Heat Removal Verification Tests Using Concrete Casks

Background

The concrete cask is remarkable as an interim storage method of spent nuclear fuel which is more economical compared with the metal cask. In the concrete cask, a natural circulation cooling system which removes heat from the canister is adopted. Flow rate depends on the sensitive balance between heat rate and the pressure loss of the flow channel in the cask. Therefore, in order to obtain the accurate data of temperatures at each position in the cask, it is necessary to perform verification tests using a full scale concrete cask.

Objectives

The objectives of this study are to perform heat removal tests using a reinforced concrete cask (RC cask) and a concrete filled steel cask (CFS cask) (Figure 1), to measure temperatures of each position in the cask and flow rate in the normal condition and in the accident condition, and to evaluate the integrity of components of the cask.

Principal Results

1. Normal condition (with heat rate of the initial storage stage corresponding to 22.6kW, and heat rate of the final storage stage corresponding to 10kW)

1) RC cask:

In the test simulating the initial storage stage, the maximum temperature of the concrete container showed 91˚C, which was over the limited temperature for the long-term, i.e.90˚C (Figure 2). It was considered that the pressure loss was large in the flow channel of the cask. Therefore, the thermal design (ex. flow channel shape) must be changed. The ratio of heat removed from the cask was calculated using the experimental data. It was found that 80 % of the total heat was removed by the cooling air and that the heat transfer from the bottom of the concrete container to the floor was insignificant (Figure 3). These data become useful information for design of the cask.

2) CFS cask:

In the test simulating the initial storage stage, the maximum temperature of concrete container was under the limited temperature for the long-term.

In both casks, the area of the canister surface temperature below 100˚C, which may be susceptible to the stress corrosion cracking of metal, was observed in the tests under the condition of the final storage stage.

2. Accident condition (at the initial storage stage with 50% blockage of the air inlet)

The tests were performed under the condition of two inlets blockage of four inlets as the accident condition. In both casks, the maximum temperatures in the concrete container were under the limited temperature for the short-term, i.e., 175 ˚C within 24hours (Table 1). The increase of temperature in the concrete container was 5˚C in the RC cask and was 10˚C in the CFS cask, respectively. Decrease in the rate of air flow was 4% in the RC cask and was 23% in the CFS cask, respectively. The flow pattern is different between the RC cask and the CFS cask. However, it was found both casks had enough heat removal capacity under the accident condition.

This study has been carried out under the contract from Ministry of Economy, Trade and Industry.

Future Developments

A metal corrosion (stress corrosion cracking) phenomenon for a canister in the final storage stage will be studied and countermeasures will be proposed.

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Reference

H. Takeda, et.al., 2004, “Study on Concrete Cask for Practical Use - Heat Removal Test under Normal Condition -”, CRIEPI Technical Report N04029 (in Japanese)

M. Wataru, et.al., 2004, “Study on Concrete Cask for Practical Use - Heat Removal Test under Accident Condition -”, CRIEPI Technical Report N04030 (in Japanese)

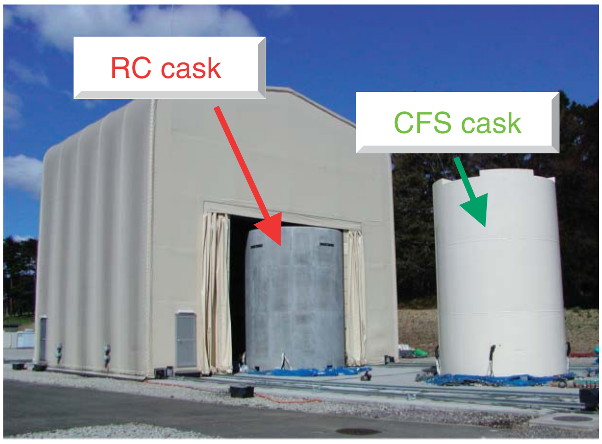

Fig.1 Full scale casks

Two types of full scale casks were used in heat removal tests. Change of the decay heat of spent fuel was simulated using electric heaters.

