Priority Subjects — **Further Improvement of Facility Operations and Maintenance Technologies**

Integrity Assessment of Aged LWRs

Background and Objective

For the long term operation (LTO) of LWRs, it is necessary to evaluate the safety and integrity of materials and components based on scientific knowledge. Meanwhile, in order to conduct research in the name of LTO, basic experimental or evaluation methods are also required. We will elucidate the degradation mechanism of reactor pressure vessels, core internals, piping and insulation cables for safe LTO by improving evaluation methods, experimental techniques and facilities.

Main results

1 Improvement of prediction accuracy for irradiation embrittlement and environmental degradation of RPV steels

Through the observation of surveillance specimens exposed to relatively higher fluence, it was ascertained that neutron irradiation embrittlement due to unpredictable factors did not appear in the higher fluence region. The irradiation embrittlement correlation in the present code has been revised based on the analysis of the latest surveillance data, which led to improvement of the prediction accuracy (Fig. 1) (Q12007). Round robin tests have been conducted among a national university, industries, and an institute. The tests reveal the validity of the fracture toughness test using miniaturized CT specimens, which can be taken from examined half pieces of surveillance Charpy specimens.

2 Evaluation of the wall thinning profile caused by flow accelerated corrosion in separation and union pipes

In some parts of T-tubes with reinforcing plate or T-joints which have curvature at their junctions (crotch), it is difficult to accurately evaluate wall thinning profiles due to configurative restraints. For such pipe elements, by conducting flow analysis, the mass transfer coefficient which is related to flow accelerated corrosion (FAC) was calculated in order to evaluate wall thinning profiles and relative thinning rate. An obvious wall thinning tendency is recognized beneath the reinforcing plate of T-tube and at crotch of T-joint (Fig. 2). Although the wall thinning profile can be obtained adequately by measuring the current locations, a more detailed wall thinning profile can be evaluated by the flow analysis.

3 Improvement of prediction accuracy for wall thinning

The effect of dissolved oxygen concentration on FAC rate was evaluated. FAC of the carbon steel at 180°C is suppressed in neutral water (pH 7.0) containing more than 25 to 30 ppb oxygen or, in alkaline solution (pH 9.8) containing more than 1 to 4 ppb oxygen. It is demonstrated that the increase in pH decreased the dissolved oxygen concentration necessary for FAC suppression (Fig. 3). Considering the effect of oxygen concentration, our FAC prediction model is improved. (Q12008)

4 Development of a prediction model for the degradation of cable insulation

A new degradation model for polymeric insulations used in safety-related cables was developed in order to account for the effect of antioxidants and to simulate several synergisms in various thermal and radiation environments. A chemical reaction scheme was used to represent oxidation reactions via the decomposition of peroxide radicals. The calculation result confirms that the new one-dimensional model qualitatively fits an aging depth profile of thermally-aged polyethylene. High activation energy was applied to the initiation reaction in order to simulate the dose rate dependencies of material lifetimes at several fictitious temperatures (Fig. 4). The contribution of heating to material degradation gradually becomes dominant with increasing temperature. Non-Arrhenius behavior is also successfully demonstrated with reasonable apparent activation energy for the terminal product generation.

Other reports: (Q10035), (Q10016)

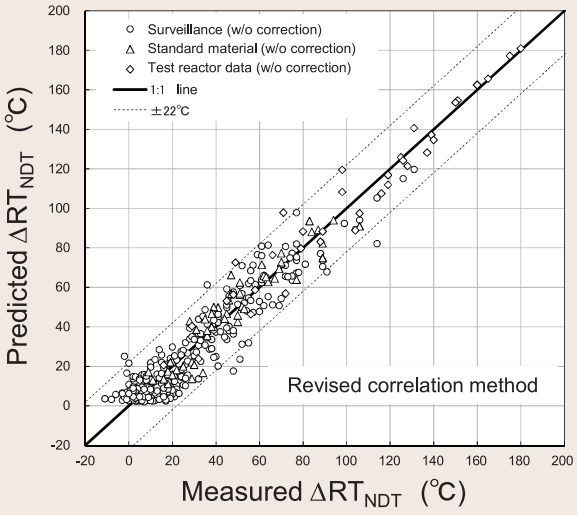

Fig. 1: Comparison of the predictions using the revised correlation method with the measurements of the surveillance program

The prediction accuracy has been improved through the large embrittlement region including high fluence surveillance data as well as test reactor irradiation data.

