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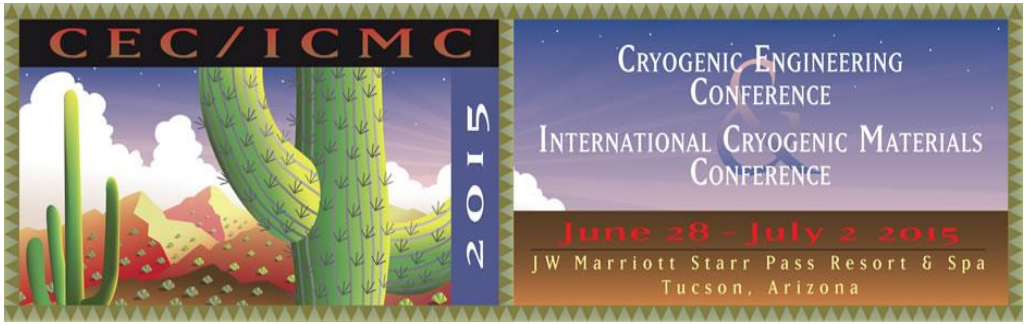
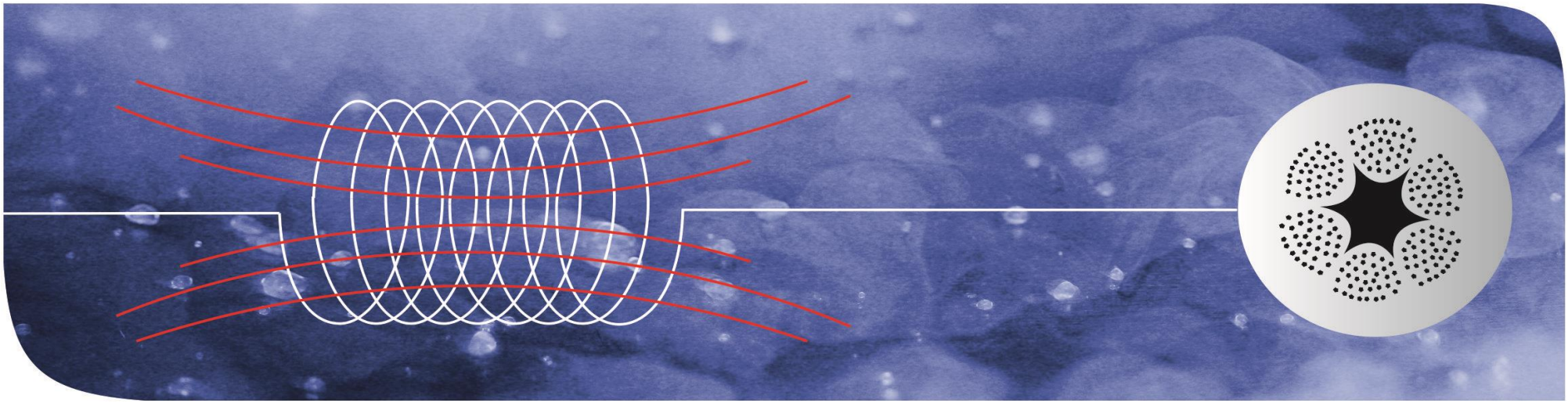


A conceptual study on the use of a regenerator in a hybrid energy storage unit (LIQHYSMES)

Institut für Technische Physik | Kryotechnik



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Summary

1. **Motivations**
2. **Considerations on the use of H_2**
3. **Idea: *Liq-Hy-SMES* layout**
4. **Configuration: material choice and design**
5. **First results and comments**
6. **Future developments**

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Motivations

- **Germany: Grid intermittency due to Wind and Solar component (more than 30GW each)**
- **Strong imbalances between suppliers and customers (not available when needed)**
- **Need of accurate control to stabilise the grid and to deliver the required energy when used (forecast intermittency)**
- **Big concern in high demand energy industry due to abrupt shut down**
- **Correlations for heat transfer coefficient, through a sophisticated temperature measurement system using Fiber Bragg Grating sensors**

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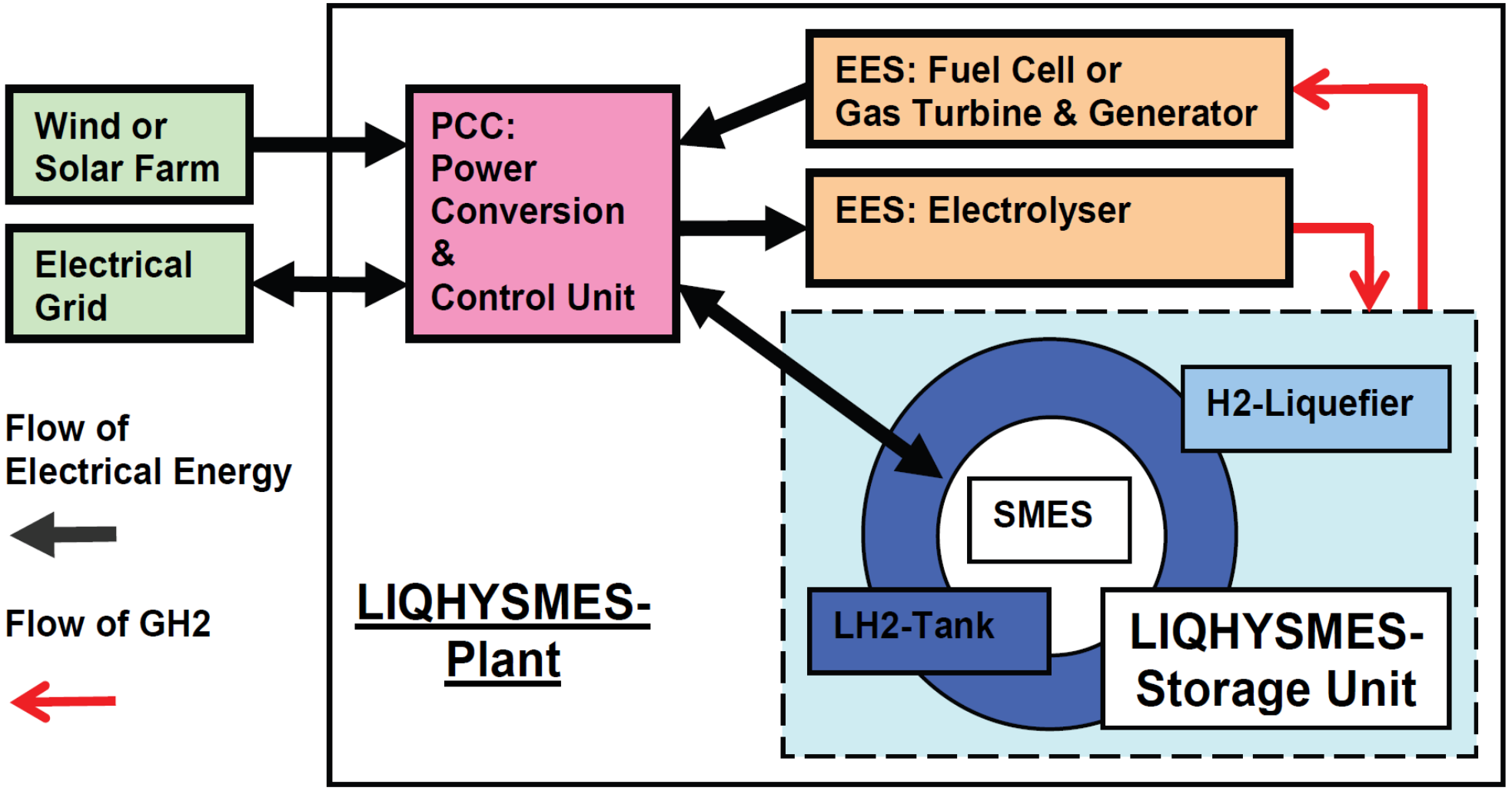
On the use of Liquid H_2

