Final Commissioning and Experimental Performance Characterization of a Bench-scale Thermochemical Heat Storage System (SEU/SPG)

Background

Thermal energy Storage (TES) is an inevitable element in todays' energy systems, in the battle against climate change. Thermochemical heat storage (TCS) is a very attractive TES technique offering very high energy storage densities, temperature flexibility and minimal losses at long-term TES. In this project, a full-scale experimental operation (after final commissioning steps) and performance characterization of a bench-scale TCS system for the reversible reaction (absorption/desorption) of $SrCl_2$ and NH_3 ($SrCl_2 \cdot NH_3 \rightarrow SrCl_2 \cdot 8NH_3$), will be done. This rig was designed and has being built under the parent project 'Neutrons for Heat storage' (NHS), aiming for low-temperature heating applications (40-80 °C). This project is a collaboration between the Technical University of Denmark (DTU), Institute for Energy Technology (IFE) - Norway, KTH - Sweden, and Amminex Emissions Technology - Denmark. The system offers simultaneous operation with two identical reactors operating in absorption (heat release) and desorption (heat storage) modes each with a capacity of ~0.8 kWh. The system layout (first simplified version in [1] refined and adapted by Brynjarsson, 2021 [2], and Seetharaman, 2022 [3]) is shown in Figure 1, and looks in reality as in Figure 2 today. The system was partially commissioned for the very first absorption in one of the reactors (reactor B) by Seetharaman, 2022 [3] verifying the expected storage density is met (0.8-0.9 kWh). It is now ready for final full-commissioning (by finalizing e.g., a few pipe and controller connections in the desorption path) and complete experimental operation for performance evaluation.

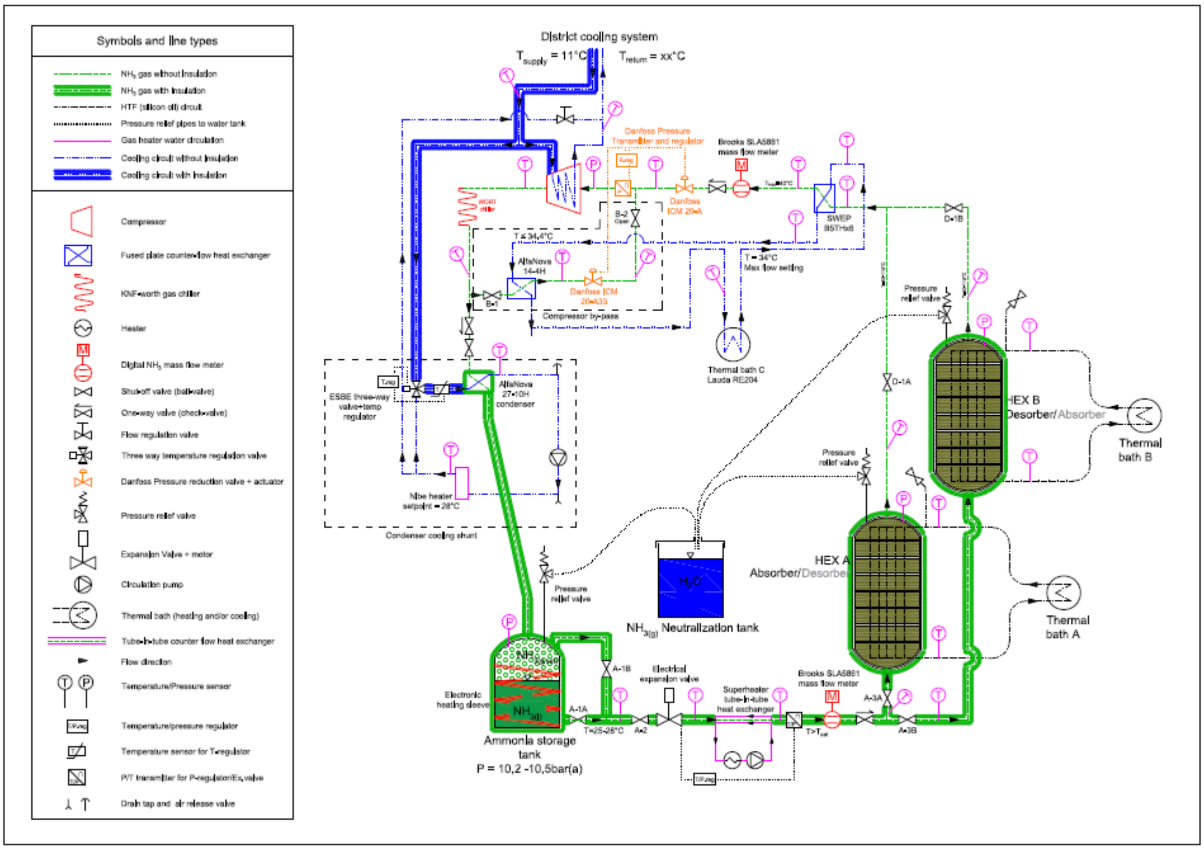

Figure 1. The System Layout of the designed $SrCl_2$-NH_3 TCS system [2]

In this project, the student(s) need to actively participate in the final commissioning steps and then the experimental operation and performance evaluation of this bench-scale TCS system. You are expected to systematically analyze the system's performance parameters for numerous temperature and pressure condition sets. These performance parameters should encompass chemical kinetics, hear transfer, reaction advancement and the system's performance in-terms of heat storage/release power and capacity, among others. A final key outcome here could be empirical characteristic curves for the specific TCS system and reactors, on how the reaction temperature and pressure govern the performance parameters. In the project report, you need to critically and comparatively discuss these results on the contexts of TCS, TES, as well as sustainability. **The project is meant for 1-2 students. The objectives and tasks can be discussed and planned accordingly.**

