Engineering-scale T-H-M Validation Test for a HLW Disposal System

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1. Introduction

The concept of a Korean HLW repository is based upon a multi barrier system composed of engineered barriers and the surrounding plutonic rock [1]. The repository is constructed in a bedrock of several hundred meters in depth below the ground surface, and its engineered barrier system consists of wastes, disposal containers, buffer/backfill, and concrete plug. Figure 1 shows the schematic picture of a reference disposal system developed in 2002.

The engineering performance of a HLW repository is dependent, to a large extent, upon the characteristics of the engineered barrier system, especially the T-H-M processes that may occur as a result of the combined effects of the heat generated by the radioactive decay, of the ground water flowing in from the surrounding rock, and of the swelling pressure exerted by the compacted buffer material. For this reason, the T-H-M processes in the engineered barrier system are one of major issues in the performance assessment of a HLW repository.

This paper presents KENTEX (KAERI Engineering-scale T-H-M Experiment for Engineered Barrier System) facility and the results of its pre-operational calculation made using a computer code. Further works are described as well.

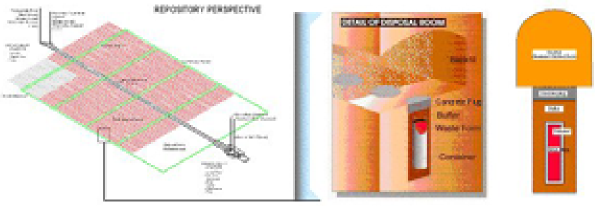

Figure 1 Schematic picture of a reference disposal system developed in 2002.

2. 'KENTEX' facility

The objectives of the 'KENTEX' are to provide the information (large-scale apparatus, sensors, monitoring system etc.) needed for the "in situ" test, to undertake a validation of the computer code for the T-H-M performance assessment of the reference disposal system, and to demonstrate the engineering feasibility of fabricating and emplacing the buffer of a repository. Its facility (Figure 2), a third scale of the reference disposal system consists of four major components: the confining cylinder with its hydration tank, bentonite block, heating system, and sensors and instruments.

Figure 2 Picture of the KENTEX facility.

The confining cylinder with its hydration system is to simulate the borehole with ground water from the surrounding rock mass in the reference disposal system. It is a steel body with a length of 1.36 m and an inner diameter of 0.75 m and the hydration system consisting of a water tank and related pipes which are connected to 24 nozzles in the confining cylinder. To uniformly apply the groundwater to the surface of the bentonite blocks, each nozzle is inserted with two metal filters and the confining cylinder is lined with various layers of geotextile.

The bentonite blocks are fabricated of the bentonite taken from Jinmyeong mine which is located in Kyungju, Kyungsangbuk-do. The bentonite is prepared after its raw material is dried below 110 ^{o}C, pulverized, and passed through No. 200 of ASTM (American Society for Testing and Materials) standard sieves. The fabricated blocks have average value of 13 % of water content and 1700 kg/m^3 of dry density, respectively. The shape, dimension, and number of the bentonite blocks are shown in figure 3. The bentonite blocks emplaced in the confining cylinder (figure 3) have a percentage of construction gap of 5.9 % and thus the average dry density of the bentonite blocks in the confining cylinder is 1600 kg/m^3. There are 176 blocks emplaced in 16 sections.

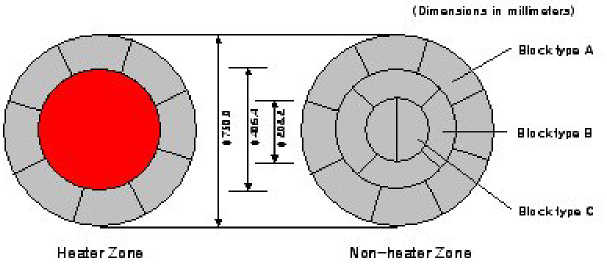

Figure 3 Bentonite blocks used in the KENTEX facility.