- *Offers a relatively efficient method of moving significant volumes*
- *Independence of specific storage materials (porous/nano-structured) or geological formation*
- *Problem: removing enough heat from the gas in order to liquefy it costs a lot of energy!*
- *Consequently the more energy we use to liquefy it, the more its value as a fuel/energy carrier is reduced*
  - *Moreover: (and especially for this project):*

    Small process ⇒ *High inefficiency*
- *Slow reaction time for the electrical grid*

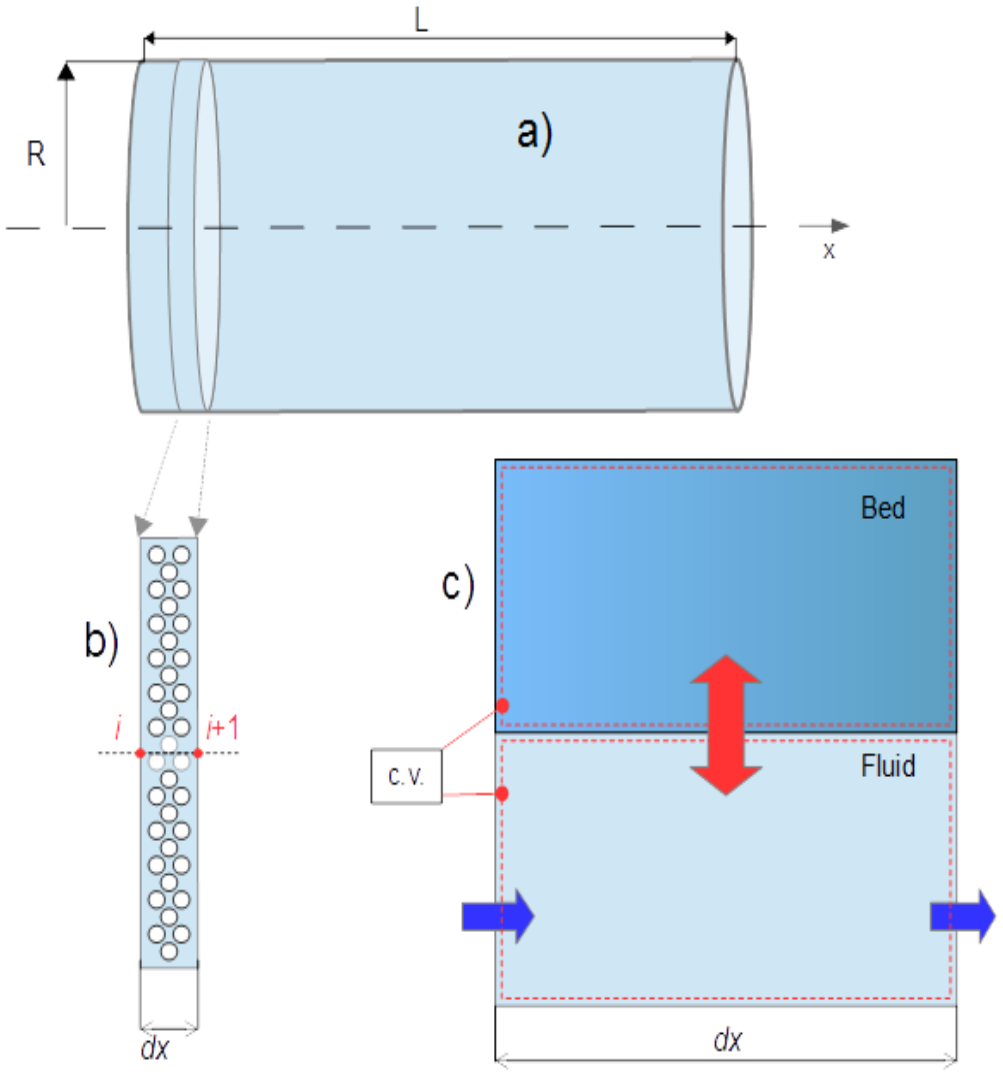
IDEA: Liq-Hy-SMES layout



Sander & Gehring: LiQHYSMES – A novel energy storage concept for variable renewable energy sources
IEE Transactions on applied superconductivity, vol.21, no.3, June 2011