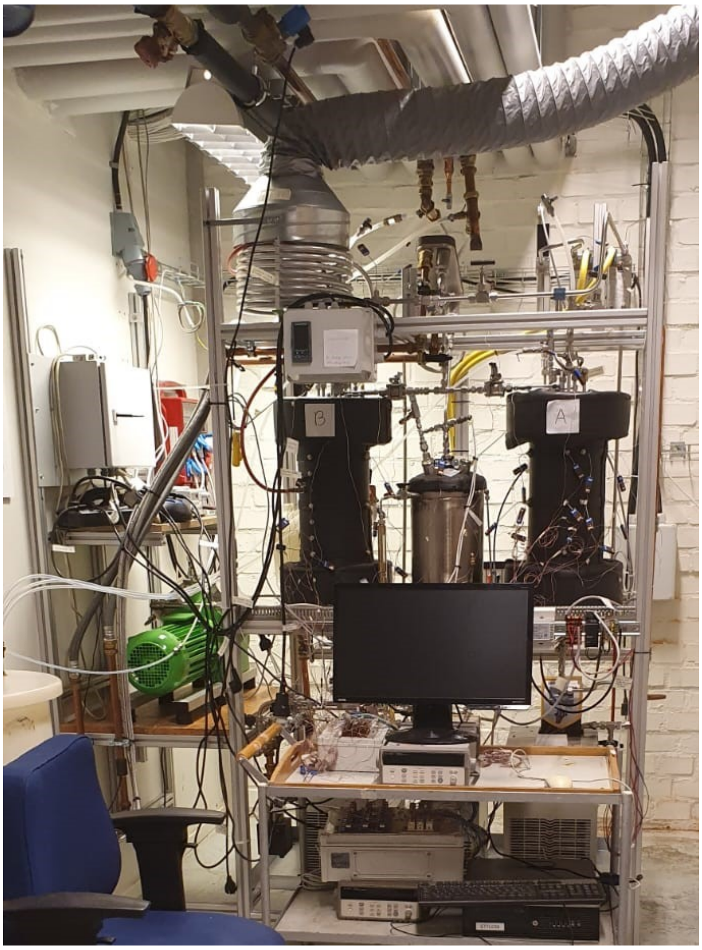

Figure 2. The partially commissioned TCS bench-scale rig ready for final full commissioning and experimental operation

Project learning objectives

After the project is performed, the student should be able to/should be:

- Knowledgeable in hands-on experience in practical aspects of trouble shooting, final commissioning and operating an experimental reactor-based rig
- Knowledgeable and self-sustained in conceptualizing and then performing experimental measurements in the stated TCS rig, for the design conditions and for varied conditions within the safety margins specified in the risk assessment
- Find out and identify the key governing mass transfer, heat transfer and chemical kinetic equations for the relevant context and calculate the key TES parameters to characterize this TCS system operation
- Derive empirical correlations on the system performance characteristics, based on the parameters obtained, as functions of temperature and pressure
- Critically and comparatively discuss the obtained experimental and calculated results from the TCS rig operation
- Generalize the obtained results and their derived parameters into the contexts of TES and sustainability
- Seek advice effectively and perform the research tasks independently when necessary, and take initiatives as necessary for the progress of the project

- Draw key engineering and design conclusions based on the critical analysis of the obtained results, and therein, propose relevant future work to improve the system design and operation.

Methodology:

The proposed methodology for this thesis work includes the following. It should start with a brief survey of literature on project's background and other relevant information (on ammonia-metal halide TCS systems, their experimental operation and performance evaluation), to understand and explain the underlying theory and concepts. Thereafter, full engagement in the final commissioning steps followed by the experimental operation of this TCS system is expected. The system's experimental operation should be done aiming to establish a thorough characterization for a range of chosen conditions. Based on these measurements, the system's TES performance should be then evaluated by deriving appropriate operational characterization parameters (e.g. heat storage/release power and capacities, among others) and therein empirical correlations on the system performance characteristics. These derived characteristic correlations should be then critically discussed in-terms of its suitability as a TES system. Overall engineering and scientific conclusions should be drawn, in the end. The report writing must be a continuous process parallel to the project work, from the very beginning to the end.

The project report should be written in English and the student(s) should have sufficiently good writing skills to write a clear and a comprehensible report.

Pre-requisites:

- Knowledge and preferably experience in the involvement in real-life or experimental systems commissioning and/or operation. Additional merits if this experience comes concerning systems which have higher safety requirements.
- Fundamental knowledge on chemical kinetics, thermodynamics and heat transfer

Advantages of being engaged in the project:

- A wide variety of hands-on experience on experimental thermochemical heat storage systems (as an emerging TES technology with a lot of interest today)
- One of a kind experimental experience on handling gases, rather high temperatures and pressures and a solid training on the safety measures, valuable for any industrial atmosphere
- The potential to write a conference or even a journal scientific article based on the obtained results, together with the project team.

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References

[1] S. N. Gunasekara, M. Laios, A. Karabanova, V. Martin and D. Blanchard, "Design of a bench-scale ammonia-SrCl2 thermochemical storage system using numerical modelling," in *Eurotherm Seminar n-112*, Lleida, 2019.

[2] H. Brynjarsson, "Review and Design Adaptations of a SrCl2-NH3 bench-scale Thermochemical Heat Storage system," KTH Royal Institute of Technology, Stockholm, 2021.

[3] H. B. Seetharaman, "Commissioning and Perfromance Evaluation of a Bench-scale Thermochemical Heat Storage System," KTH Royal Institue of Technology, Stockholm, 2021.