Single Fuel Assembly Temperature Experimental Facility (STEP)

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1. Introduction

The government has proposed a high-level radioactive waste management plan to store temporarily high-level radioactive wastes at plant sites in a dry storage method until an interim storage facility or a permanent disposal facility is in operation [1].

One of the most important results of the dry storage system thermal evaluation is confirmation that the fuel cladding temperature will remain below a specified limit to prevent unacceptable degradation during storage [2].

COBRA-SFS(Spent Fuel Storage) code for thermal-hydraulic analysis of multi-assembly spent fuel storage has been developed to analysis of spent fuel storage [3]. Recently, The KAERI has performed the sensitivity analysis by using the COBRA-SFS to determine the priority of the model development and experiment variables [4] and also figured out and constructed a temperature experimental facility with a model PWR spent fuel assembly named STEP.

This paper discusses the experimental setup, experiment carried out and initial test results of STEP.

2. Hardware Description

The equipment can be categorized in three general groups; mechanical, electrical, and instrument/data acquisition system.

2.1 Mechanical system

STEP consists of the assembly storage cask, the 14xl4 electrically heated model fuel assembly, the transition piece, fuel tube, the cask lid, and chamber as shown in Fig.1. The cask comprises the containment and pressure boundary for the STEP equipment. The cask is fabricated from pipe with a 5 mm thick, 545.8 mm diameter inner wall, and 4,400 mm long of stainless steel. Top of the cask has a bolted cask lid, which the bulk of various internally mounted thermocouple leads are passed through. An insulating blanket of 50 mm thick of ceramic wool covered the cask to minimize the heat loss.

The model fuel assembly is designed and built to be structurally and thermally characteristic of a typical 14x14 commercial PWR spent fuel assembly. With a total power range of 0~1 kW, the assembly consists of 179, 9.5 mm diameter, independently powered, resistance element tubular heater units. The heater pin has a 3,800 mm heated length. Also 17 unheated 12.7 mm pins are simulating control rod guide tubes. The transition piece and fuel tube assembly serves the functions of supporting the model fuel bundle assembly within the cask. The fuel tube is a rectangular 220 mm I.D., 5 mm thick, and 3,870 mm length with stainless steel. The chamber supports the load of a fuel tube and an assembly as well as provides paths for electric power lines and for gas backfill system.

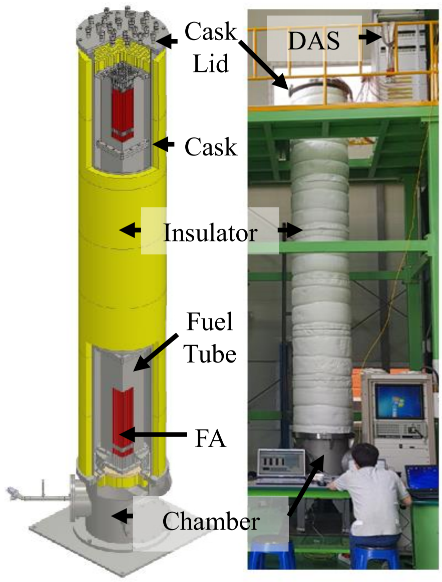

Fig. 1. Single Fuel Assembly Temperature Experimental Facility (STEP).

2.2 Electrical system

The model fuel assembly power is fed from a 220 V AC. 5 separate electrical power supply and control systems are needed for STEP to simulate the 5 radial power distributions. Power is manually controlled by controller which allowed the total assembly power to be set to the appropriate level of 0.5 ~ 3 kW. Each heater rods in the assembly has their respective electrical leads terminated at a connector in power distribution box in the chamber.

2.3 Instrumentation/Data Acquisition System.

A total of 190 separate thermocouples are mounted on the STEP. 1 through 104 are attached on assembly at eight different axial levels. 105 through 128 are positioned on outer surface of fuel tube. 129 through 152 and 153 through 160 are attached on inner and outer surface of cask, respectively. 161 through 190 are located in the center of subchannels by supporting device. Electric transducers are installed in the each power supply system. The electric transduces has specification with 50 A and 300 Volt input as well as 1~5 Volts analog output signal. Reading from the thermocouples and power supply system are stored in data accusation system. DAS is equipped with 4 Keysight 34972a data loggers and a laptop with Agilent VEE Pro. 9.0 Program.

3. Test Operation

We measured the surface temperature of fuel rods, a fuel tube, and a cask as well as the temperate in exit subchannels at the steady state condition under the 1kW power supply with uniform and non-uniform radial power distribution at an initial operation. The powers of 5 rod group are 205 kW, 202 kW, 202 kW, 205 kW, and 206 kW as well as 0 kW, 0 kW, 333 kW, 333 kW, and 333 kW for uniform and non-uniform power distribution, respectively. The Fig. 2 shows the axial temperature distribution of a hottest rod as radial power distribution change. The maximum temperature is 272℃ and 295℃ on uniform and non-uniform radial power distribution, respectively. The temperature increase factor, at which is ratio of temperature percent increase to power percent increase, is 0.135. We obtained a heat transfer coefficient from the measured data of temperature difference between on the surface of rods and in the middle of a subchannel. The heat transfer coefficient for a hottest fuel rod is 3.48 $w/m^2 \cdot$℃ and is close to the recommended user input value of 3.66 in the COBRA-SFS code.

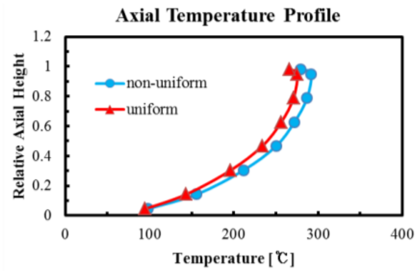

Fig. 2. Axial Temperature Profile on a Hottest Rod.

4. Conclusions

The STEP is designed and constructed to investigate the heat transfer characteristics of a spent fuel under simulated dry storage conditions. We have confirmed the performance of the STEP through an initial operation. The fuel cladding temperatures will be measured as functions of cask backfill gases. The test data are intended to be used in evaluating predictions of a thermal analysis computer code used to model spent fuel dry storage systems.

ACKNOWLEDGEMENT

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