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Cold Thermal Energy Storage for refrigeration systems: Current status and future perspectives

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Overview

- Background and current status
- What is Cold Thermal Energy Storage (CTES) and Phase Change Materials (PCM)?
- Development of a CTES unit and test facility for CO_2 refrigeration systems
- Results
- Lessons learned and future perspectives

Background and motivation

- Industrial refrigeration systems in food processing plants often have large peaks in the refrigeration demand
- Case study:
  New poultry processing plant Norsk Kylling in Orkanger
  – R744/R717 cascade plant
- Refrigeration loads refrigeration plant:
  approx. 1 MW @ -40 °C freezing
  approx. 6.5 MW@ -5 °C chilling/cascade

If we aim to obtain peak shaving of the refrigeration demand, high capacity and heat rates are required from storage!

Current situation and aim of research

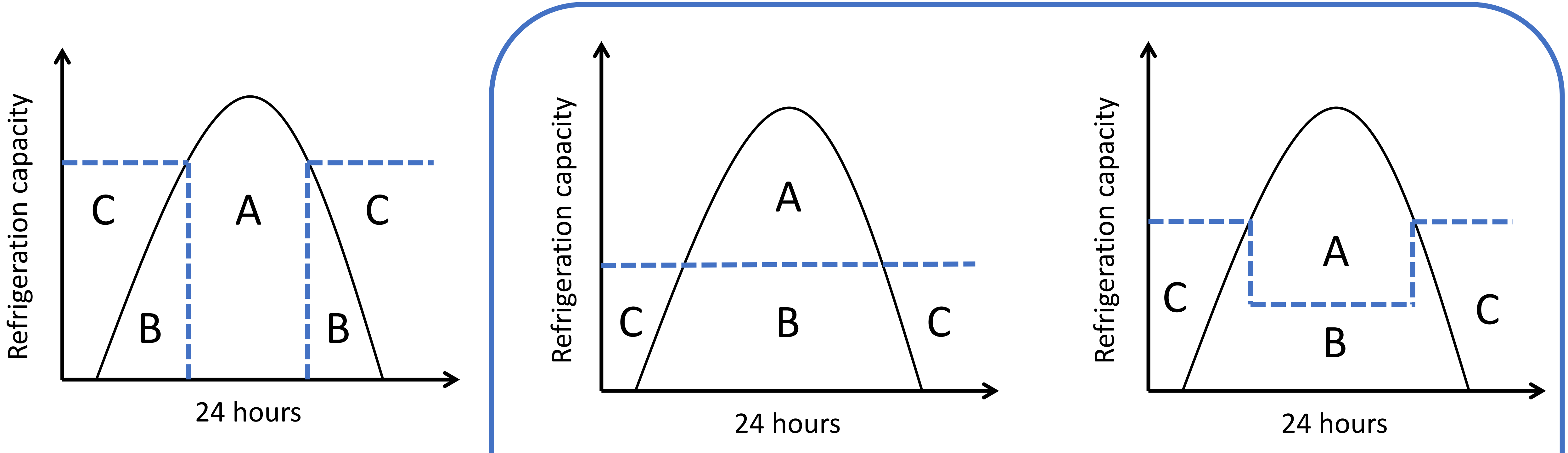
Current situation

- CTES normally integrated into **secondary refrigerant circuit** (glycol, brine, ice water…)
  → Increased energy demand during charging due to decrease in evaporation temperature
- Most designs based on pipes → limited heat transfer area
- Limited installations in the field → Tailor-made solutions results in increased costs
- Ice/water is the most commonly investigated storage material → limits storage to 0°C

Target: Increase competitiveness

- Development of CTES unit that can be integrated in the **primary refrigerant circuit** that provides a **high discharge rate**, sufficient **capacity** with a **flexible** design that can be easily **upscaled**
- Test PCM with phase change temperature below 0 °C
- Characterisation of the CTES unit by **lab testing** under controlled conditions
- Identity potential for **further improvement** and implementation

What is Cold Thermal Energy Storage (CTES) and how does it work for refrigeration system?