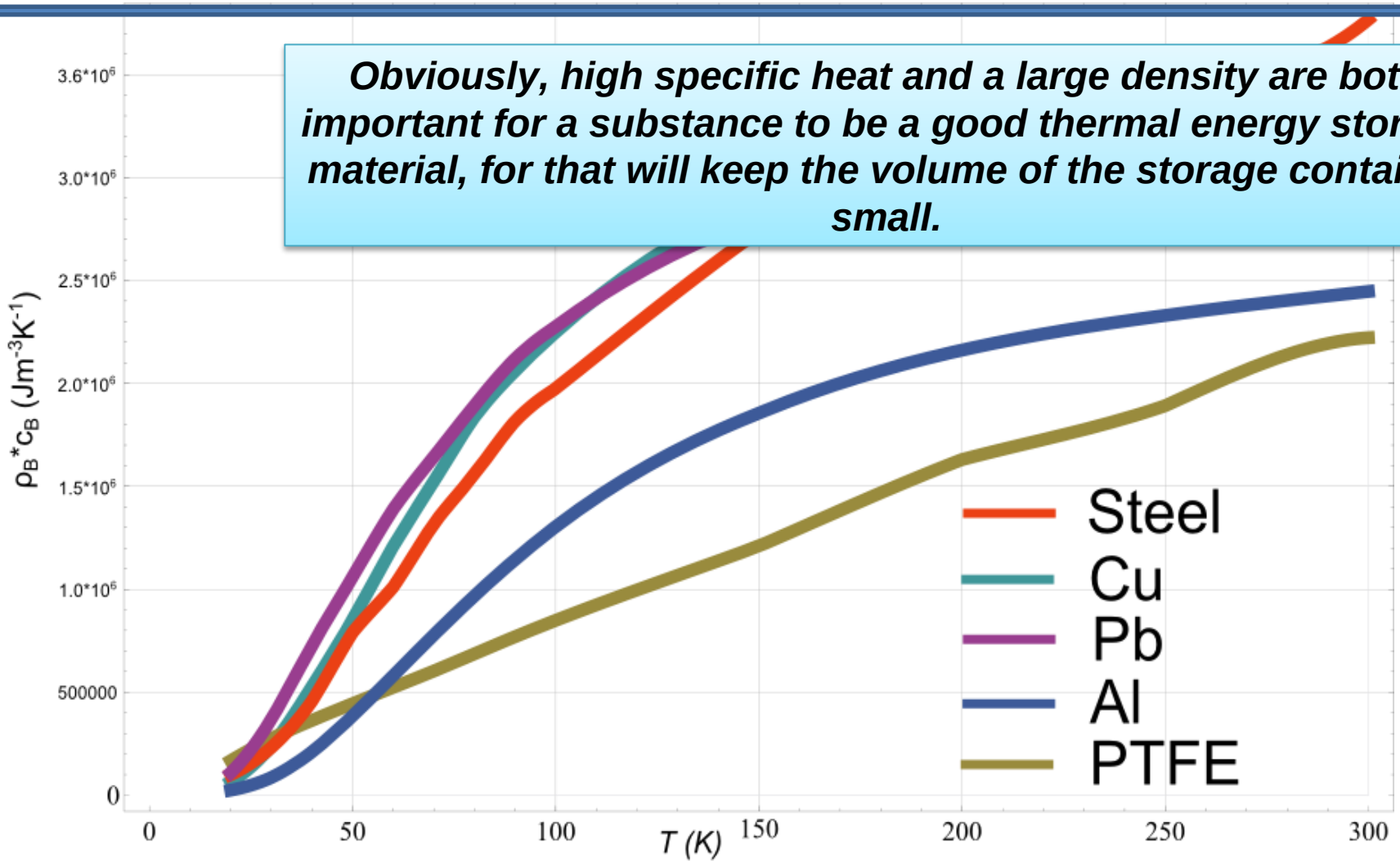
Configuration: material choice and design

- *Uniform radial distribution (fluid and material)*
- *Axial heat conduction negligible if compared with the convective heat transfer*
- *Packed bed of spheres: only a point of contact between the spheres*
- *No heat loss from the walls of the regenerator to the surroundings during the filling/emptying process*
- *Entrained heat capacity of the fluid is considered negligible*



Configuration: material choice and design

Obviously, high specific heat and a large density are both important for a substance to be a good thermal energy storage material, for that will keep the volume of the storage container small.



