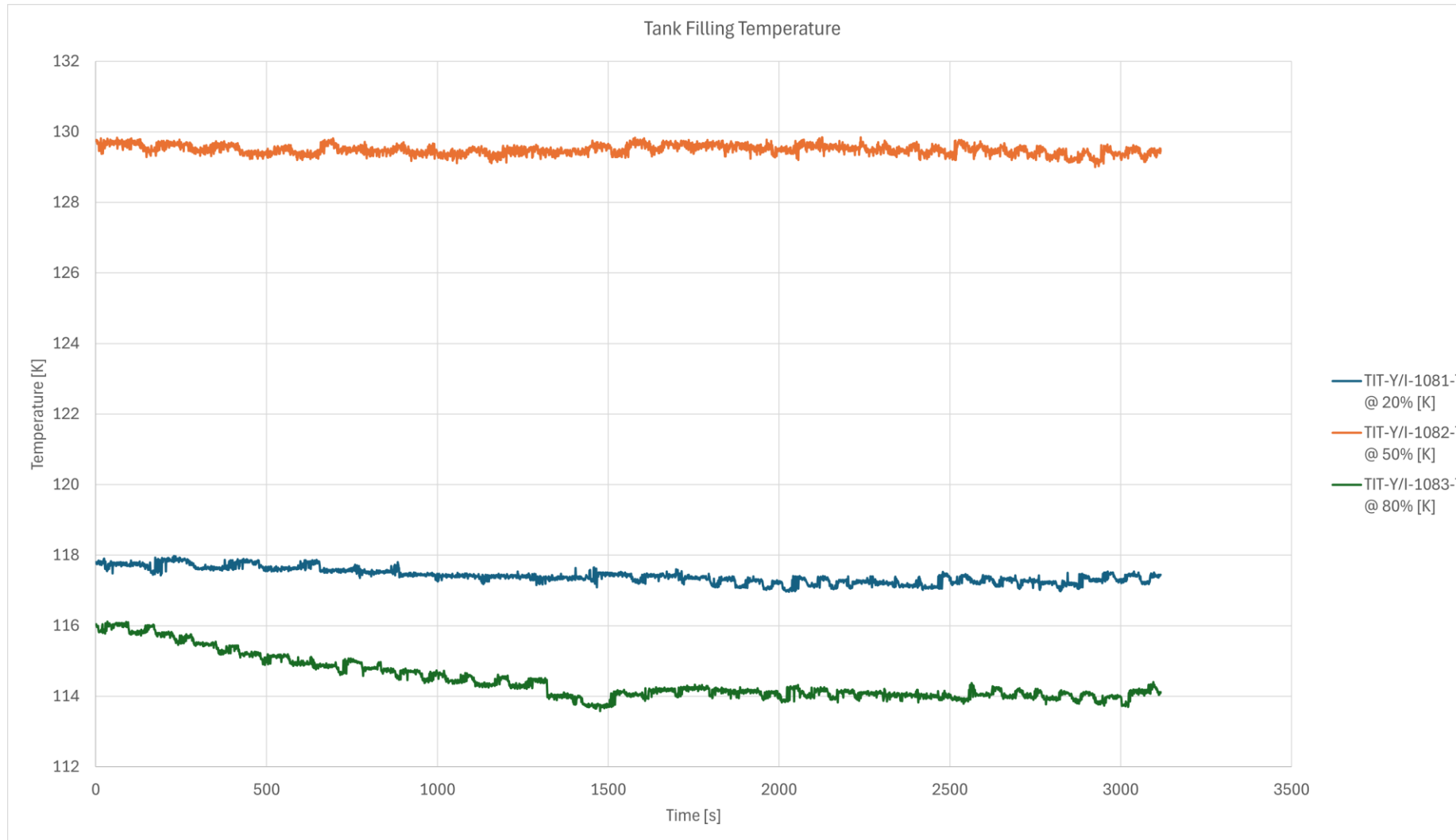
- Temperature distribution due to top filling.
- Warmest region in the middle of the tank.