a) Full storage

b) Partial storage with load levelling

c) Partial storage with load limiting

Refrigeration system

Refrigeration load

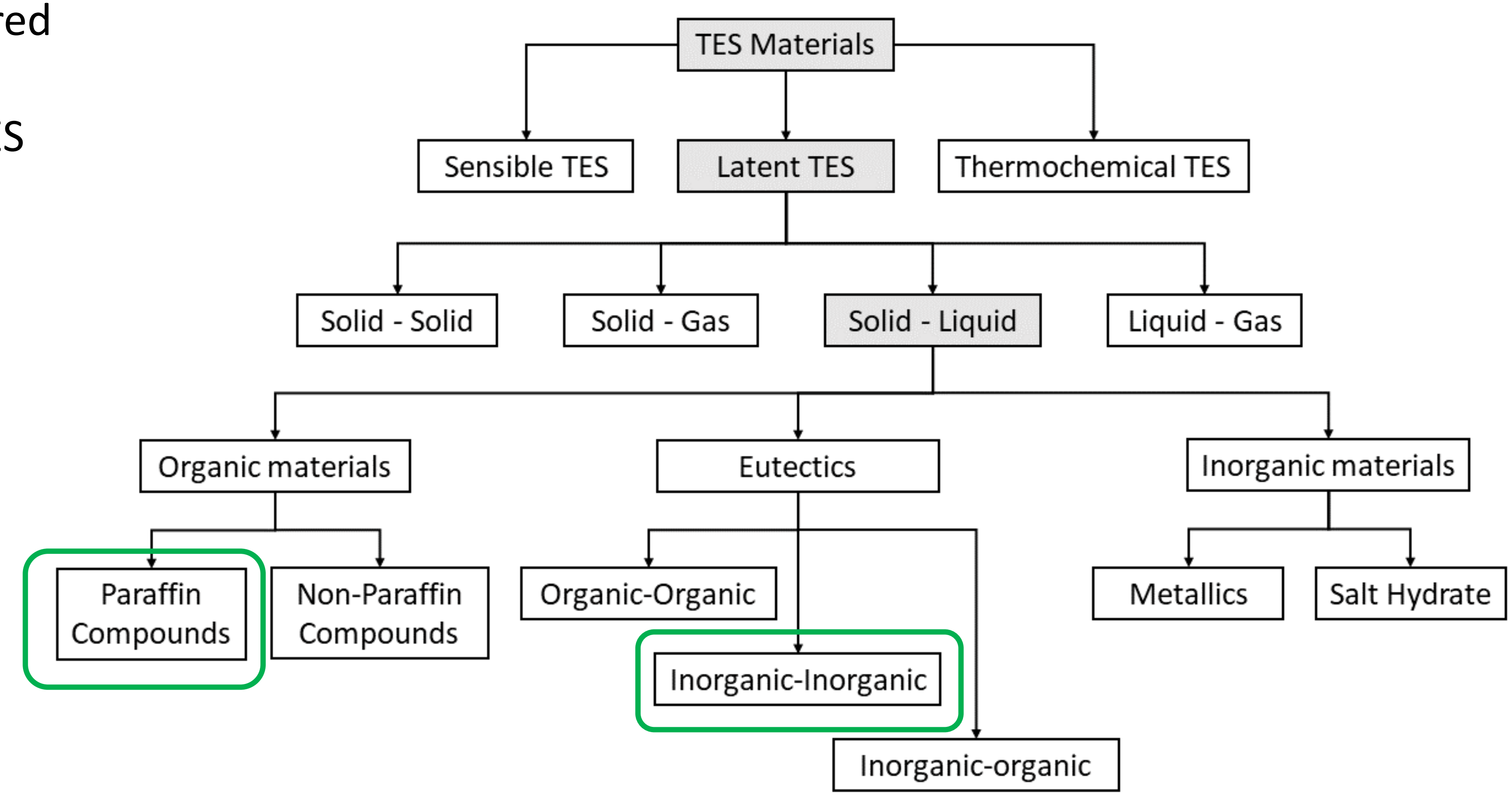
A – Load covered by storage

B – Load covered by refrigeration system

C – Storage charged by refrigeration system

What are phase change materials (PCM)?

- Materials where the energy is stored as **latent** heat
- Mainly two groups of PCM for CTES (< 10 °C):
  - Mixtures of alkanes (paraffin)
  - Eutectic mixtures of salt hydrates and water
- We selected RT-9HC (Rubitherm)
  - -9.6 °C



