7-3 Numerical Simulation for Safety Evaluation of the Steam Generators in Fast Reactors

— A Multiphysics Evaluation System for Tube Failure Accidents —

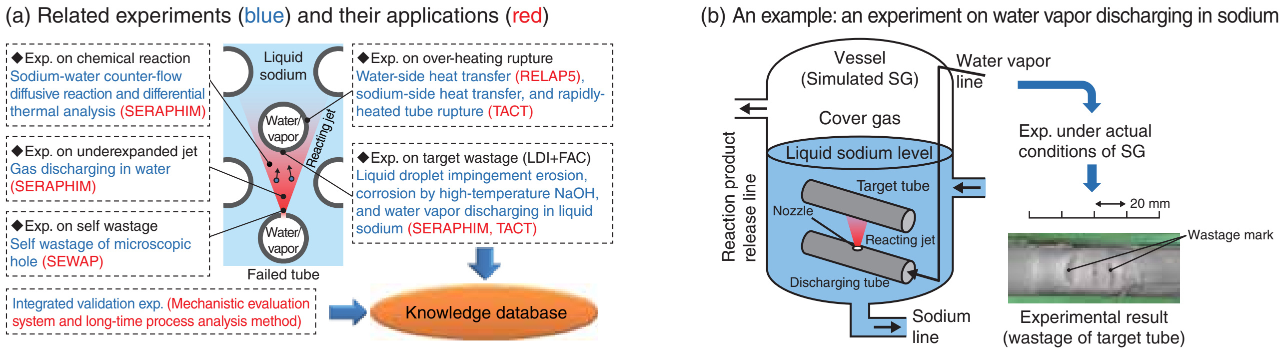

Fig.7-6 Phenomena appearing under tube failure accidents in a steam generator and their related experiments
Some experiments related to tube failure accidents were performed to develop and validate the numerical methods.

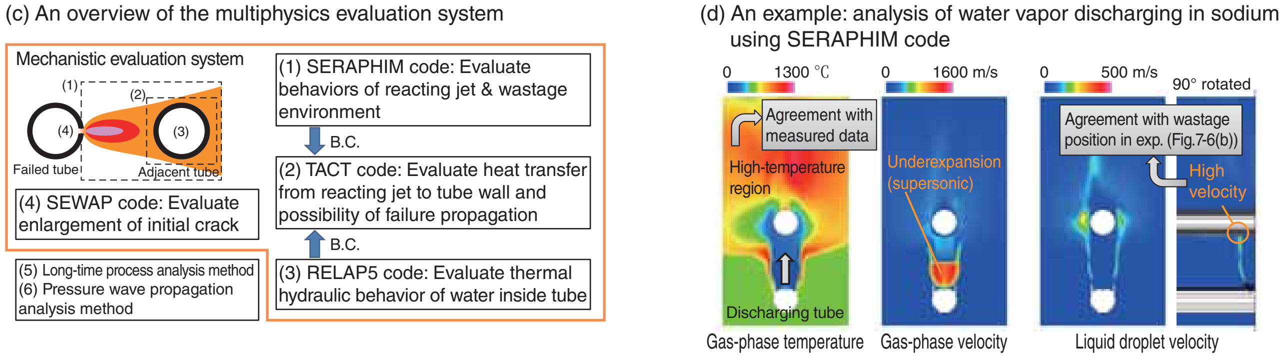

Fig.7-7 A multiphysics evaluation system and an example of numerical simulation
To evaluate tube failure accidents, a multiphysics evaluation system comprising mechanistic numerical methods was developed. The applicability of the numerical methods was confirmed through the analyses of the related experiments.

When pressurized water or vapor leaks from a failed heat transfer tube in a steam generator (SG) of sodium-cooled fast reactors, a high-velocity, high-temperature jet reacts chemically with the surrounding sodium and causes wastage and degradation of the mechanical strength on the adjacent tubes (Fig.7-6). Significant progress of such material damage may lead to failure propagation. Prevention of failure propagation is a major concern in designing the SG. In this study, a multiphysics evaluation system comprising mechanistic numerical methods was newly developed to evaluate the possibility of the occurrence of the failure propagation. The developed system is applicable to a wider variety of operating conditions and design options of the SG than the conventional evaluation method based on exhaustive demonstration experiments.

The systematic experiments shown in Fig.7-6 were conducted for the elucidation of phenomena and the acquisition of data to validate the numerical methods. In these experiments, we succeeded in identifying a dominant process in the sodium-water chemical reaction, measuring the sodium-side and water-side heat transfer behaviors, measuring the rupture behaviors of the rapidly-heated tube, deriving a correlation between the wastage rate and some parameters relevant to liquid droplet impingement erosion and flow accelerated corrosion, and so forth. As an example, Fig.7-6 shows the experiment on water vapor discharging in liquid sodium to obtain data for target wastage under actual plant conditions. A knowledge database including the quantitative uncertainty of the experimental data was constructed. As shown in Fig.7-7, the mechanistic numerical methods were developed for the three regions: (1) the reacting jet, (2) the heat transfer tube, and (3) the inside of the tube. About region (1), a SERAPHIM code with an incorporated wastage environment evaluation model was developed. The applicability of the SERAPHIM code was confirmed through the analysis of the abovementioned water vapor discharging in liquid sodium (Fig.7-7). A TACT code involving the numerical models for heat transfer from the reacting jet to the tube wall and failure judgment (region (2)), and a RELAP5 code involving the water-side heat transfer correlation applicable to the rapid heating condition (region (3)) were also constructed. Our evaluation system can make a large contribution toward designing the SG with an appropriate safety margin.

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Reference

Uchibori, A. et al., Development of Numerical Evaluation Methods for Multi-Physics Phenomena under Tube Failure Accident in Steam Generator of Sodium-Cooled Fast Reactor, Nippon Kikai Gakkai Ronbunshu, B Hen, vol.79, no.808, 2013, p.2635-2639 (in Japanese).