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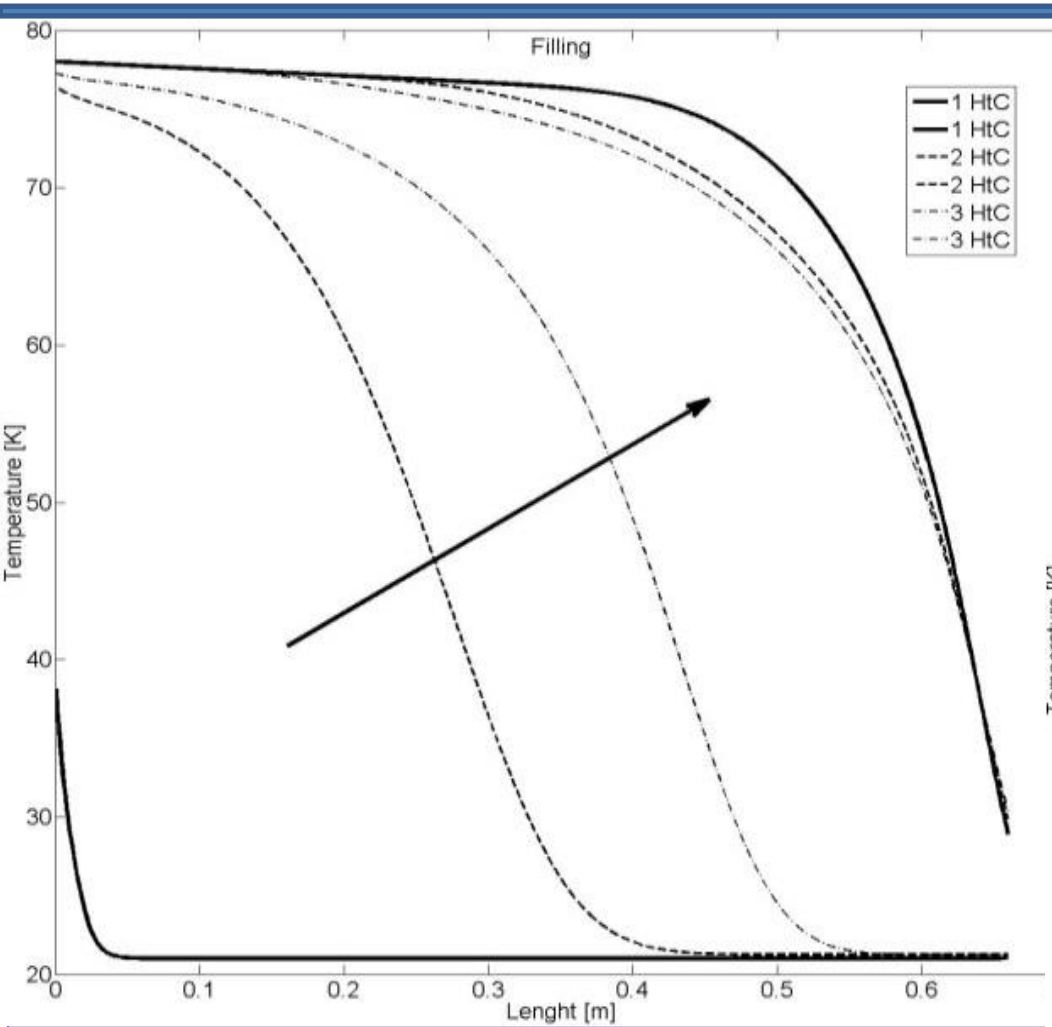
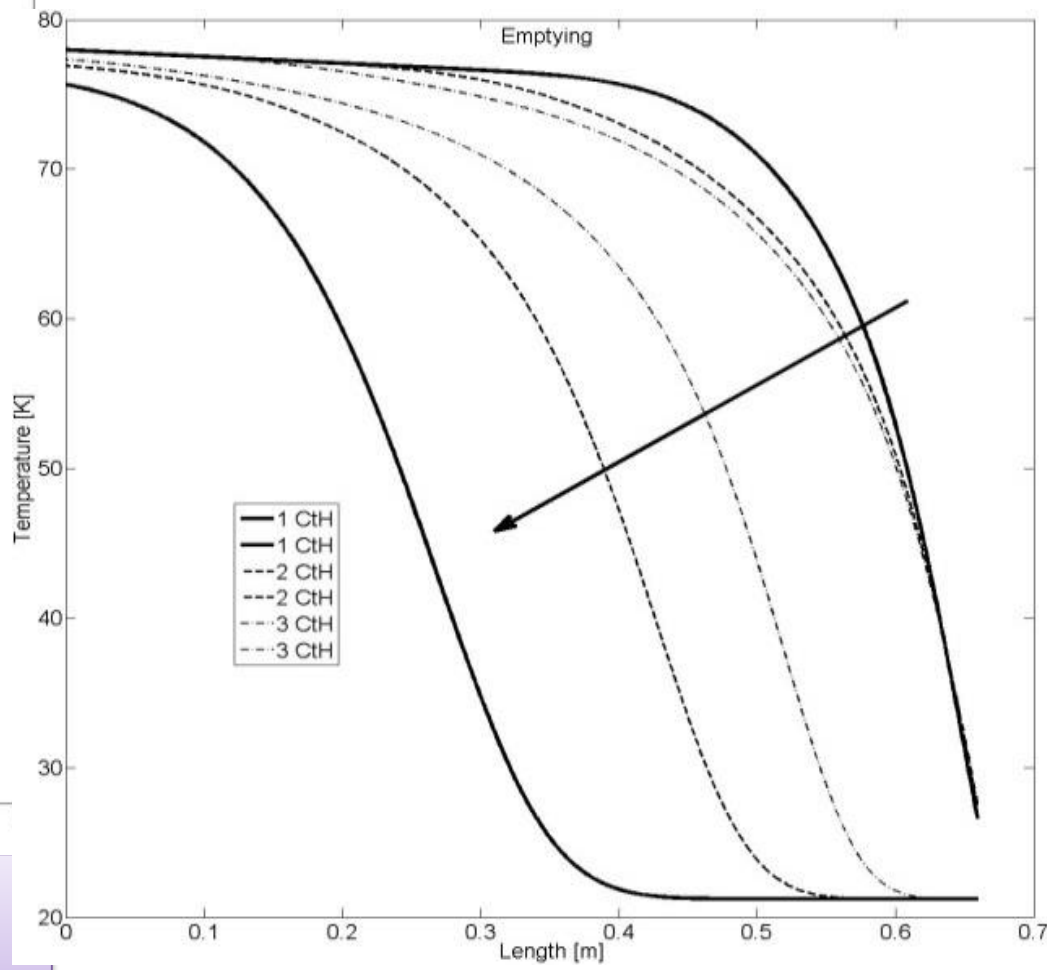
Results and comments -1