CRODA

PLUSS TECHNOLOGY FOR A BETTER WORLD

PureTemp

Climator moving energy in time

microtek laboratories, inc

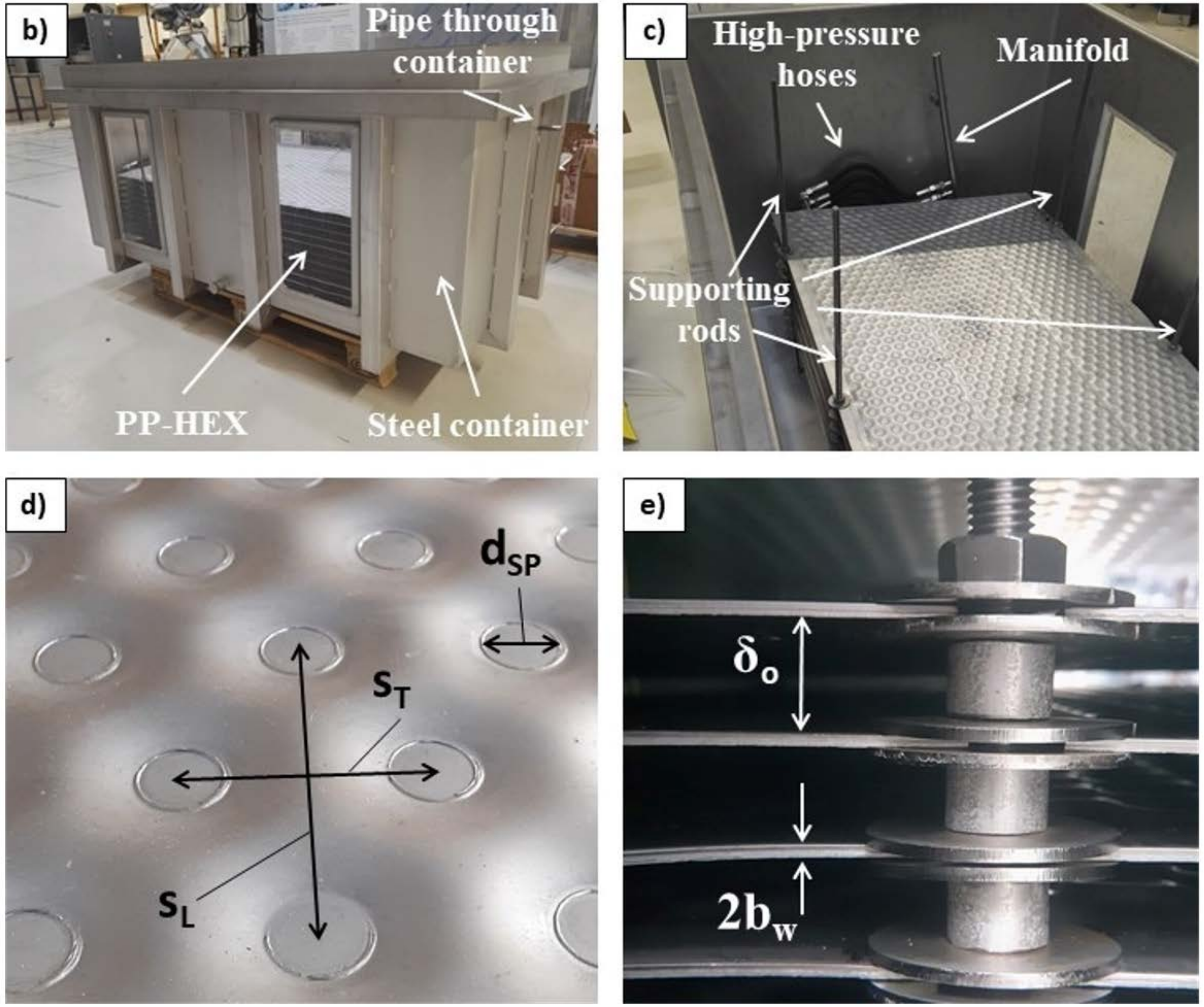
savENRG Phase Change Material

AXIOTHERM

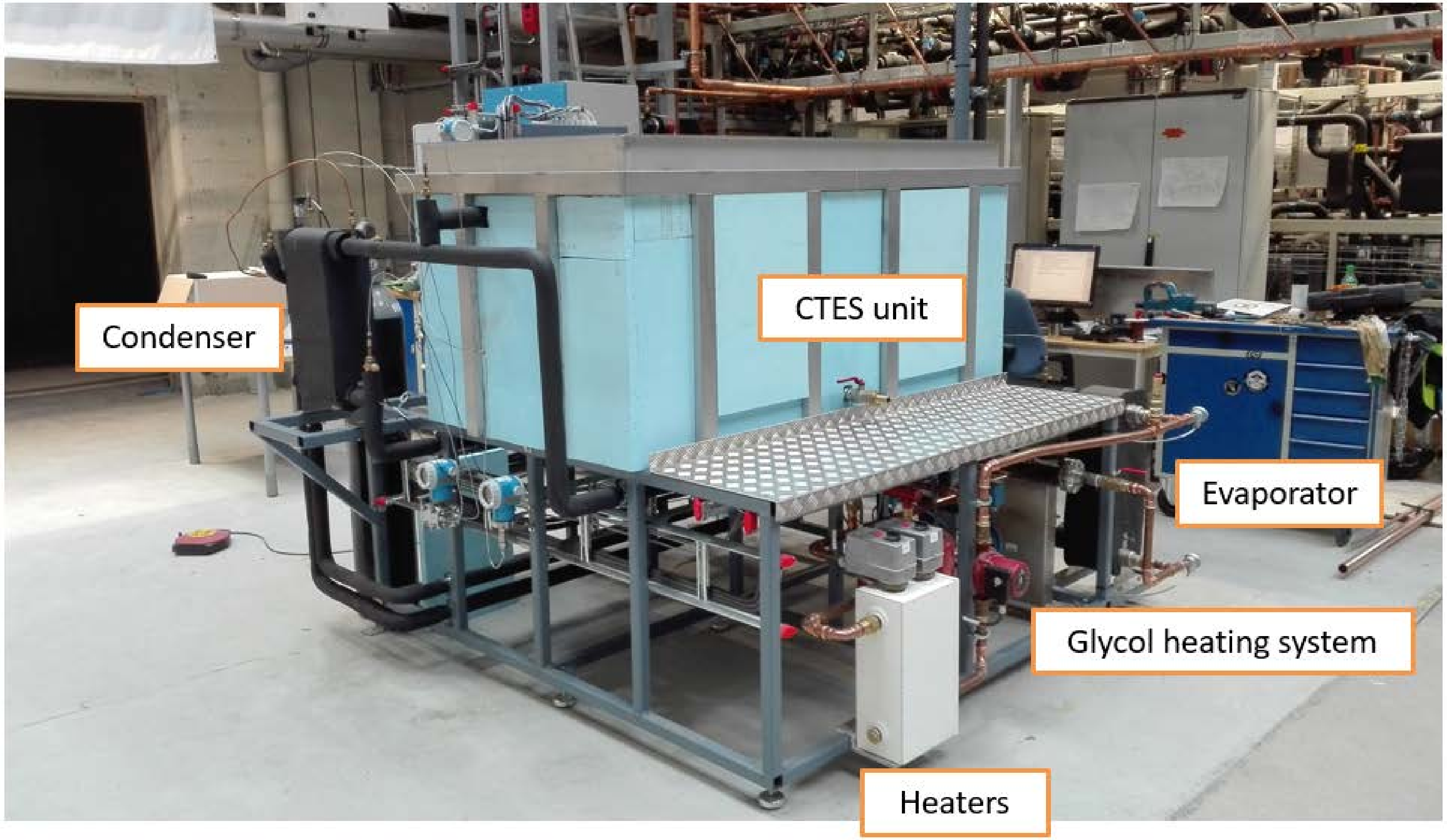
RUBITHERM PHASE CHANGE MATERIAL

