Basic Technology Subjects

Nuclear Technology Research Laboratory

Brief Overview

The Nuclear Technology Research Laboratory aims at positively contributing to the solving/alleviation of energy and global environmental problems by developing nuclear technologies, including base technologies, to support the safety and stable operation of LWRs as well as the recovery from the accident at the Fukushima Daiichi nuclear power plant, so that the use of nuclear energy may be accepted by society in a positive manner.

Achievements by Research Theme

Reactor Systems Safety Technology

In order to continuously improve the light water reactor safety, the development of measures to prevent and mitigate accidents is important in increasing the reliability of nuclear reactor system during operational and accidental conditions. To this end, we aim to sophisticate the evaluation system applied to thermal-hydraulics and risk assessment.

- The Filtered Containment Venting System (FCVS) is required as a severe accident mitigation measure of nuclear reactors. The experimental results showed sufficiently high iodine decontamination performance for a FCVS in operating range (Fig. 1).
- To clarify the reactor core cooling characteristics during a severe accident, a boiling two-phase flow experiment was conducted with a simulated fuel rod bundle. The boiling two-phase flow (e.g. bubble diameter and void fraction) acquired boiling two-phase data (bubble diameter, void fraction and so on), which was expressed as a function of radial power profile, inlet velocity and temperature for the quantitative prediction.
- Regarding the Bayesian methods developed in JANSI for the estimation of component failure rates using 26-year-event data and initiating event frequencies for Japanese nuclear power plants, we have devised a method to resolve the convergence problem in Monte Carlo calculation which arose for rare-event data. JANSI will use the devised method to update the domestic failure rates with 29-year-event data.
- The effect of droplets in wet steam on resonance frequency was investigated in order to evaluate the vibration fatigue of piping and components due to acoustic fluctuations of wet steam at a pipe branch of power plants. A theoretical analysis indicated that droplets in wet steam reduce the resonance frequency when steam wetness is more than several percentages and resonance frequency is less than several hundred hertz (L14006).

Nuclear Fuel and Reactor Core

For enhancing the safety of light water reactor fuel and core, research is promoted to determine the corrosion and degradation mechanisms of fuel cladding, understand the characteristics and behavior of fuel under accidental conditions, and improve the methods of core burnup performance analyses. Characterization of molten fuel and technology development for spent fuel subcriticality measurement are also continued for contributing to the decommissioning of the Fukushima Daiichi nuclear power plants.

- The residual stress distributions in the oxide films formed on fuel claddings were determined from diffractometry by using the X-ray microbeam at the synchrotron radiation facility, SPring-8. The result indicated that the oxide film with preferentially-oriented grains withstands high compressive stress, which presumably suppresses oxygen and hydrogen diffusion in the oxide and accordingly provides a good corrosion resistance. This suggests that controlling the oxide film grain structure is an effective way to improve the corrosion resistance of cladding materials.
- A computer code to simulate several phenomena in nuclear reactor severe accidents was developed based on a particle method, where an object is treated as a cluster of hypothetical particle. Models for heat transfer, surface tension, solidification and melting were developed and implemented in the new code. Further improvement in the code will enable the reasonable simulation of complicated phenomena, such as fuel melting and molten material relocation.
- The criticality safety design of spent fuel storage facilities can be rationalized by considering the reactivity decrement of spent fuel assemblies. This requires the confirmation of the burnup histories of respective spent fuel assemblies. For developing a method to confirm the burnup histories, the radioactivity ratios, $^{134}Cs/^{137}Cs$ and $^{154}Eu/^{137}Cs$, were evaluated from gamma-ray spectra measured for high burnup (approximately 56GWd/t) fuel rods. The evaluated values agreed with the radioactivity ratios obtained by the calculation tracing the burnup histories. This means that the method of using radioactivity ratios is applicable to high burnup spent fuels (L14003).

Nuclear Fuel Cycle

We contribute to closing the nuclear fuel cycle by conducting studies necessary for the early commencement of commercial

operation for Rokkasho Reprocessing Plant. Other studies for new additional facilities at the reprocessing plant are also conducted. A prevention technique for radioactive contamination during severe accidents and a treatment technique of damaged fuels by applying a pyrochemical technology are discussed.

- In order to obtain basic data necessary for safety analysis during storage of hull waste (chopped fuel pin), the vaporization behavior of water contained in crystallized zirconium molybdate (Mo-Zr) is estimated and the pressure increase in the container for the hull waste on which some Mo-Zr is adhered is evaluated. Vitrification tests of the incinerated ash are conducted as an example of application of vitrification technologies for the low level waste generated at nuclear power plants.
- We are continuing the technical support for the radioactive contaminated water treatment facility. For the purification of sea water contaminated with relatively low radioactive, we proposed the combined process of the zeolite absorption process, the zeolite regeneration process by elution and the precipitation method for the removal of radioactive elements effectively from seawater.

Human Factors Research

In order to contribute to building an organization that exhibits good performance free of human error during both normal operation and emergencies, we will develop measures toward preventing human error and fostering a safety culture by bringing out the features of individuals, teams, and organizations.

- Through literature review and an interview survey on training/education methods to improve workers' risk perception, we categorized the methods into 10 categories and extracted 24 conditions needed to make the training/education successful. In particular, we identified that making trainees feel fear of risk/hazard, recognize gap between self-evaluation and reality and evaluate from others as the most important of the said 24 conditions. Educational effectiveness for their risk perception is expected to be increased by providing educations and trainings with consideration of these conditions.
- We proposed systematized measures for introducing safety rules in the process of developing corrective actions of an incident with consideration to the effect of level of rule detail on the psychological process of workers*. These measures enable restricting the number of excessively detailed rules introduced as corrective actions on a human factor incident.

* For example, while an excessively detailed rule leads to confidence towards the result of a safety behavior, it also supposedly leads to a decrease in work efficiency.

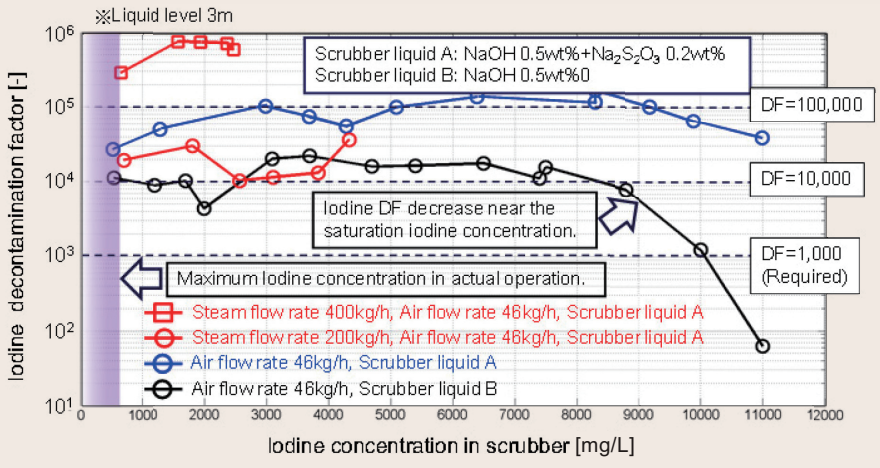

Fig. 1: Iodine decontamination performance

Iodine DF (vertical axis) with the full-height facility as a function of the iodine concentration in the scrubber (horizontal axis). Iodine concentration can be reduced less than 1/1000 with FCVS even beyond the operating range show in the left of the figure (iodine concentration range 0 – 600 mg/L).