Temperature profiles at 10 MPa





But ideally, fluctuations are within 3-5% of the total capacity

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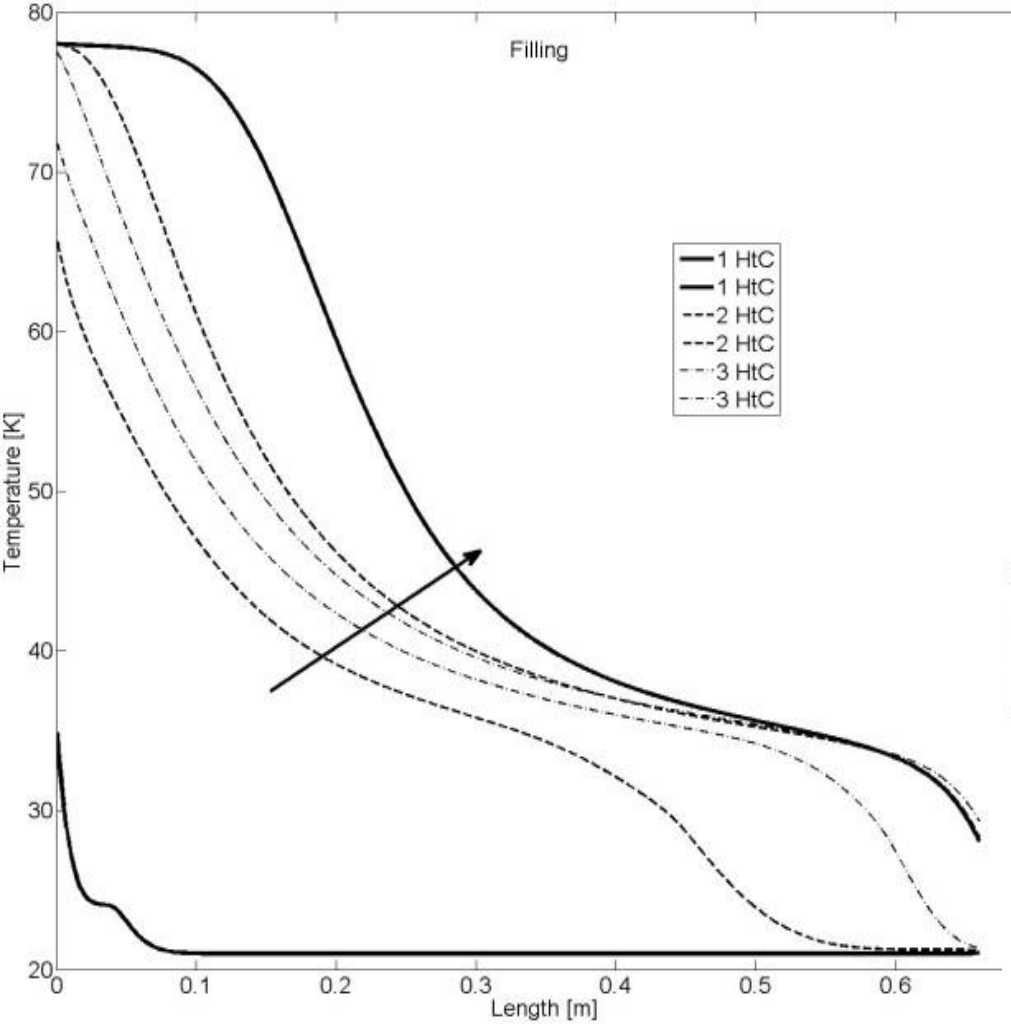
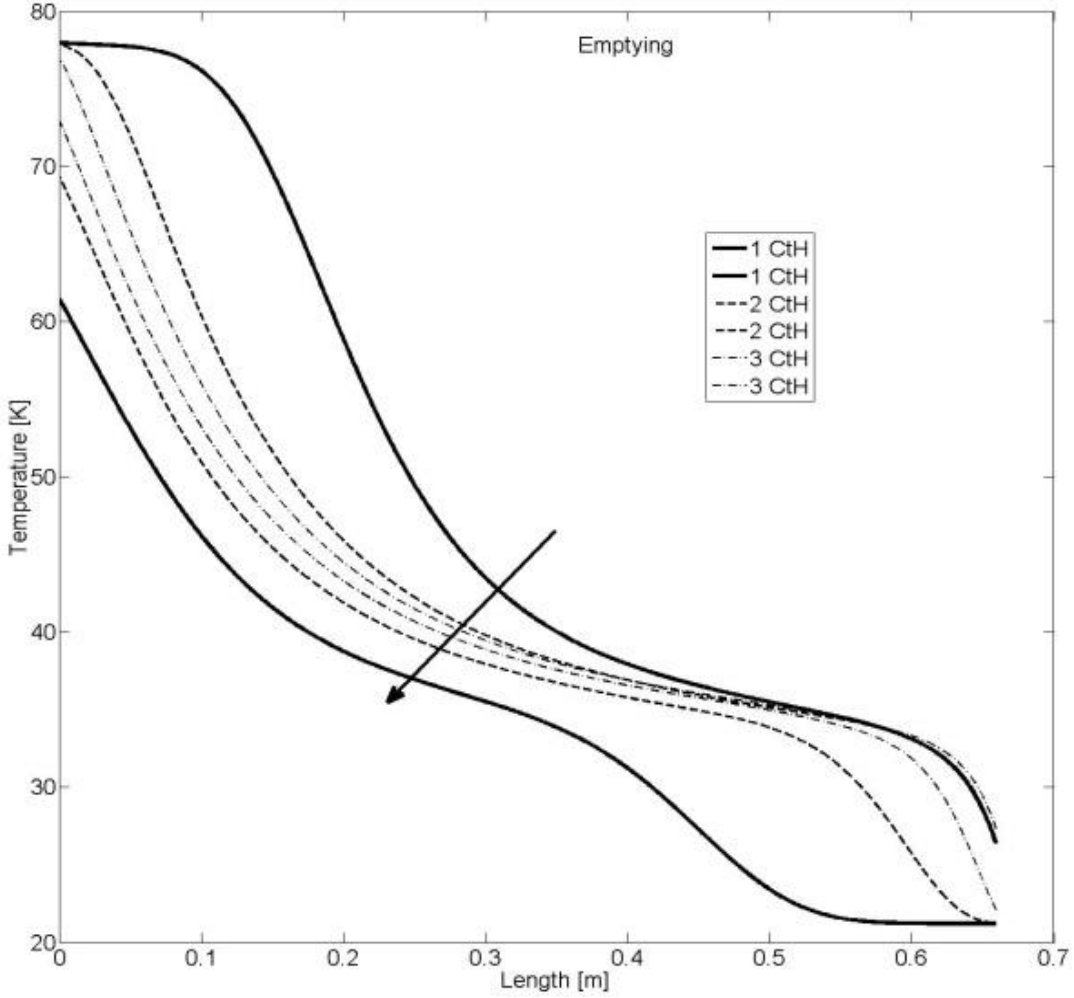
Results and comments -2

Temperature profiles at 1.4 MPa





Results and Comments -3

Why the regenerator perfomances are decreasing....

Which issues does a regenerator have using hydrogen?

