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Engineering-scale Test for Validating the T-H-M Behavior of a HLW Repository: Experimental Set-up

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Abstract

The thermo-hydro-mechanical (T-H-M) process is one of major issues in the performance assessment of a high level waste (HLW) repository. An engineering-scale test was planned and its experimental set-up has being installed, to validate the T-H-M behavior in the buffer of a reference disposal system. The experimental set-up consists of 4 major components: the confining cylinder with its hydration water tank, the bentonite block, the heating system, and the sensors and instruments. The monitoring and data acquisition system is employed to control the heater to maintain the temperature of 95 °C at the interface of the heater and bentonite blocks and to collect signals from sensors and instruments installed in the bentonite blocks.

1. Introduction

The concept of a HLW repository in Korea 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. The HLWs are encapsulated in disposal containers, which are deposited into boreholes on the floor of the emplacement rooms. The gap between the container and the wall of a bore hole is then filled with a buffer material and the inside space of the emplacement rooms with a backfill material. 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 design and construction of the engineered barriers and especially on the change that may occur in the thermal, hydraulic, and mechanical behaviors as a result of the combined effects of the heat generated by the radioactive decay, of ground water flowing in from the surrounding rock, and of the swelling pressure exerted by compacted buffer material. The thermo-hydro-mechanical (T-H-M) process, in this reason, is one of major issues in the performance assessment of a high level waste (HLW) repository.

This paper presents the experimental set-up of engineering-scale test to validate the T-H-M behavior in the buffer of the reference disposal system: design concept, specification and fabrication of major components, installation, and data acquisition and heater control.

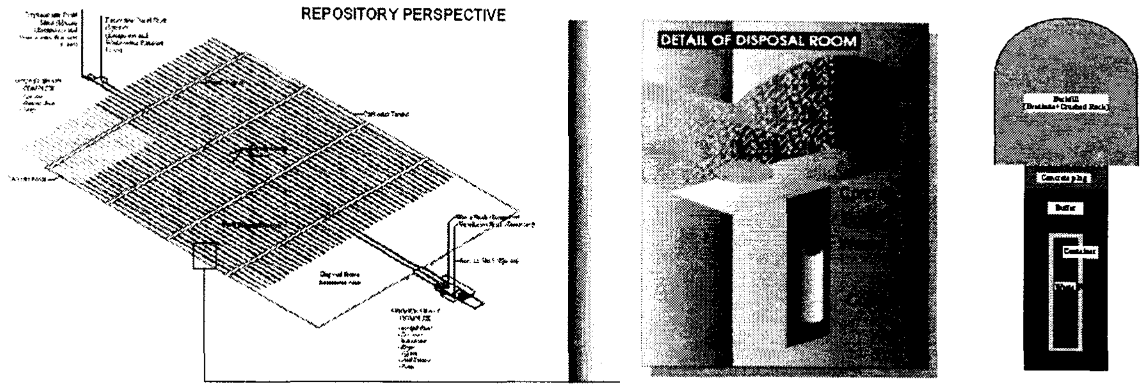


Fig. 1 Schematic picture of a reference disposal system developed in 2002.

2. Experimental Set-up

Figure 2 represents an experimental set-up for KENTEX (KAERI Engineering-Scale T-H-M Experiment for Engineered Barrier System), which was designed to validate the T-H-M behavior in the buffer. This set-up is a third scale of the reference disposal system and consists of four major components: the confining cylinder with its hydration tank, bentonite block, heating system, and sensors and instruments.

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.

