EuroSun2026

HIGH-TEMPERATURE WATER VAPOUR TRANSMISSION MEASUREMENTS FOR POLYMER LINERS IN SEASONAL THERMAL ENERGY STORAGE

Summary

Seasonal thermal energy storage is essential to bridge the winter gap between renewable energy production and heat demand. Polymer liners in pit and cavern thermal energy storage systems limit water vapour transmission, but their diffusion tightness decreases at elevated temperatures, potentially compromising insulation and increasing heat loss, while additionally jeopardizing structural integrity. Standard WVTR methods such as ISO 15106-3 are not suitable for temperatures up to 95 °C or for direct liquid water contact. A dedicated high-temperature WVTR test rig was therefore developed, enabling measurements under realistic operating conditions with high sensitivity at very low diffusion levels (< 0.157 g m^{-2} d^{-1}). The system has been referenced and is ready for liner testing, with benchmarking against commercial instruments planned for completion by summer 2026.

Keywords: humidity diffusion, seasonal thermal energy storage, polymer liners, water vapour transmission rate (WVTR)

Field of application for the findings: Development of Liners suited for Thermal Energy Storages

Addressed audience: Industry

1. Background

In Switzerland, 46.7 % of the total energy demand is heat, while only 19.9 % of this demand is covered by renewable energy sources (Bundesamt für Energie, 2025a, 2025b). Seasonal thermal energy storage is therefore central to closing the winter gap between renewable production and heat demand. Systems such as pit thermal energy storage or cavern thermal energy storage are insulated and filled with hot water in the district heating temperature range. A polymer liner is used to limit the water vapour transmission rate (WVTR). However, based on previous in-house measurements, the diffusion tightness of polymer materials is limited and decreases further with increasing temperature. As a result, water vapor passes through the liner and moistens the insulation layer and even the structural elements. Inadequate vapor barriers therefore jeopardize insulation performance and can affect structural integrity over decades. To address this challenge, it is important to quantify the water vapor transmission through the liner material. Standard methods such as ISO 15106-3 (ISO, 2015) provide a framework for WVTR measurement, but they are not designed for temperatures up to 95 °C and do not consider direct contact between liquid water and the test specimen, as encountered in real applications.

2. Measurement Setup

To obtain relevant data for pit and cavern thermal energy storage liners, a dedicated WVTR test rig was developed. The system design and the measurement routines are guided by ISO 15106-3 but are adapted for operation at temperatures up to 95 °C and the possibility of direct liquid water contact at the specimen surface. To our knowledge, no other commercially available system provides this combination of high-temperature operation and controlled liquid water exposure. The goal was to develop a robust, reproducible method that can compare different commercial and experimental liner materials under realistic operating conditions and provide input for long-term performance assessment.

The measuring principle is based on a two-chamber permeation cell consisting of a wet chamber filled partially with liquid water and a dry chamber that is continuously flushed with dry nitrogen as the carrier gas. The two chambers are separated by the test specimen, through which water vapour diffuses during the experiment. In addition, the measuring cell can be inverted, enabling direct contact between the liquid water and the specimen surface. A photographic view of the measuring chamber is shown in Figure 1. Water vapour diffusing through the specimen is transported by the gas and measured downstream (see Figure 2). For humidity detection a coulometric trace moisture sensor with a range of 0–500 ppmV and a dew point capability down to –100 °C was employed.

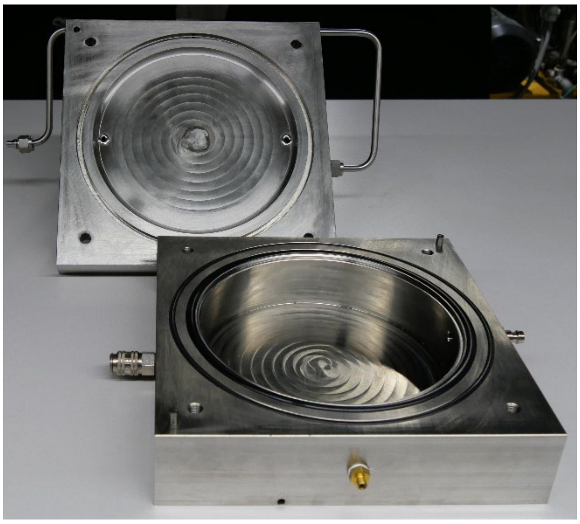

Fig. 1: Measuring chamber with the dry chamber above and the wet chamber below.