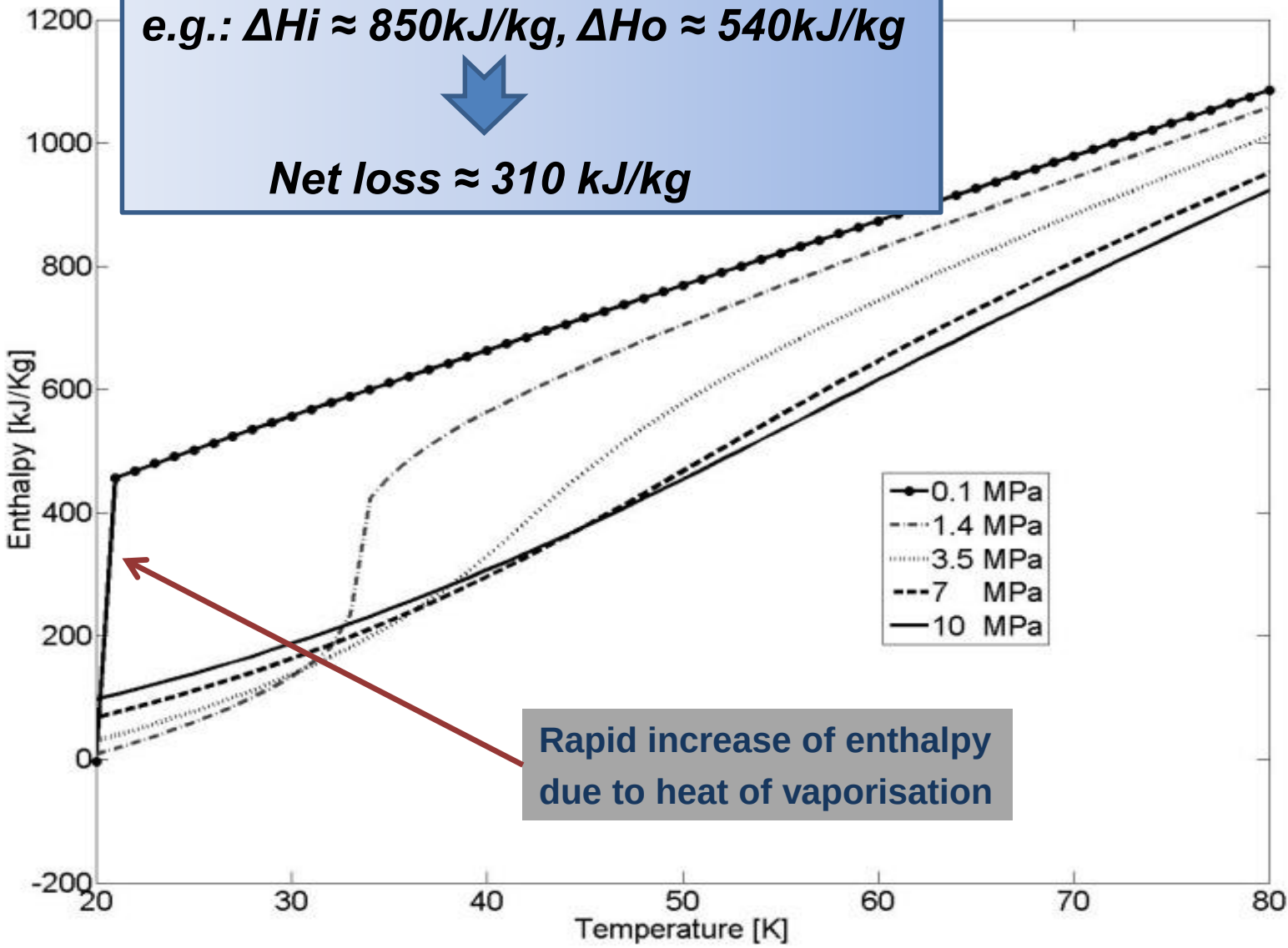
Above 80K, the slope is similar for 40bar and 1bar

