

1-3 Residual Heat Removal Using Buoyancy Force

– Evaluation Method for Core Hot Spot under Natural Circulation –

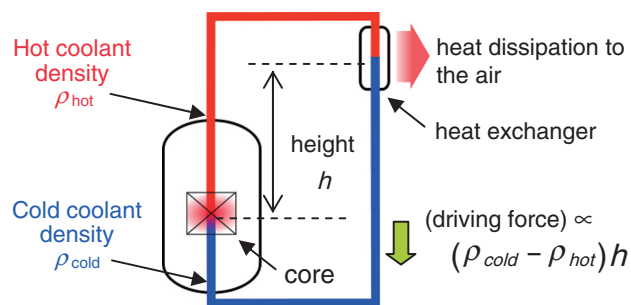


Fig.1-6 Natural circulation in the heat transport systems
Coolant flow is driven by buoyancy force without pumps.

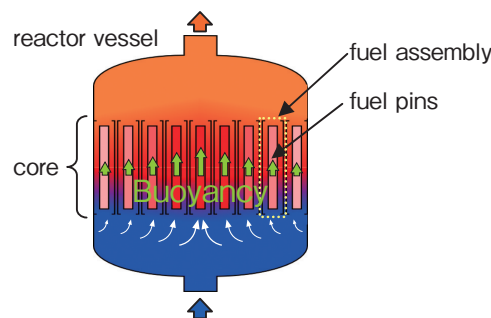


Fig.1-8 Flow redistribution in a core
Since a higher temperature induces a larger flow rate because of buoyancy, the coolant temperature distribution in a core becomes flatter than that under forced convection.

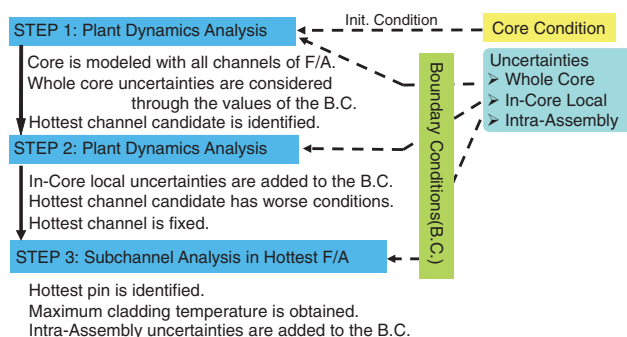


Fig.1-7 Evaluation method for core hot spot under NC
Three-step thermal hydraulics analysis is carried out to identify the hottest fuel assembly (F/A) and the hottest fuel pin under natural circulation conditions. Uncertainties are considered through their boundary conditions.

Although the residual heat after reactor scram ($\approx 5\%$ of rated operation) decreases with time, for reactor safety, it is important to maintain the circulation of coolant through the core and to remove the decay heat.

In sodium-cooled fast reactors, natural circulation (NC) occurs because of buoyancy, which is proportional to the large temperature difference between the heat source (core) and heat sink (heat exchanger) and its height difference, as shown in Fig.1-6. The “JOYO” and “MONJU” reactors in Japan are designed to remove the residual heat in the core by NC of the coolant, even if the electric pumps should not be able to operate. The advanced fast reactor (JSFR) has a fully NC decay heat removal system.

A safety criterion for the core structural integrity under decay heat removal operations is the hottest coolant temperature, which is evaluated by conservative consideration of various uncertainties. Under NC, however, the coolant flow rate and temperature distributions in the core

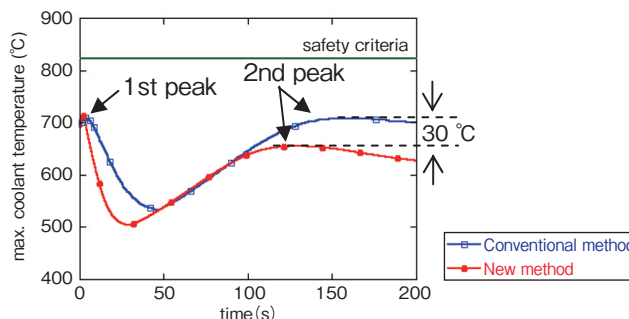


Fig.1-9 Evaluated hottest coolant temperatures (loss-of-external-power event)
The new method can evaluate a core hot spot reasonably with eliminating too much conservativeness.

change dynamically, and the uncertainty does not always affect in the same way, so it should be treated differently from the situation when under forced convection. We developed a new evaluation method (Fig.1-7) that can consider the characteristic phenomena particular to NC and their flattening effects on the coolant temperature distribution in the core (Fig.1-8). The hottest coolant temperature evaluated at the secondary peak can be reduced by approximately $30\text{ }^{\circ}\text{C}$ compared to that in the conventional method (Fig.1-9). The results of this study are applied to the development of reactors that make use of natural circulation.

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Reference

Doda, N. et al, Development of Core Hot Spot Evaluation Method for Natural Circulation Decay Heat Removal in Sodium Cooled Fast Reactor, Proceedings of the 14th International Topical Meeting on Nuclear Reactor Thermalhydraulics (NURETH-14), Toronto, Canada, 2011, NURETH14-170, 13p., in CD-ROM.