Development of CTES for CO_2 refrigeration systems using PCM

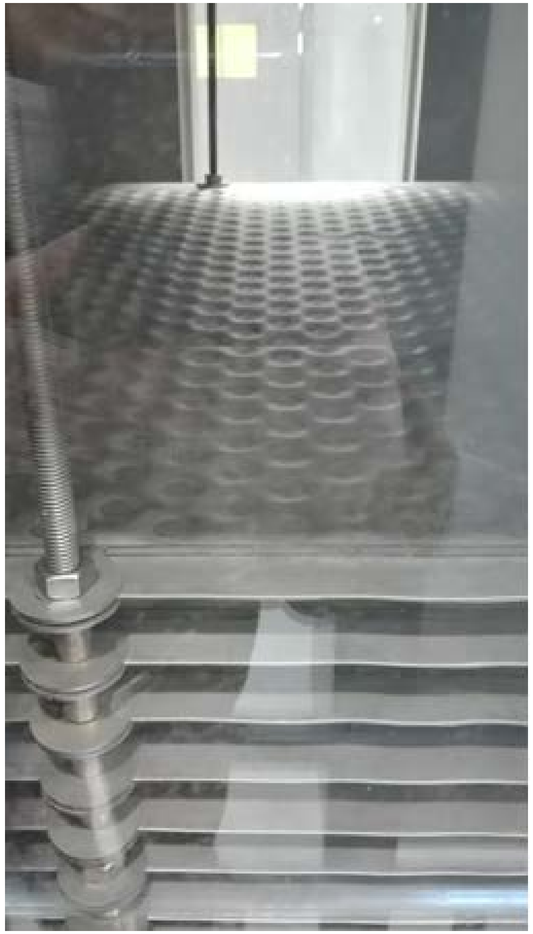
- Based on Pillow-Plate design
- Plate stack placed in a container of steel
- Multiple configurations: 15, 30 and 45 mm (δ_o)
- Container filled with the PCM



