7–2 Reliable Decay Heat Removal by Natural Convection

- Core Cooling Experiment Using Dipped DHX and Development of Evaluation Method -



Fig.7-5 Schematic and imaging of the test section of PLANDTL-2 and target phenomena in natural circulation decay heat removal with D-DHX

The PLANDTL-2 test section (a) models major components of a SFR with 1/5th scale to simulate core cooling behavior (b) by a dipped-type direct heat exchanger (D-DHX).

Decay heat removal systems (DHRSs) that take advantage of thermal properties of liquid sodium (Na) have been studied to enhance the safety of SFRs. A DHRS using a heat exchanger dipped in the upper plenum of the reactor vessel (i.e., a dippedtype direct heat exchanger, D-DHX), shown in Fig.7-5(a) is a prime candidate. This system can work in case of the loss of external power supply to the plant, because high-temperature Na from the core is cooled through the D-DHX returns to the core by natural convection. During the operation of the D-DHX, the low-temperature Na from the D-DHX penetrates the fuel assembly (FA) and the gap between FAs. To clarify the core coolability using the D-DHX, it is important to investigate the thermal interaction between the low-temperature Na and the high-temperature Na. From this perspective, a series of Na experiments using Na experimental apparatus PLANDTL-2 were performed under D-DHX operation to clarify the core coolability and to validate numerical analysis methods.

An overview of the test section of PLANDTL-2 is shown in Fig.7-5; here, major components of SFRs, such as an upper plenum, a simulated core, and a D-DHX were installed at approximately a 1/5th scale. The core was modeled by hexagonal wrapper tube channels consisting of 30 electric heating channels and 25 non-heating channels. More than 550 points of thermocouples were installed inside the test section



(a) Upper plenum (vicinity of D-DHX)

(b) Core outlet





Fig.7-7 Example numerical simulation of PLANDTL-2 In the numerical result (b) using the CFD analysis model (a), typical phenomena were observed, such as the formation of the lowtemperature region formation and penetration into the core.

to obtain a detailed temperature profile across the reactor vessel; a resulting representative measured temperature distribution is shown in Fig.7-6. Here, a low-temperature region was formed in the bottom of the upper plenum by the Na from the D-DHX (Fig.7-6(a)). The low-temperature Na penetrated the inside of the channels and the gaps between them from the outer region of the core (Fig.7-6(b)). The results indicate that the core was stably cooled by the D-DHX operation and the safety-enhanced SFR was feasible.

Measured data in PLANDTL-2 were also used to validate the evaluation method based on numerical analyses using computational fluid dynamics (CFD). As shown in Fig.7-7, it is expected that prediction of thermal hydraulic phenomena inside the reactor vessel becomes possible through the validation using the data obtained in PLANDTL-2. This will allow for the replacement of large-scale SFR tests with numerical analyses, thus reducing the development costs in future.

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Reference

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