Numerical Modeling and Performance Optimization Study of a Dehumidification Process in Nuclear Waste Storage

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Abstract

One of the main parameters to consider during the nuclear waste storage design phase is the drum corrosion risk. The humid-air corrosion models available in literature predict that, for carbon steel, the phenomena start to become appreciable for relative humidity (RH) values close to 65%. In general, the corrosion rate increases exponentially with relative humidity above the RH threshold. To reduce the corrosion risk an alternative technique rather than installing HVAC system is using dehumidifiers.

The main objective of this study is to develop a numerical model that replicates the functioning of industrial isothermal dehumidifiers in order to obtain indications about their performance. The geometry of the rad-waste interim storage and its thermo-physical properties, considered during simulations, are taken from a specific ongoing project while the characteristic functioning curves of the dehumidifiers represent the industrial state of art. The 3D simulation of the coupled heat and moisture transfer has been performed with COMSOL Multiphysics®-Heat Transfer Module 4.3b. For a realistic prediction of moisture distribution in the storage facility exposed to external climatic conditions, ambient temperature and humidity level are considered in the model. The performance of two different kinds of industrial dehumidifier are compared in order to choose the best configuration to implement within storage facility.

The dehumidifiers considered during the simulation differ in terms of handled mass flow and condensation capacity. The simulation is based on the following steps: stationary fluid flow study (single-phase incompressible turbulent k-eps closure model, see Figure 1), time dependent fully coupled heat and moisture transfer study (heat transfer in fluid by forced convection and transport of diluted species to reproduce humidity field, see Figure 2-3). For the second step, temperature and relative humidity represent the dependent variables, whereas position and time are the independent variables of the problem. The theory of transient conduction in a semi-infinite solid subjected to a sinusoidally varying temperature on its exposed face is used to obtain the boundary conditions on the storage wall.

The results presented in this study confirm that COMSOL Multiphysics® is a useful tool for hygrothermal simulation. The development of this study has allowed us to choose the kind, the number and the position of industrial isothermal dehumidifiers in a nuclear waste interim storage,

thus reducing the drum corrosion risk and estimating their workload in terms of functioning hours and condensate water production.

Reference

[1] J.H. Lee et al., Humid-Air Aqueous Corrosion Models for Corrosion-Allowance Barrier Material, INTERA, Inc./CRWMS M&O, 101 Convention Center Drive, Suite P-110, Las Vegas, NV 89109, USA

Figures used in the abstract

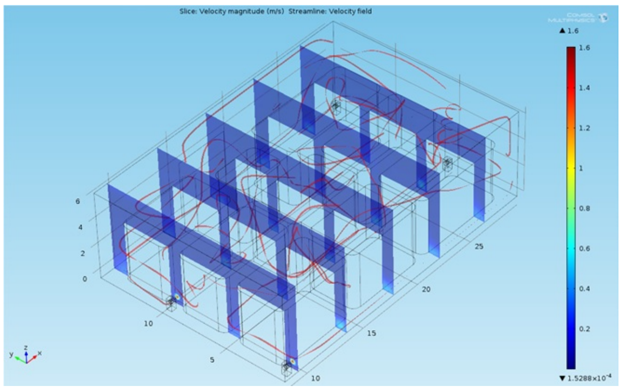

Figure 1: Velocity magnitude and streamlines into Waste Storage

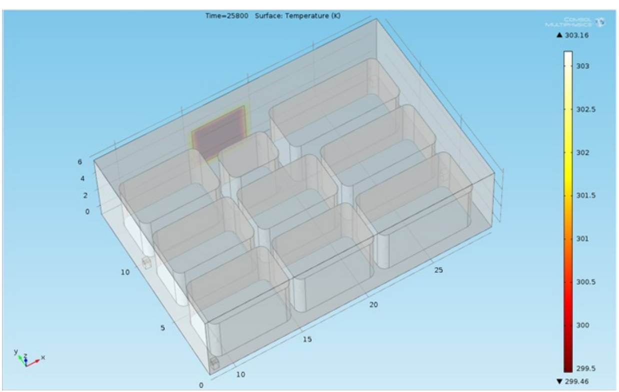

Figure 2: Waste storage wall and drums surface temperature

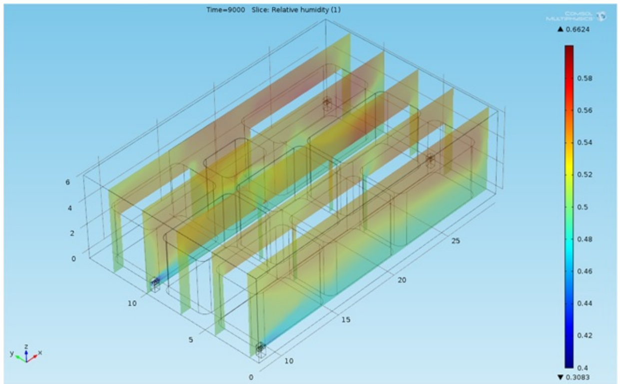

Figure 3: Relative Humidity field into Waste Storage