Experimental test facility for CTES in refrigeration systems



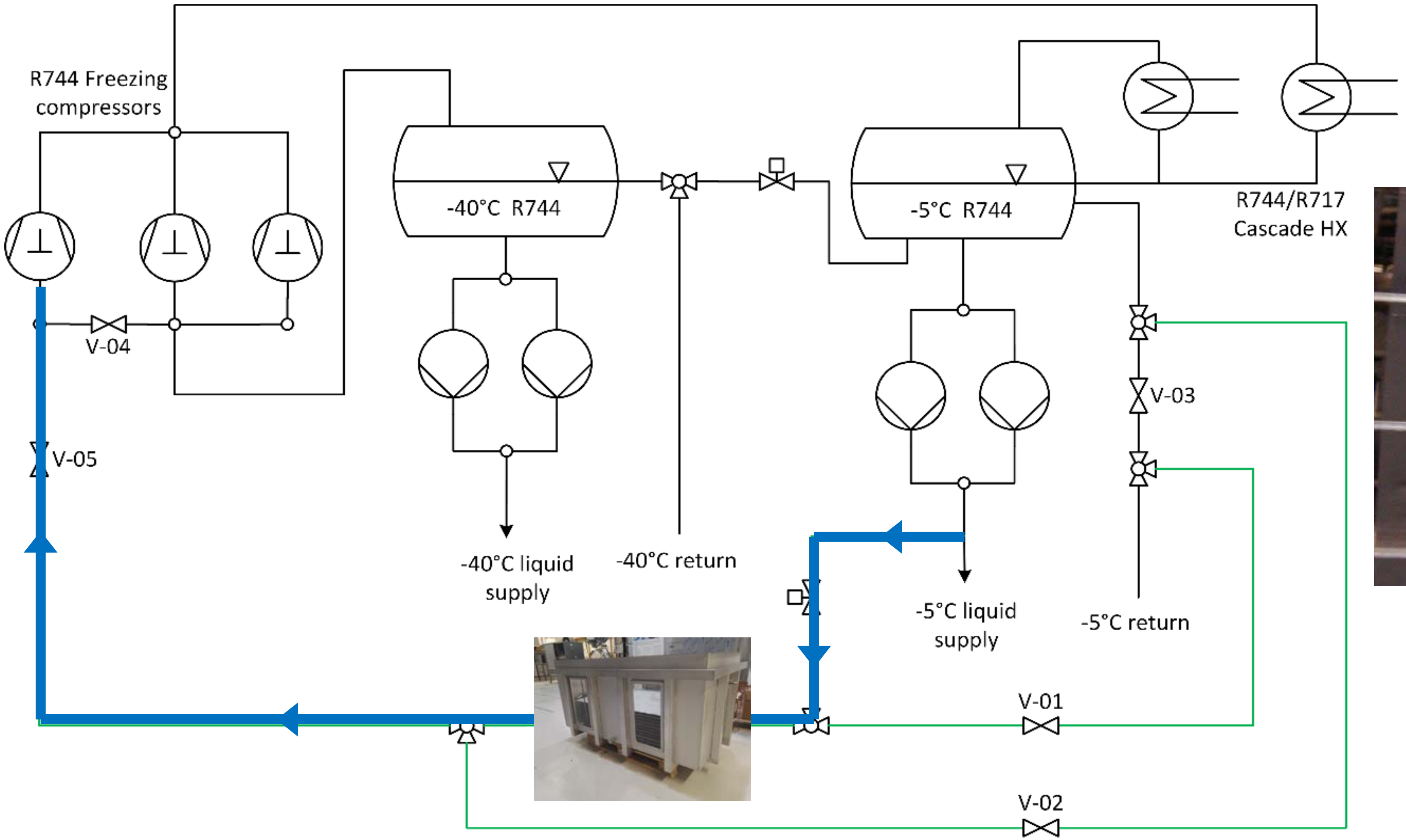
Test facility in Varmetekniske laboratorier, NTNU



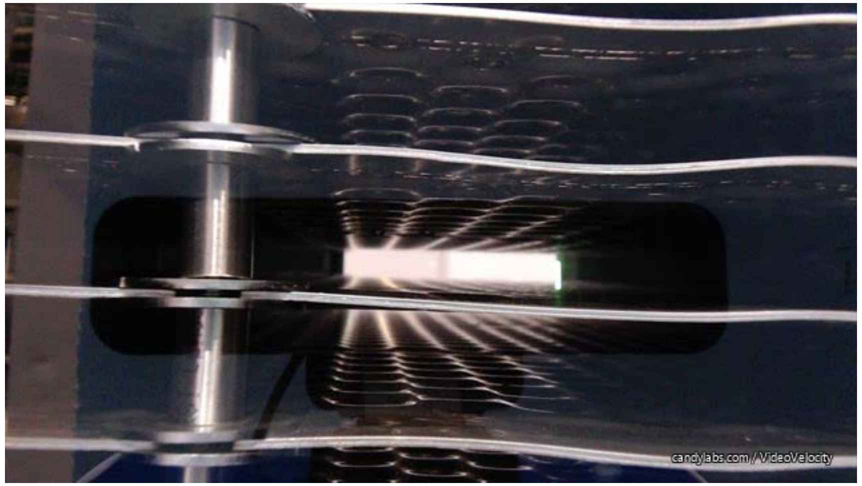
Heat exchanger in CTES unit

How can a CTES system be integrated into a refrigeration plant?

