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SOLAR THERMAL ASSISTED AIR DEHUMIDIFICATION IN WATERWORKS

Summary

Dehumidification is essential in waterworks to prevent condensation and corrosion on cold pipe surfaces, but its energy demand has received little attention so far. Field measurements in three waterworks showed both insufficient dehumidification under critical summer conditions and over-dehumidification during low-load periods. The results highlight considerable potential for improving control strategies and reducing electricity consumption. For one elevated tank, a solar-thermal-assisted desiccant wheel system was designed and installed as a demonstration plant. The system combines a desiccant wheel with evacuated tube collectors and a buffer storage tank to (pre)heat regeneration air. Simulation results show that solar heat can cover a major share of the regeneration heat demand. Compared with a purely electrically regenerated desiccant wheel, annual electricity savings of about 80 % are expected. The plant will be commissioned shortly, and operational monitoring will assess humidity control, solar fraction and energy savings.

Keywords: Dehumidification, desiccant wheel, solar thermal plant

Field of application for the findings: Solar air conditioning

Addressed audience: Researchers

1. Introduction

In waterworks, air dehumidification is often required to prevent condensation on cold pipe surfaces and the resulting corrosion. While the energy demand of water supply systems is mainly attributed to pumping (Grzegorzek et al., 2023), the energy demand for dehumidification in waterworks has hardly been investigated so far. Dehumidification loads are mainly caused by infiltration through the building envelope and, in some cases, by internal moisture sources such as backwashing and cleaning processes.

Depending on the required indoor air dew point temperature, either condensation dehumidifiers or desiccant wheels are applied. However, condensation dehumidification becomes critical when low dew points are required, whereas desiccant wheels can operate effectively under such conditions. Most commercially available small desiccant wheel units use electrical heating for regeneration. Since in Central Europe the highest dehumidification loads occur in summer, when solar irradiation is also highest, solar thermal regeneration appears promising. So far, solar-assisted desiccant systems have mainly been studied for comfort air conditioning (Angrisani et al., 2014; Comino et al., 2020; Lai et al., 2022) and not for waterwork applications, where lower dew point temperatures are often required.

The aim of this study is to provide insights into dehumidification practice in waterworks, identify efficiency potentials, and investigate the reduction in electrical energy demand by integrating solar thermal heat into a commercially available desiccant wheel system implemented in a demonstration plant at a waterwork.

2. Measurements in waterworks

To investigate dehumidification under practical operating conditions, measurements were carried out in three waterworks of different sizes, namely two elevated tanks and one pumping station (Tab. 1). At all sites, air temperature and relative humidity were measured at different positions, and the surface temperatures of selected pipelines were monitored over periods of one to two years. Two of the sites use condensation dehumidifiers, while one site is equipped with desiccant wheels.

Tab. 1: Overview of investigated waterworks

Name	Type	Room volume	Dehumidification Technology	Electricity consumption for dehumidification	Measurement period
A	Elevated tank	630 m³	5 x stand-alone condensation dehumidifier	0.33 MWh/a	03.02.-04.12.2023
B	Elevated tank	2500 m³	3 x stand-alone desiccant wheel	72 MWh/a	25.04.24-04.11.25
C	Pumping station	5000 m³	1 x air handling unit (condensation dehumidification)	no data	31.03.23-04.11.25

Based on the measured air temperature and relative humidity, the dew point temperature was calculated and compared with the measured pipe surface temperature in order to evaluate whether the installed dehumidification systems reliably prevent condensation.

3. Design of solar-thermal-assisted desiccant wheel demonstration plant

The waterwork A was selected for the implementation of a solar-thermal-assisted adsorption dehumidification system. Fig. 1 shows the integration of the desiccant wheel and the solar thermal system including all measurement points. The process air is recirculated room air, while ambient air is used as regeneration air.

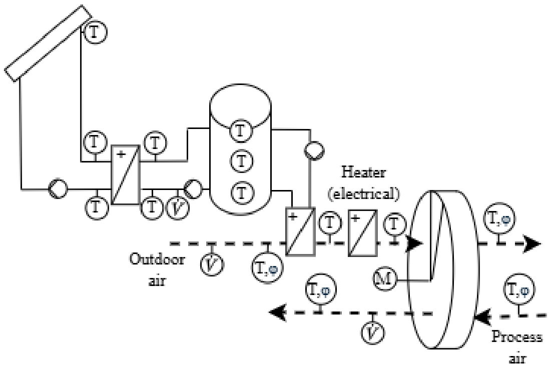

Fig. 1: Scheme of demonstration plant including all measurement points

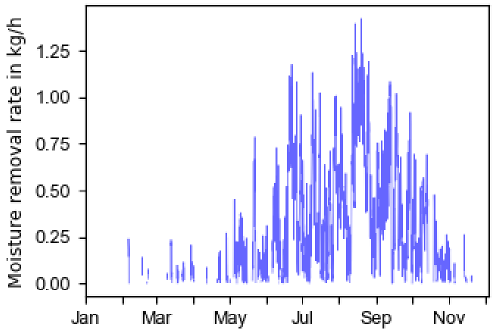

Fig. 2: Required moisture removal rate for water work A

Based on the measurement data, the infiltration rate was assumed to be 0.2 h^{-1} and the required room air dew point temperature was set to 8 °C. The dehumidification load (moisture removal rate) was determined based on the measured outdoor air conditions in the year 2023, shown in Fig. 2.