Task 3.2 LH₂ Transfer Activities - Results



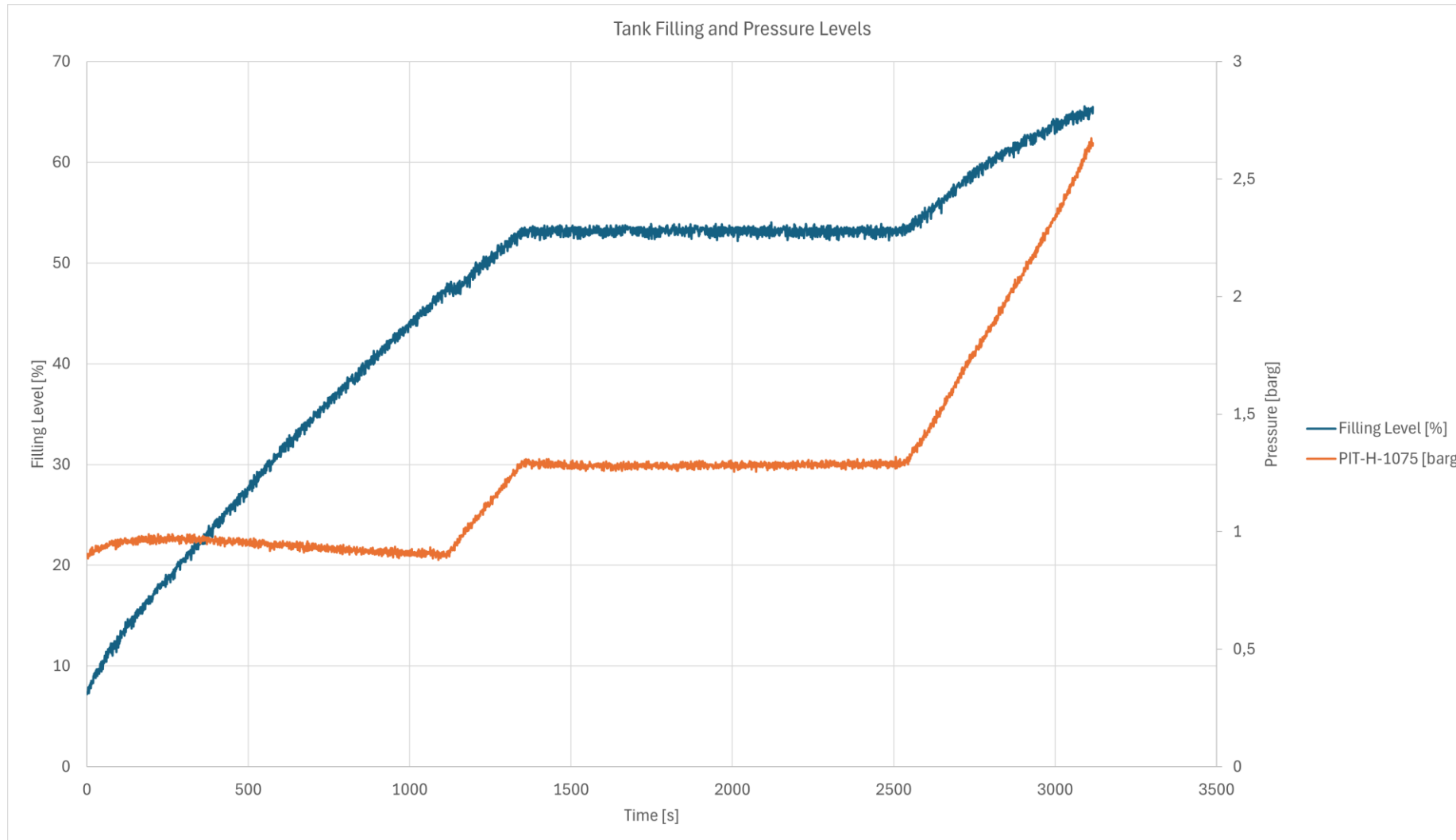
- “Warm” tank top filling, only evaporation.
- High pressure, which cannot be relieved, not even with by-pass.
- No mass transfer.
- Huge losses.
- Significant mass transfer only possible after switch to bottom filling.

Task 3.2 LH₂ Transfer Activities - Results



- Temperature distribution with simultaneous top and bottom filling.
- Warmest region in the middle of the tank.
- Temperature read out seems odd, since there is no significant drop. Cause unknown.

Task 3.2 LH₂ Transfer Activities - Results



- Pause in filling procedure due to re-pressurisation of trailer (plateau).
- Smooth filling procedure.

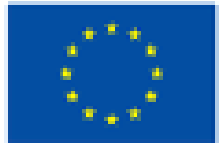
Summary and Conclusion

- Hardware problems with e. g. tank insulation and temperature sensor off-set impacted abilities to test and produced less favourable results in terms of accuracy.
- High boil-off rate → high losses → weekly re-fill → costly
- Although sensor data not accurate, i. e. TT off-set, behaviour could be assessed.
- At least with a warm tank, top filling only is not recommended.
- For this specific setup, the filling process proposed by manufacturer proved to be impractical → alternating with hand valves.
- Bottom filling only or both bottom and top filling simultaneously seem to be the best filling types.



Thank you for your attention

Daniela.lindner@dlr.de
Benjamin.broesicke@dlr.de



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