Bottom cycle of a CO2/NH3 cascade refrigeration system
→ often installed in combined freezing/cooling plants



Charging cycle



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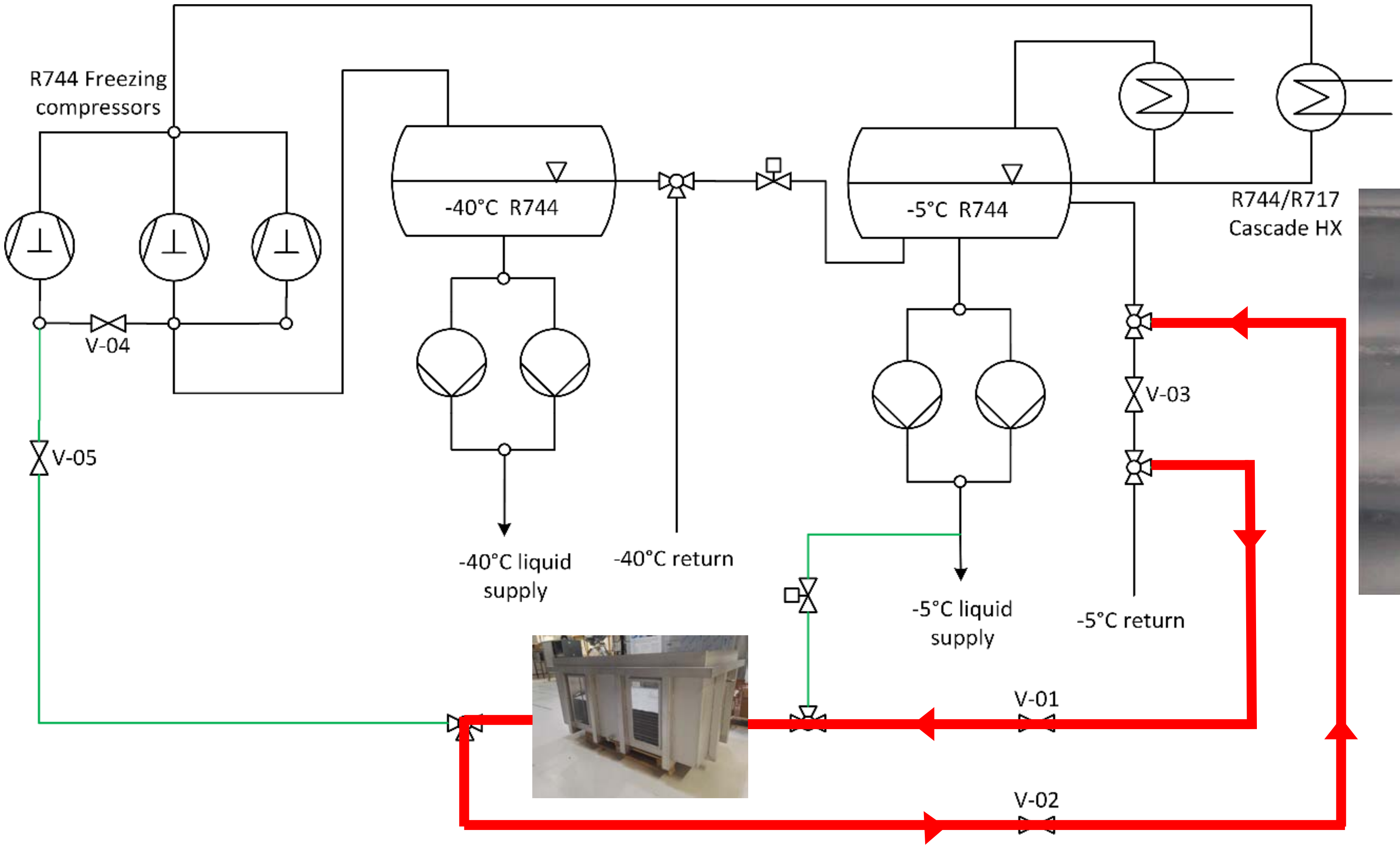
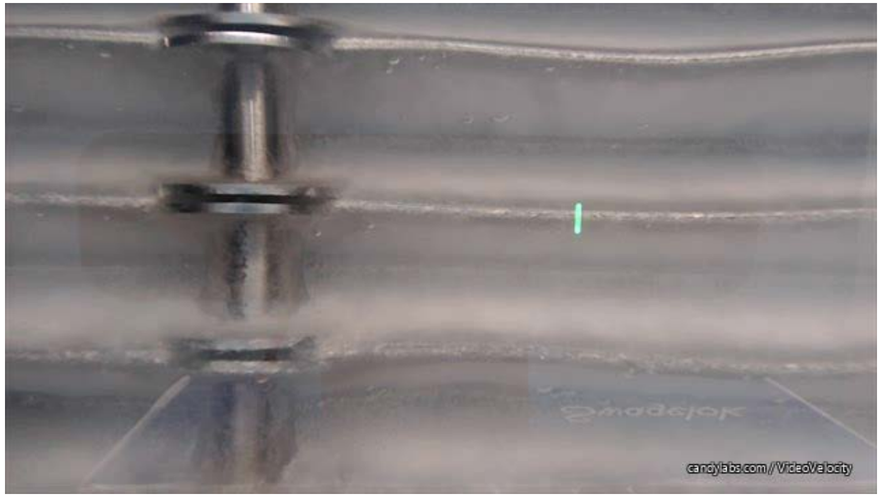
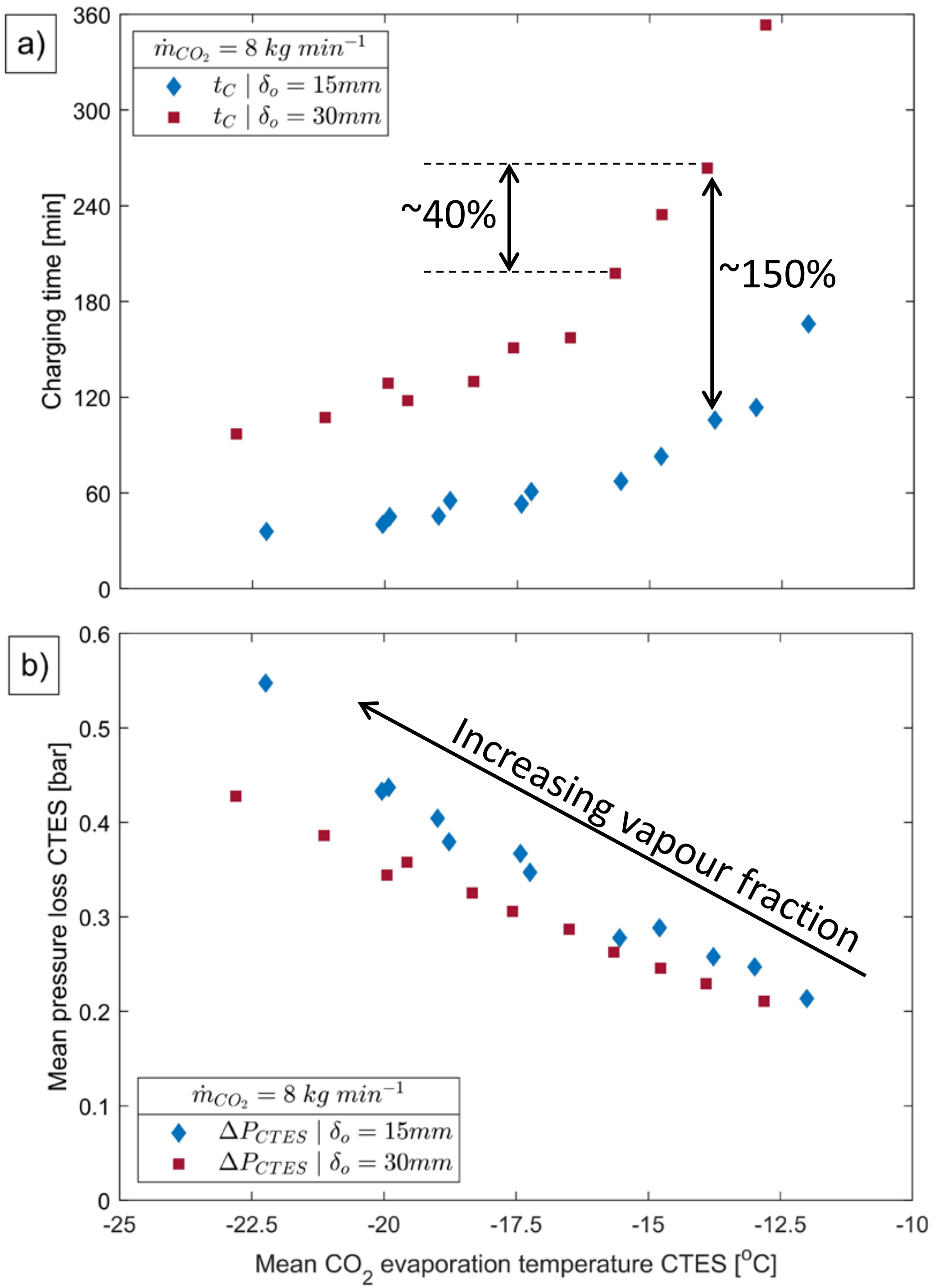