Commercially available stand-alone desiccant wheels for waterwork applications typically use electrical regeneration with air temperatures of up to 120 °C. In the present study, however, the system was designed for operation at lower regeneration temperatures in order to increase the use of solar thermal heat. Based on manufacturer simulation software, different system sizes were compared. A characteristic relationship between moisture removal rate, regeneration air humidity ratio and regeneration temperature was derived.

The selected desiccant wheel provides a moisture removal rate of 1.0 kg/h at a regeneration air temperature of 75 °C and a humidity ratio of 12 g/kg. Under the same inlet air conditions, the unit could remove 1.6 kg/h if operated with electrical regeneration at higher temperature which results also in a higher required regeneration heat input. Therefore, compared with a conventional electrically regenerated system, the desiccant wheel had to be deliberately oversized in order to achieve the required performance at reduced regeneration temperature.

The installed solar thermal system consists of a 13 m² (gross area) evacuated tube collector, an 800 l buffer storage tank and an air-to-water heat exchanger for preheating the regeneration air. The electrical heater is activated only when solar heat is insufficient, and the system is switched off when no dehumidification is required.

4. Results and conclusions

Fig. 3 shows representative measurement results for waterwork C, which is equipped with an air handling unit supplying outdoor air. The room air dew point temperature exceeds the pipe surface temperature (7.8 °C in average) during the period from April 2023 to November 2024, which causes condensation on the pipe surfaces. To prevent condensation, the dew point temperature should remain 2–3 K below the pipe surface temperature. Under these conditions, the use of condensation dehumidification (as currently installed) becomes critical, as evaporator frosting is likely to occur. The dehumidification load during the summer months could be reduced significantly by reassessing the outdoor air supply. Another option for achieving the required low air dew points at this waterwork would be the additional use of a desiccant wheel.

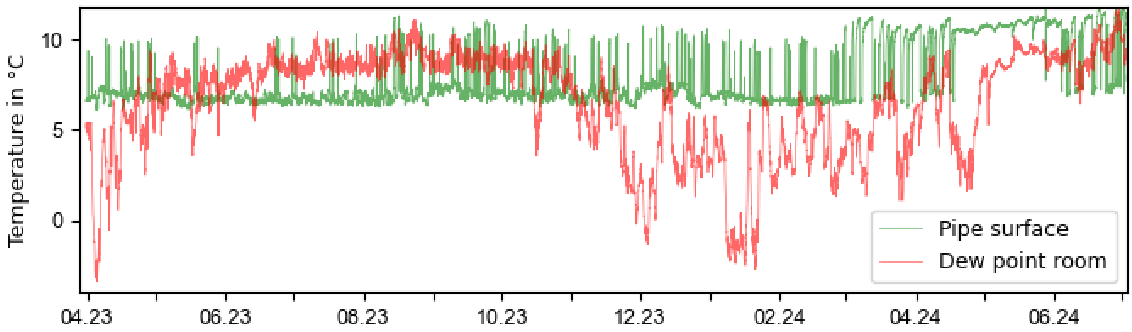

Fig. 3: Measured dew point and pipe surface temperatures from April 2023 to July 2024 in waterwork C

In contrast, no critical condensation risk was observed in waterwork B. However, the measurements indicate that the indoor air was dehumidified more than necessary outside the summer period, resulting in unnecessarily high electricity consumption for the desiccant wheels. This highlights that existing dehumidification systems in waterworks may suffer both from insufficient performance under critical conditions and from inefficient operation during low-load periods.

At present, the waterwork A is dehumidified by five mobile condensation dehumidifiers, which have to be emptied regularly of condensate. Their annual electricity consumption is about 3300 kWh. Based on the derived characteristic curve for the desiccant wheel the annual regeneration heat demand of the new system is estimated at 2650 kWh, while the fan electricity demand amounts to around 700 kWh. Simulations with the software Polysun predict a solar fraction of 83%. Compared with a purely electrically regenerated desiccant wheel, this corresponds to electrical energy savings of approximately 2200 kWh per year. The demonstration plant at waterwork A has already been installed and will be commissioned in spring 2026. Monitoring will focus on dew point control, the interaction between solar thermal regeneration and electrical backup heating, and the resulting energy savings under real operating conditions. These first operational results will be presented.

5. References

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