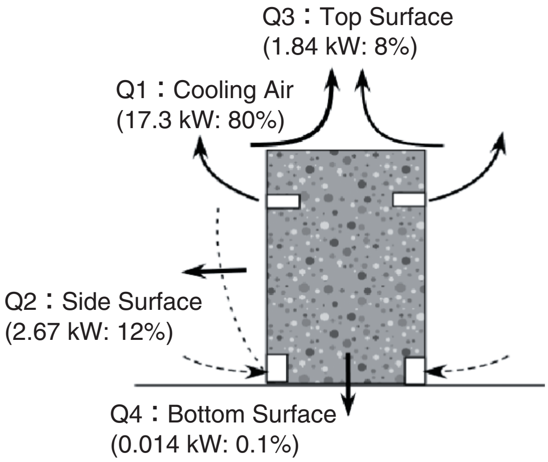

Fig.3 Heat balance

In the RC cask with 22.6kW, it was found that 80 % of the total heat was removed by the cooling air and that the heat transfer from the bottom of the concrete container to the floor was insignificant.

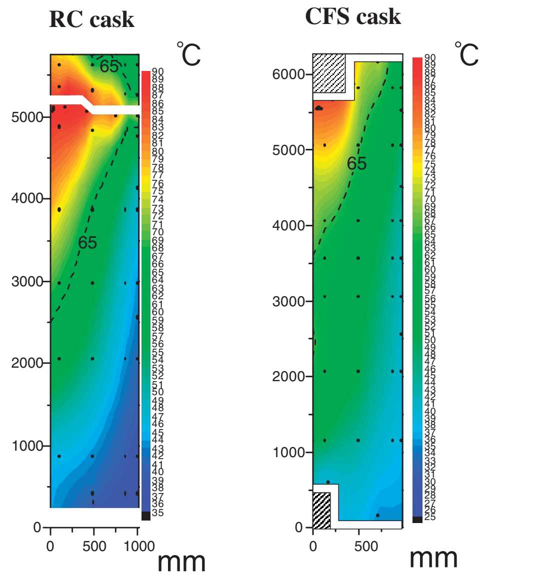

Fig.2 Temperature distributions

In the RC cask with 22.6kW, the temperature of the concrete inside of outlet duct was over limited temperature for the long-term, i.e. 90℃. It was considered that the pressure loss was large in the flow channel of the cask.

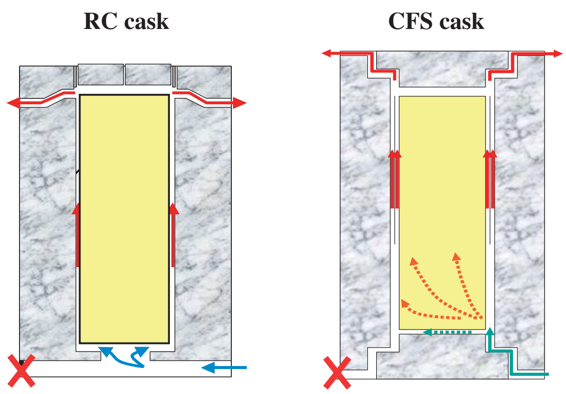

Fig.4 Flow patterns under 50% blockage of the inlet

In the RC cask, the air is uniformly distributed to the annulus gap from the bottom cavity. On the other hand, in the CFS cask, the air flows to the annulus gap directly.

Symbol × means the position of inlet blockage.

Table 1 Temperature and flow rate at 22.6kW under the normal condition and the accident condition of 50% blockage of the inlet

	RC cask		CFS cask	
	Normal	50% blockage	Normal	50% blockage
Tin of air (℃)	33	33	33	33
Tmax of concrete body (℃)	91 (90 *)	96 (175 **)	83 (90 *)	93 (175 **)
Tmax of canister surface (℃)	209	214	192	200
Tmax of guide tube (cell) (℃)	301	306	228	235
Δ T of air (℃)	65	70	52	66
Flow rate (kg/s)	0.335	0.321	0.363	0.280

The temperatures in the table are converted to the value where inlet air temperature is 33°C.
*: limited temperature for the long-term: 90°C
**: limited temperature for the short-term: 175°C (within 24 hours)

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