Discharging cycle



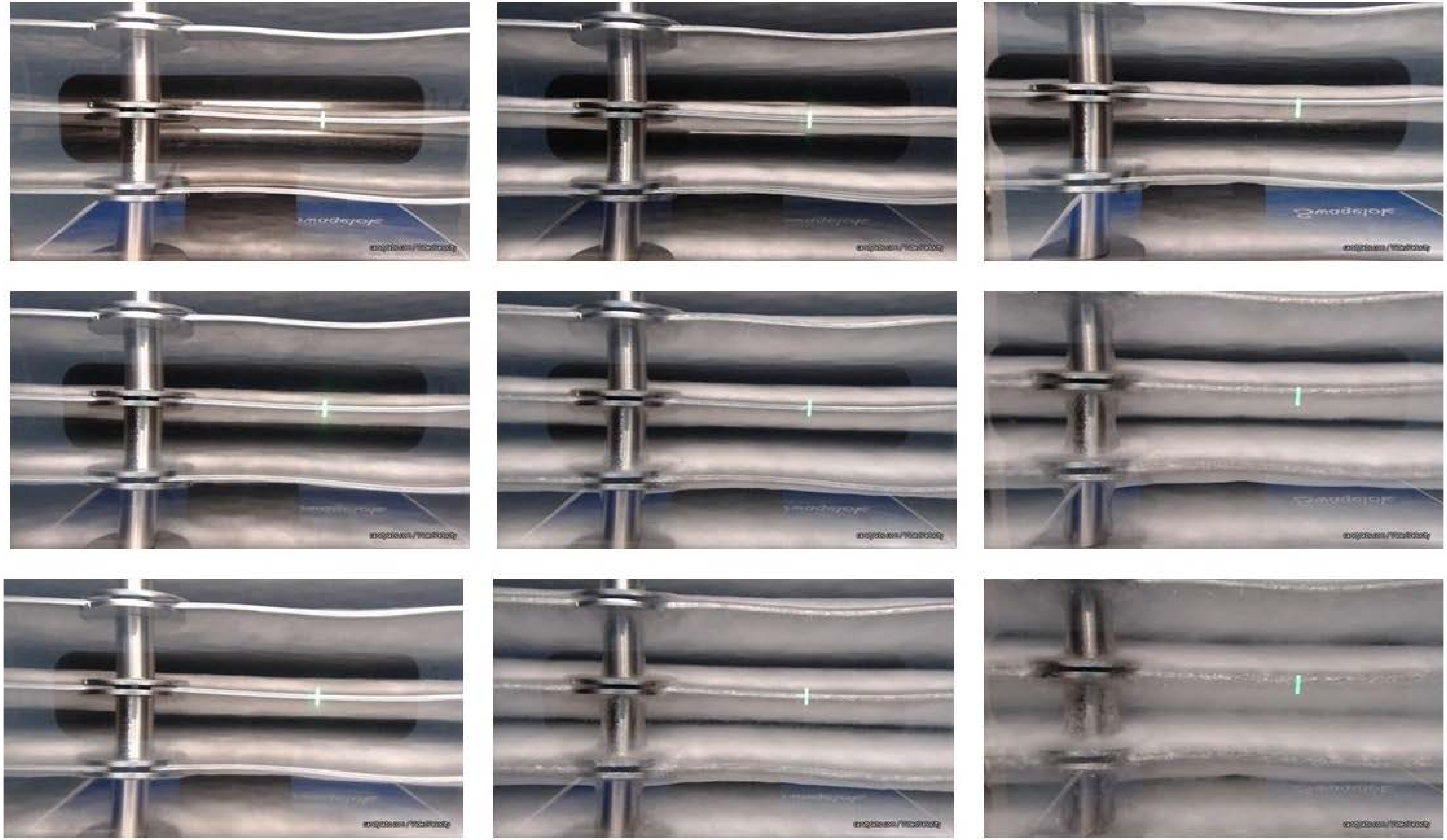
Results – Charging of CTES with PCM

- General trend 1: Increasing distance between plates increases charging time
- General trend 1: Reducing evaporation temperature reduces the charging time
  - Similar for both 15 and 30 mm configuration
- Pressure loss through the pillow plates increases with lower evaporation temperatures