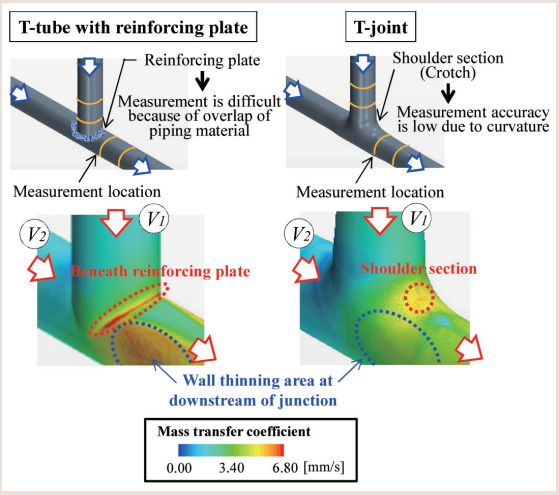

Fig. 2: Wall thinning profile of T-tube with reinforcing plate and T-joint

In some parts of T-tube with reinforcing plate or T-joint which has curvature at the junction, it is difficult to accurately evaluate wall thinning due to their configurative restraints. Mass transfer coefficient, flow factor of FAC, was calculated and wall thinning profiles of the T-tube or T-joint were evaluated, by conducting flow analysis. Apparent wall thinning is recognized where actual measurement is difficult (red dotted line). The wall thinning is also recognized at downstream of junction (blue dotted line), where wall thickness can be measured.

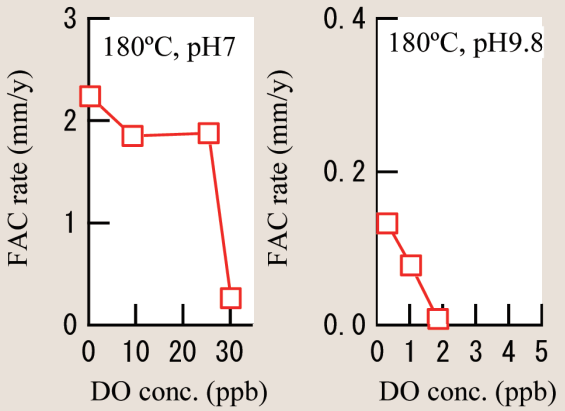

Fig. 3: Effect of dissolved oxygen (DO) concentration on the FAC rate

Specimen: Carbon steel (0.001wt% of Cr). Temperature: 180°C. Flow rate: 3.8 to 5.1 m/s. NH_3 was injected to control pH of the solution.
The effect of dissolved oxygen concentration on the FAC rate was evaluated. FAC of carbon steel at 180°C was suppressed by the oxygen more than 25 to 30 ppb in neutral water (pH 7.0), and was suppressed more than 1 to 4 ppb in alkaline solution (pH 9.8).

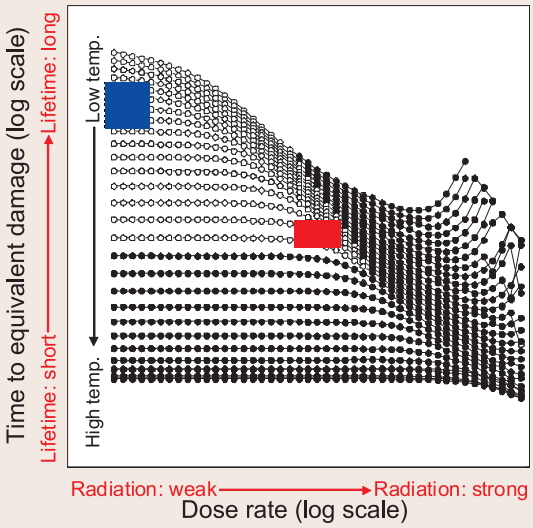

Fig. 4: Relationship between time to equivalent damage (TED) and the dose rate

Areas painted in red and blue represent the simulated conditions of accelerated aging and actual operation, respectively. Open symbols indicate that the distribution of oxidative degradation in the bulk at TED is homogeneous, while the solid symbols represent inhomogeneous distribution. The U-shaped dose rate dependencies descend to lower value with increasing temperature.