Consistent deviation below 70K

Smaller cooling capacity of the gas leaving the bath

e.g.: ΔHi ≈ 850kJ/kg, ΔHo ≈ 540kJ/kg

Net loss ≈ 310 kJ/kg



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Results and Comments -4

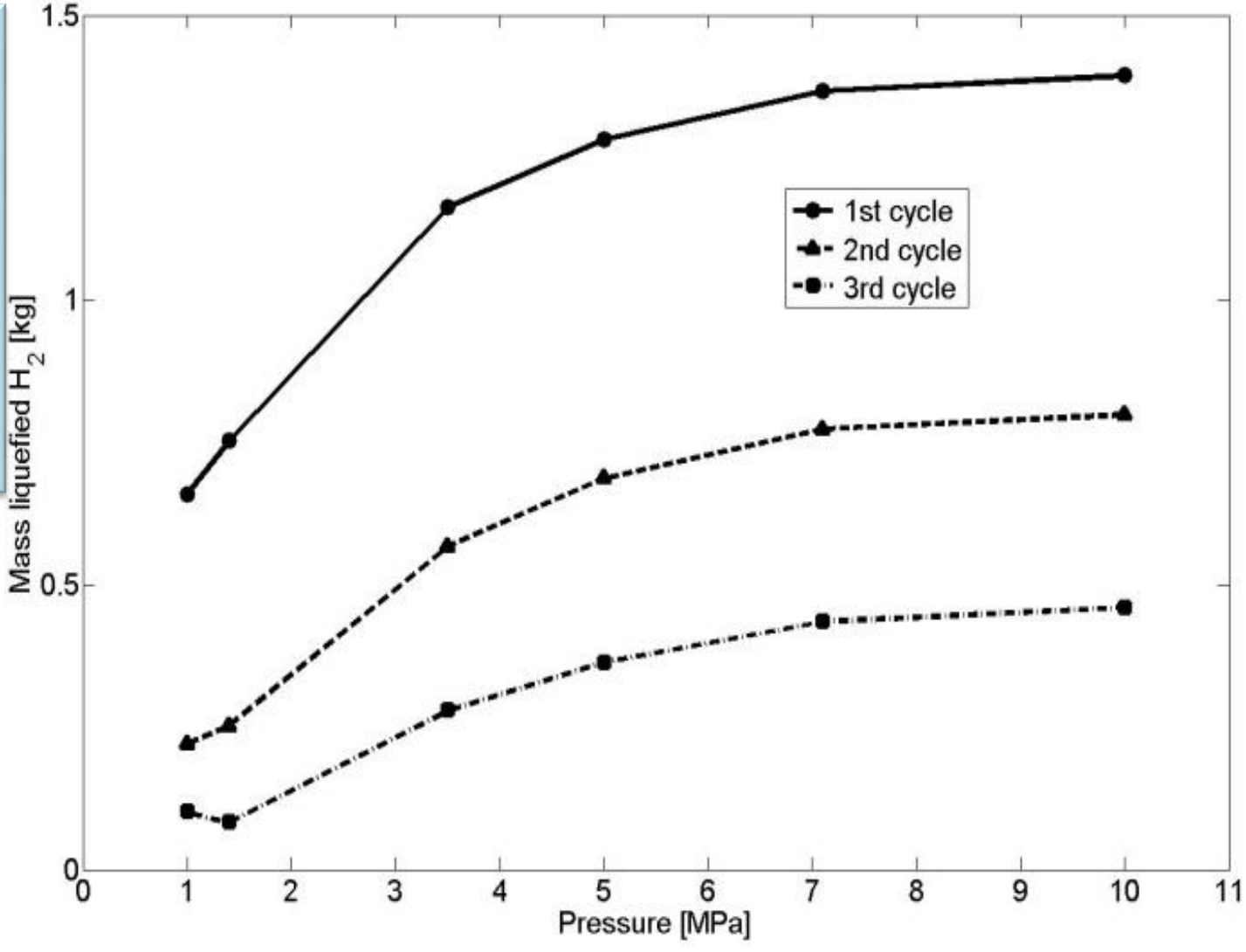
Production of liquid hydrogen

Regenerator loss of storage capacity during each cycle

Less liquid hydrogen is produced

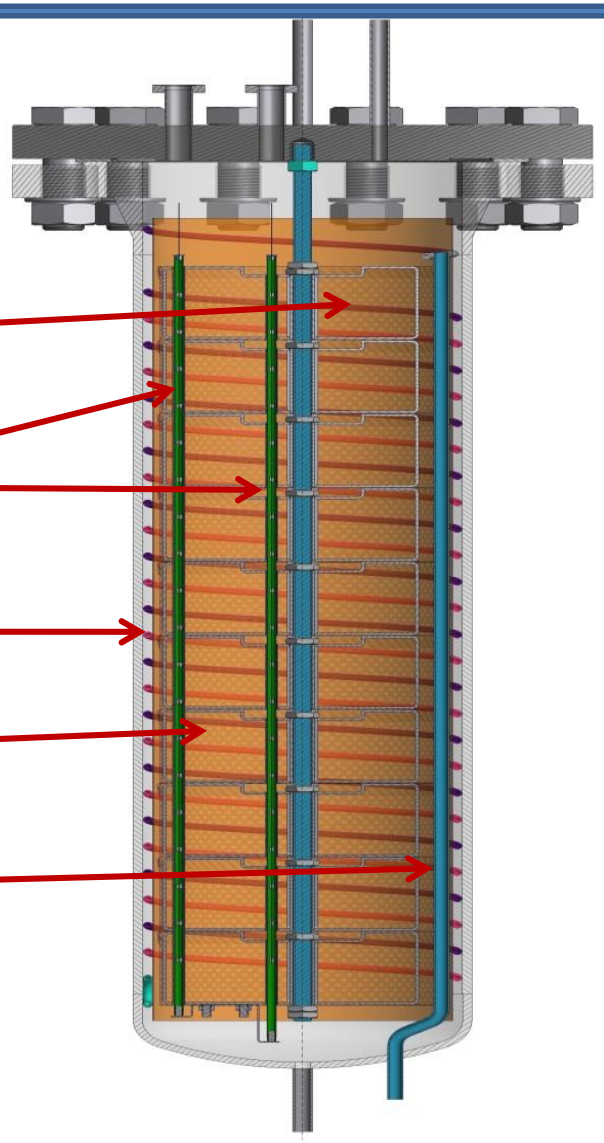
Increasing too much the max working pressure

No appreciable effects on the mass of liquid hydrogen



Final design

- Filling material: *lead*
- 2 or more lines for sensors
- Internal shielding
- Modular system
- Returning gas pipe



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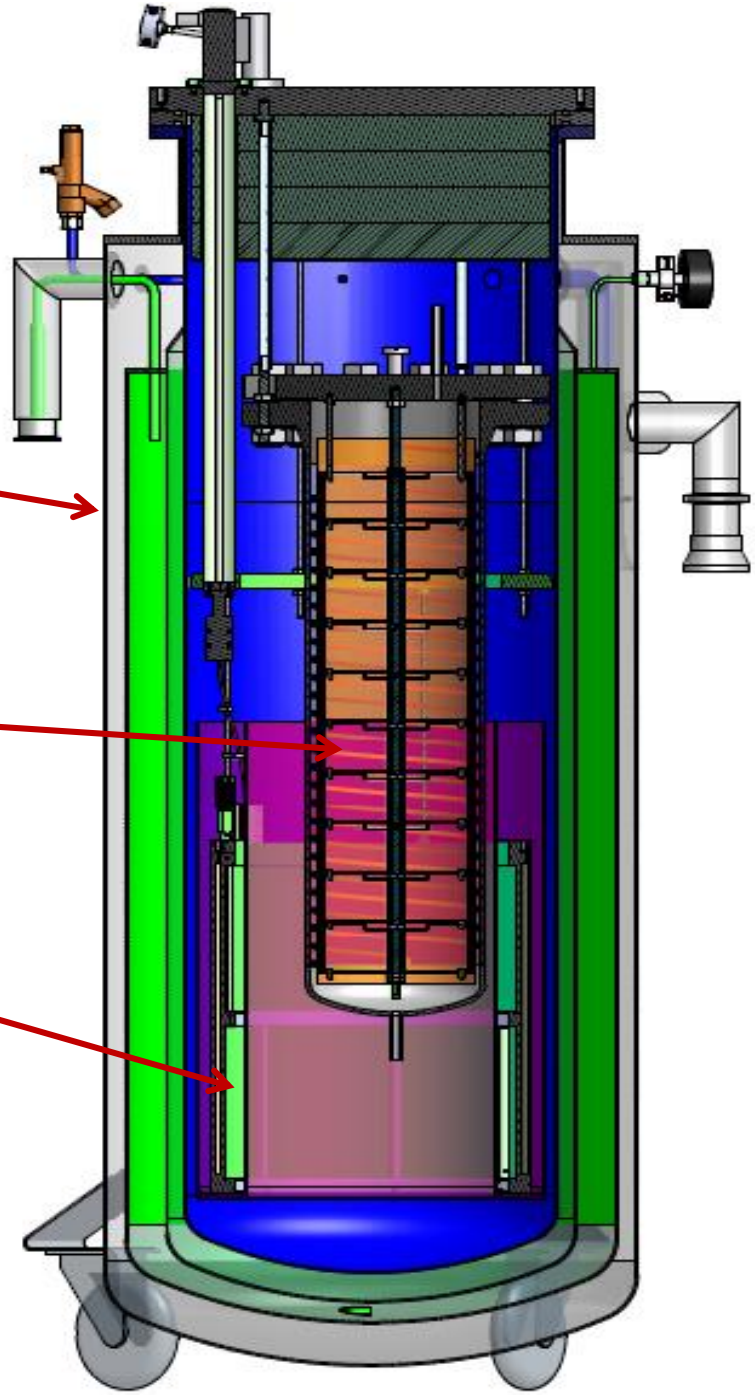
Global view