Results – Charging of CTES with PCM

T_{CO2} = -13 °C | T_{CO2} = -17 °C | T_{CO2} = -21 °C



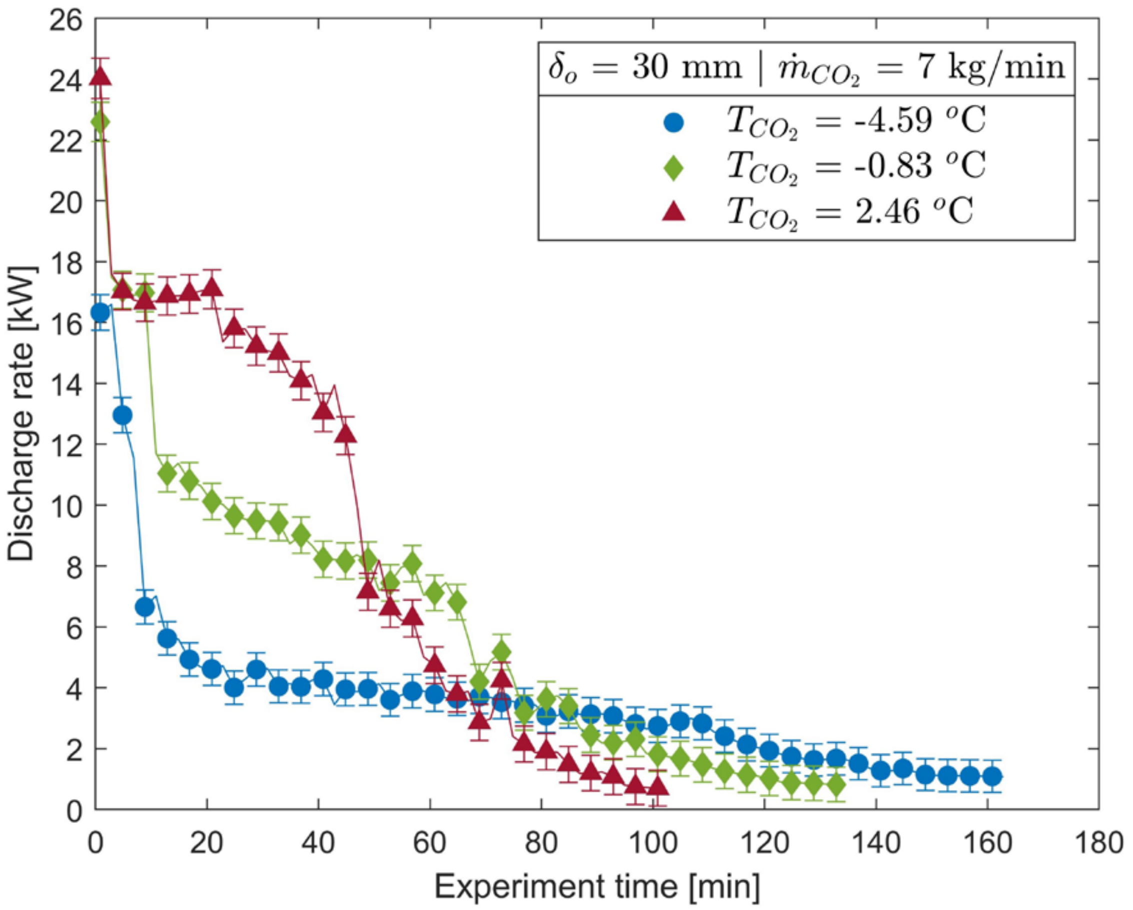
30 minutes

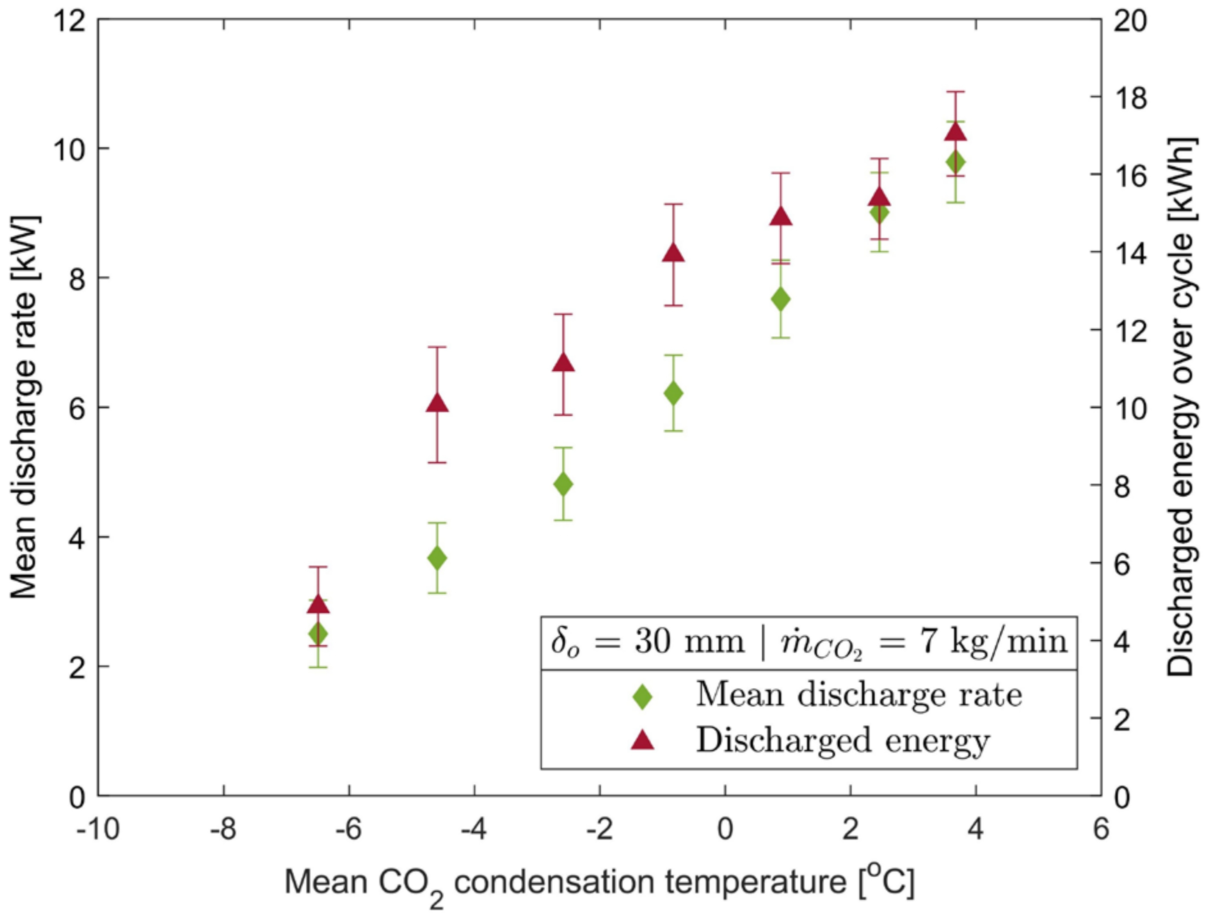
60 minutes

90 minutes

Results – Discharging of CTES unit with PCM

- The discharge rate is high during the initial phase and gradually decreases towards the end of the cycle
- Higher condensation temperature results in higher discharge rate and shorter cycle time
- More thermal energy can be transferred to storage → sensible heat contribution





Lessons learned, remaining challenges …. and how to solve them!

- Heat transfer from refrigerant to PCM during discharging
  Challenge: Limited due to low thermal conductivity of the PCM
  Measure: Addition of particles with high thermal conductivity in PCM
  Measure: Increasing the heat transfer area in CTES unit

- The available PCM on the market today
  Challenge: High cost and access to tailored PCM at relevant temperature levels
  Measure: Smart integration of the CTES unit in the refrigeration
  Measure: If possible, use ice/water as the storage medium

- Cost and competitiveness of the technology
  Challenge: Tailor-made solutions are often expensive
  Measure: Demonstration sites in the field → Build knowledge on the operation of CTES systems → mass production of CTES units
- Control
  Challenge: When to store energy in CTES system and when to use?
  Measure: Prediction control, grid interaction, pricing schemes → we need input from the industry

Summary

- We have successfully developed the «hardware» needed
  - Pairing evaporation/condensation of CO_2 and the solidification/melting of PCM
- The design can be used on various refrigeration systems and for many temperature levels (also high temperatures)
- Completed extensive lab testing and mapping of the performance of the novel CTES unit
- The evaporation/condensation temperature of the refrigerant are the most important parameters for the charging/discharging cycles of the CTES unit
- We strongly believe the technology is ready for a demonstration project at a larger scale

Thank you for the attention!
Questions and comments are welcome

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