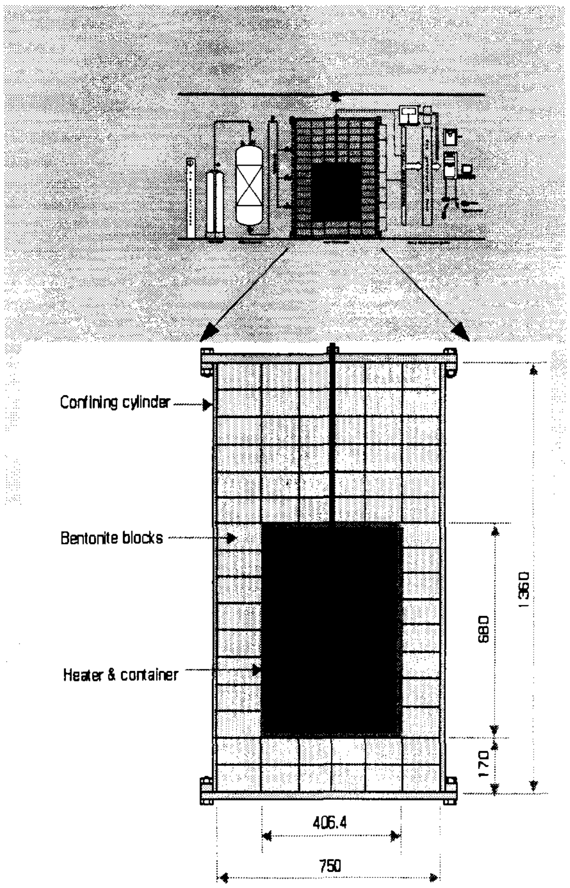
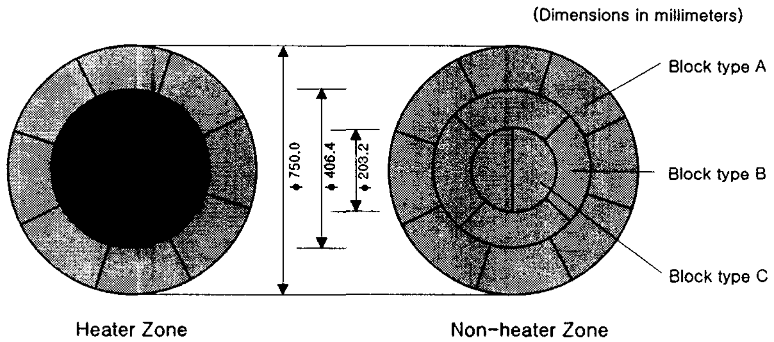


Figure 2. Experimental set-up for KENTEX

The bentonite blocks are fabricated of the bentonite which is taken from Jinmyeong mine located in Kyungju, Kyungsangbuk-do. The bentonite is prepared after its raw material is dried below 110 °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 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.

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 100 °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.



Block type	Radius mm		Angle in degrees α	Dimensions mm			Thickness mm	Number of blocks(*)
	R	r		a	b	c		
A	375.0	203.2	45	287.4	155.5	172.3	85	128
B	203.2	101.6	90	287.4	143.7	101.6	85	32
C	101.6		180	203.2	203.2	0	85	16

Figure 3 Specification of bentonite blocks used for KENTEX test.

The sensors used for the KENTEX are selected considering the working conditions: total pressure ≥ 10 MPa, temperature up to 100 °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. Table 1 summaries the measurement parameter and the type, model, and number of sensors. The sensors in the bentonite blocks are grouped into 9 sections in the alphabetic order of A - I. The location of the sensors installed in the 9 sections, which was determined by preliminary modelling during the design of the tests, is shown as an example in Figure 4.

Table 1 Specification of sensors used for KETEX test.

Temperature	Thermocouple	Watlow-Gordon T-type	42(10*)
Water content	RH & temp. transmitter Psychrometer	Vaisala HMP 234 (for <15%) Wescor PCT 55 (for >15%)	5 5
Swelling pressure	Pressure cell	Kulite BG 0234	6

(*) No. of thermocouples installed on the heater.

