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Coupled thermo-mechanical analysis of a deep gas storage salt cavern in East Yorkshire, UK

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Abstract

This paper presents the results of a detailed coupled thermo-mechanical analysis of one of the SSE caverns, which was subjected to thermally induced stresses resulting from the actual cyclic pressure changes that took place while the cavern was operated and monitored for more than six and a half years.

Because of the relatively high coefficient of linear thermal expansion, that characterises the Fordon Main Halite, the operation mode of the SSE gas storage caverns required a detailed geomechanical consideration of the induced thermal stresses. This meant that, the change of the stored gas temperature during operation and the consequences of these temperature changes on the thermal loading of the Fordon Main Halite, necessitated the implementation of a comprehensive investigation employing a thermo-mechanical coupled analysis. The employed analysis was further complicated by the fact that the Fordon Main Halite is characterised by a persistent creep response which is affected by both the applied temperature changes and the resulting deviatoric stress regime.

During the implemented coupled thermo-mechanical analysis:

- the changes in the cavern pressure and temperature were numerically determined as a function of the specified gas flow rates, related to the actual storage operating time-histories,
- the temperature depended creep properties for the salt were based on the WIPP reference creep law, as implemented in a finite difference code, and
- the modelling of the time dependent temperature distribution in the geological materials, that surround the investigated cavern, was numerically modelled by employing a heat conduction process that brings gas and rock mass to local thermal equilibrium.

The work presented in this paper has proven the importance of using a coupled thermo-mechanical analysis to assess correctly the state of stresses in the vicinity of gas storage salt caverns. Moreover, it was shown that in considering the cavern's thermo-mechanical response it is possible to implement operational parameters that satisfy the operator's requirements with respect to the flexibility of gas withdrawal and injection, and the optimisation of withdrawal rates and working gas volumes.

Key words: Bedded Salt Deposits, Caverns for Gas Storage, Computer Modelling, Rock Mechanics, Salt Properties, Thermodynamics, United Kingdom, Zechstein.