The heater in the heating system measures 0.41 m in diameter and 0.68 m in length. It has three heating elements in its inside capable of supplying a thermal power of 1000 W each, i.e., a total power of 3000 W. It is placed concentrically in the confining cylinder in direct contact with the bentonite blocks. In this test a constant temperature of 95 ^{o}C is maintained at the heater-bentonite interface by means of the heater control system. The heating system is redundant: each heating element is capable of supplying a higher thermal power than is strictly required.

The sensors used for the KENTEX are selected considering the working conditions: total pressure ≥ 10 MPa, temperature up to 100^{o}C, and harsh saline environment. The same requirements are established for the cables and their connections to the sensors. Sixty eight sensors, within the bentonite blocks and the rest of the components of the test, are installed to measure the following variables: temperature, humidity, and total pressure. The location of the sensors was determined on the basis of pre-operational calculation.

The data acquisition and heater control in the facility were done by DAS and HCS, respectively. The data acquisition system (DAS) is made up of all the electric and/or electronic components and the computer programs required for the supervision and storage on a secure magnetic device of the data obtained from the test, in an autonomous form. The system is capable of storing, analyzing and displaying the obtained data. The heater control system (HCS) is made up of all the electric and/or electronic components and the computer programs required to accomplish the following functions: supervision of heater operation and control of the power supply, data acquisition and transfer to the DAS and activation of the processes and alarms in the event of component failure.

3. Pre-operational calculation

The preoperational calculation based upon T-M processes was made using a three-dimensional FEM code, ABAQUS Version 5.8. This aimed at providing information on the sensitive location of sensors and the operation conditions for the engineering-scale test. The calculation results showed that the temperature and maximum principal stress in the bentonite blocks nearly reached the steady state after more than 20 days although the longer time was required with the farther distance from the heater. At the steady-state, the temperature at the outer wall of a confining cylinder was estimated to be about 72^{o}C. The gradient of temperature and stress was steeper in the center and bottom of the confining cylinder than in its top. The temperature and maximum principal stress distributions in the bentonite blocks were sensitive to the thermal conductivity and the thermal expansion coefficient of the blocks, respectively, which suggested that a careful attention is paid to the measurement of those data and their employment into calculation. In figure 4 are shown the temperature contour after 20 days as a typical example of the calculation results.

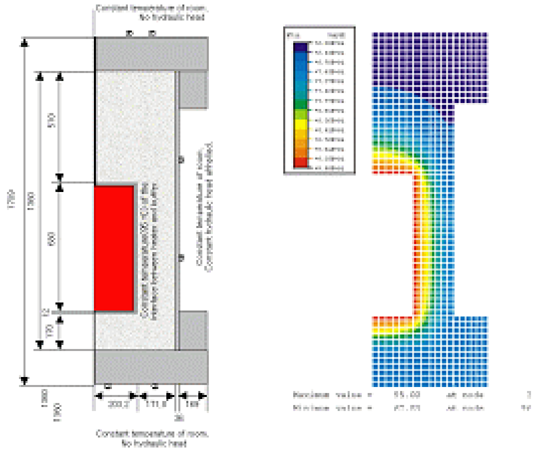

Figure 4 Temperature contour in the benotnite blocks and confining cylinder after 20 days.

4. Summary and further works

The KENTEX facility was set up to validate the T-H-M processes in the engineered barrier system, especially in the buffer of a Korean disposal system. Its design concept and criteria were established and its components were fabricated, based upon the reference disposal system developed in the year 2002. Pre-operational calculation with aid of a computer code ABAQUS was made to get information on sensor location and operation condition. The KENTEX facility is now in progress of test run. Further works will be conducted including validation tests in heating and cooling phases and model simulation for the T-H-M behavior in the buffer of reference disposal system.

REFERENCES

[1] C. H. Kang et al., "High Level Radwaste Disposal Technology Development / Geological Disposal System Development," KAERI/RR-2336/2002, KAERI(2002).