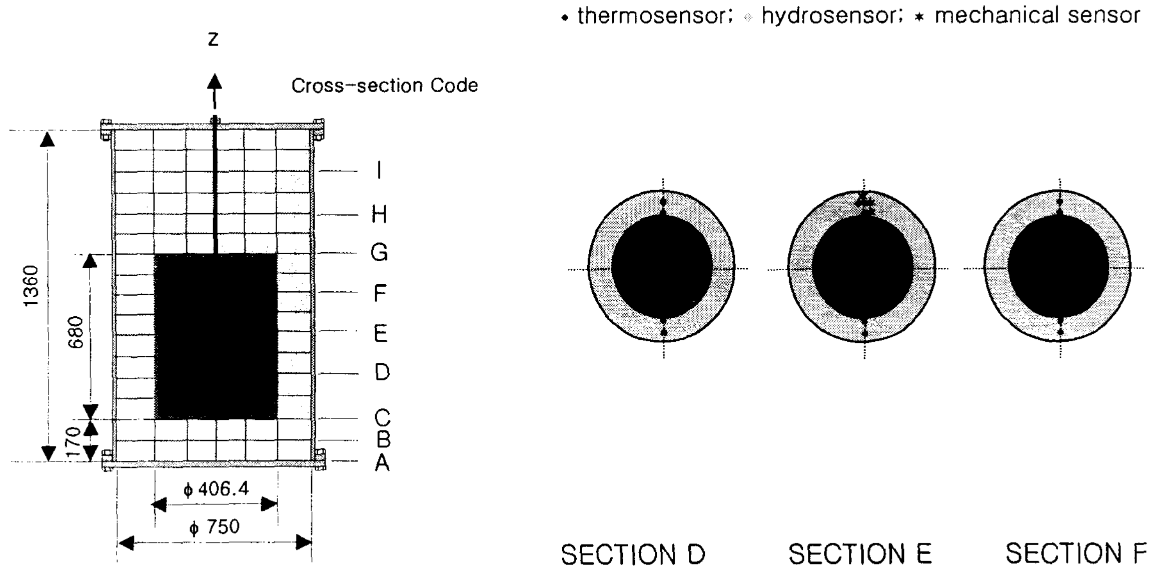


Figure 4 Location of Sensors to measure the temperature, relative humidity, and total pressure.

3. Data Acquisition System and Heater Control System

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.

The electric and/or electronic components of the DAS and HCS and the logic procedure of data acquisition and heater control is shown in figure 5.

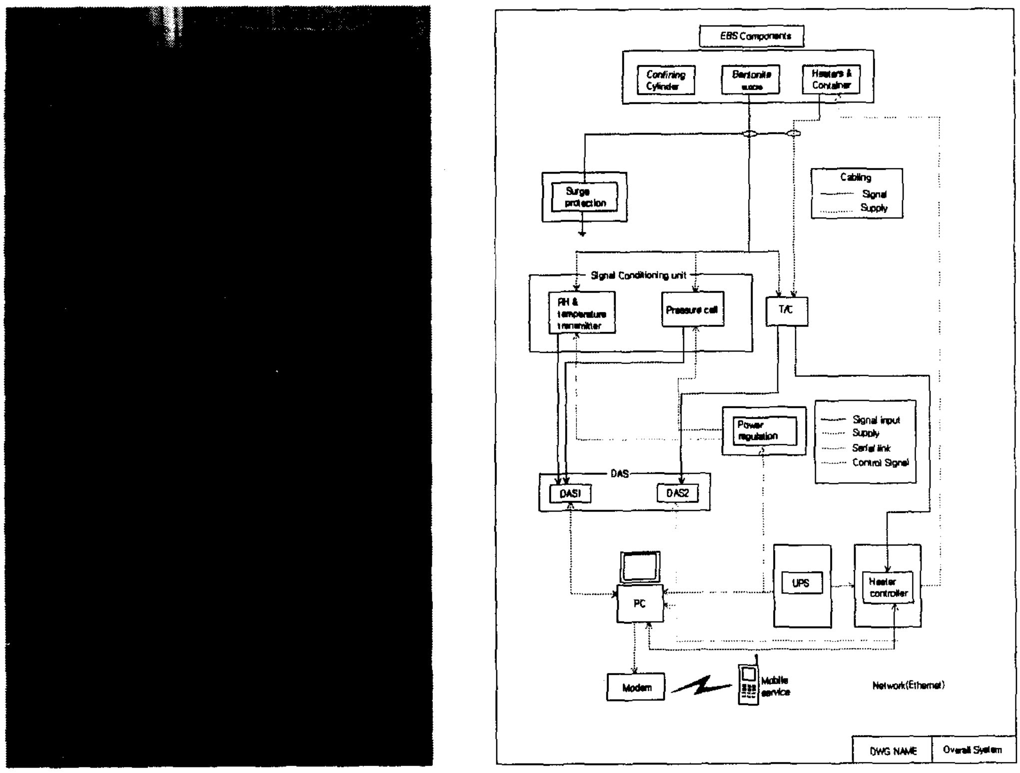


Figure 5 DAS/HCS and flow chart of data acquisition and heater control logic in KENTEX

4. Summary and Further Works

The KENTEX test was planned to validate the T-H-M processes in the engineered barrier system, especially in the buffer of a repository. The concept and criteria for the experimental set-up were established and its components were designed and fabricated, based upon the reference disposal system which was developed in the year 2002. The installation of the experimental set-up is now in progress. The operation will be followed at the end of June, 2004 and the model simulation with this will be done to validate the T-H-M behavior in the buffer of reference disposal system.

Acknowledgement

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References

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