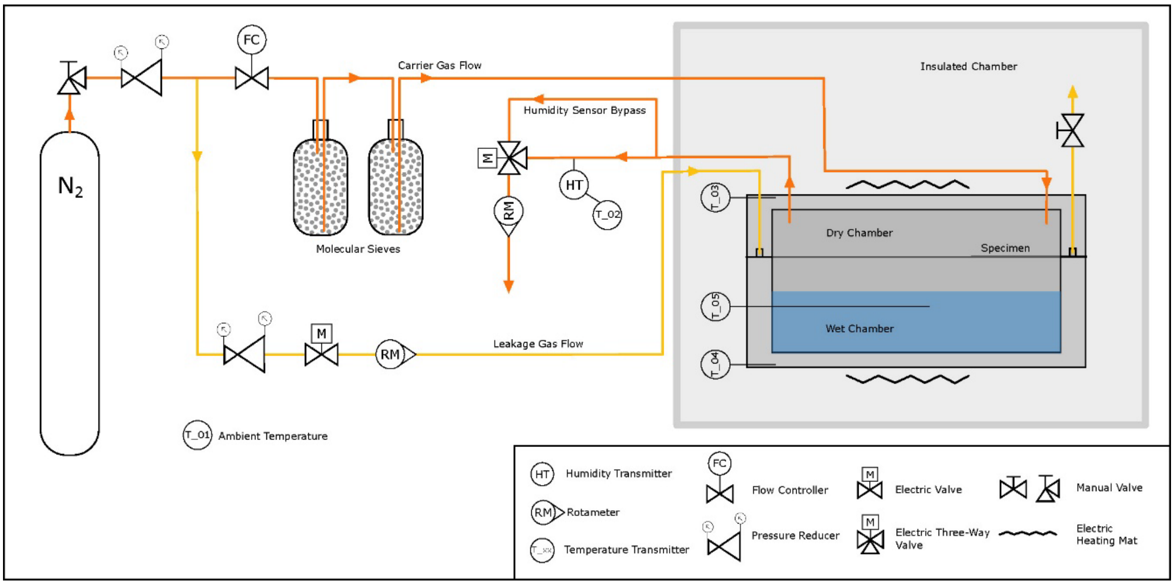

Fig. 2: Schematic layout of the WVTR measurement rig.

Operating at water contents below 10 ppmV on the dry chamber side presents significant technical challenges. At these levels, the absolute amount of water in the gas phase is exceedingly small, pushing measurement sensitivity to its limits. The system becomes highly susceptible to microscopic leaks and outgassing from tubing walls, both of which can produce signals comparable to or even exceeding the actual flux through the specimen. In addition, the gas path tends to exhibit long response times, and even minor temperature gradients along the flow path can lead to disproportionately large effects on the measured signal.

All components were individually tested and referenced to identify all uncertainties in the system. The system has now been fully assembled and is ready for liner testing.

3. Outlook

The next steps planned include comparative measurements with other providers and commercially available instruments. These studies will allow a systematic evaluation of performance differences and help assess the accuracy of existing commercial systems under identical test conditions. The objective is to critically examine and benchmark the measurement precision currently available on the market. Completion of this phase is targeted for summer 2026.

4. References

Bundesamt für Energie (BFE), 2025a. Analyse des schweizerischen Energieverbrauchs 2000–2024 nach Verwendungszwecken. October 2025.

Bundesamt für Energie (BFE), 2025b. Schweizerische Gesamtenergiestatistik 2024. August 2025.

ISO, 2015. ISO 15106-5:2015. Plastics — Film and sheeting — Determination of water vapour transmission rate — Part 5: Pressure sensor method. International Organization for Standardization, Geneva.