Liquefaction capacity: about 10l in 30min



SMES

MgB_2 wiring about 1km magnetic field 1.5-2T for 10-20kJ with a superconducting transition temperature of about 40K. Current leads cooled with evaporating hydrogen.

Future development

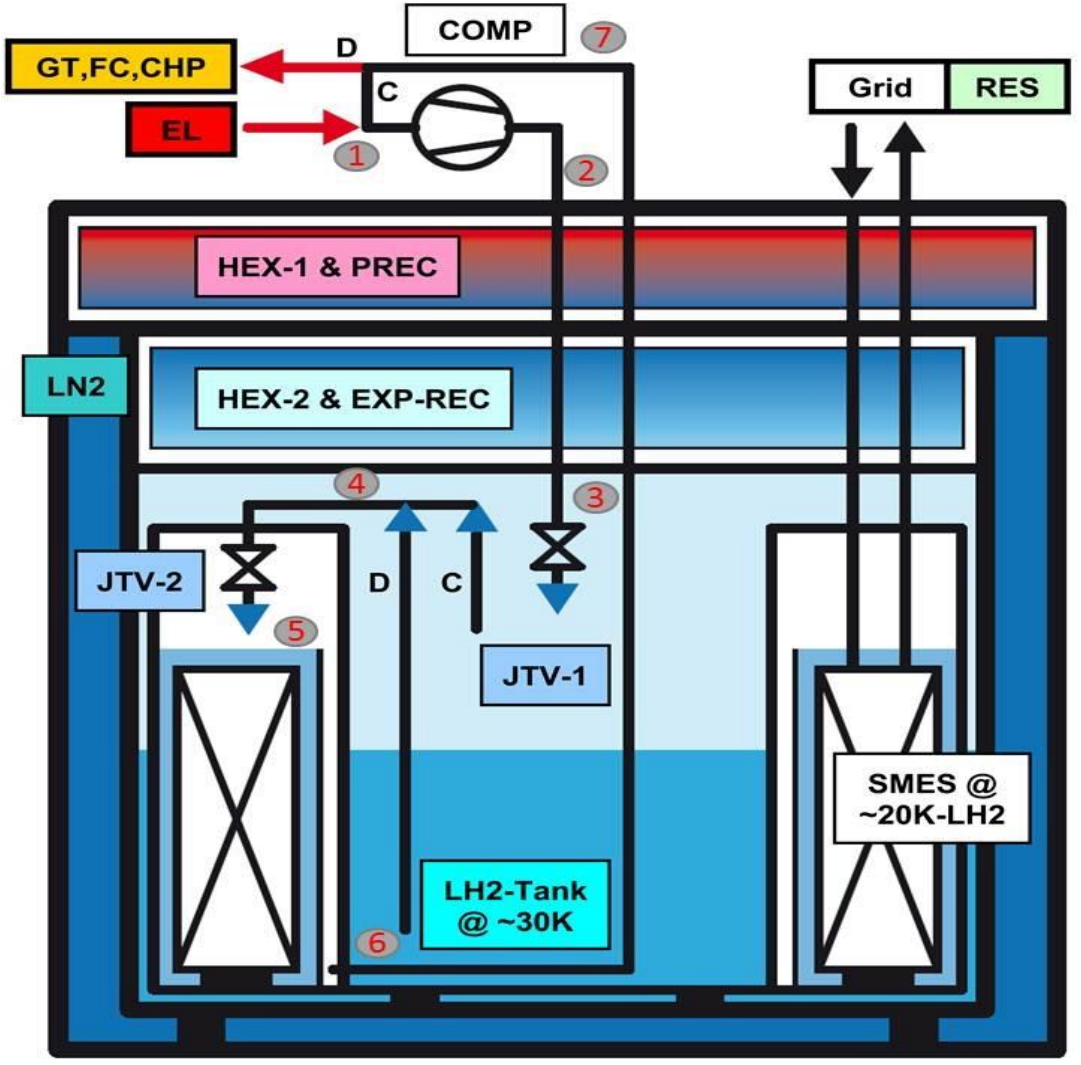
2 J-T stages:

1) 30K at 10bar

2) 20K at 1.2bar

Disadvantage: lower specific density (50kg/m3 at 10bar and 70kg/m3 at 1.2bar)

Advantage: reduced cooling requirements for gaseous H_2 before expanding in J-T



•*Sander et al. LiQHYSMES – Liquid H2 and SMES for renewable energy applications International Journal of Hydrogen Energy 39 (2014) 12007-12017*

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Thank you

for

your attention