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

Assessment of Cable Insulating Performance Used in Nuclear Power Plants

Background and Objective

Evaluating the insulating performance integrity of instrumental and control cables used in containments is important to establish safe and stable operation of nuclear power plants. Heat and radiation, along with their synergic effects, have to be adequately considered on the basis of in-service aging states to implement technically reliable aging prediction on polymeric insulating materials. The aim of the present study is to investigate and improve the lifetime evaluation method to consider several factors under normal plant operation conditions. This is undertaken through analyzing the aging trend of service-used cables.

Main results

1 Confirming integrity through analysis of service-used cables

Short available service duration is predicted based on an accelerated aging test for some kinds of frame-retardant ethylene propylene rubber insulations*1. Analysis on mechanical properties such as elongation at break and on chemical properties such as micro infrared spectroscopy as well as oxidation induction time were carried out for the corresponding service-used cable insulations in the present study. The result depicted in Fig. 1 shows that their integrity is secured even 24 years after installation (operation duration: 16 years).

2 Statistical data analysis of service-used cables

Statistical analysis was conducted for elongation at break values*2 obtained for the service-used cable insulations*1. Service period used for the analysis was evaluated assuming that the cables were used under the same condition, 60°C and 10 mGy/h, since the actual environments were different for each of the cables. A regression curve was obtained to reveal the aging trend under normal operation conditions. The curve was then used as a reference and each mechanical data was extrapolated to estimate their service duration*3. The result (Fig. 2) shows that the predicted available service duration based on accelerated aging tests is much shorter than the reference one (H13002).

3 Wear-out artificial additional aging for service-used cabl

An additional thermal aging test based on wear-out approach*4 was performed for the service-used cable insulation (Fig. 3). The mechanical aging trend observed during the test was slower than the one predicted from the acceleration aging result in the ACA project*1 (Fig. 4)*5. Moreover, by performing a recovery analysis using a logistic function it was quantitatively suggested that aging slows down.

All the analyses conducted above show that the prediction using the acceleration aging test reported in the literature*1 is too conservative.

*1 Japan Nuclear Energy Safety Organization, JNES-SS-0903, 2009 (Assessment of Cable Aging for Nuclear Power Plant, ACA project)
*2 Y. Eguchi, 2012 Equipment Qualification Technical Meeting, San Antonio, TX, 2012
*3 Criterion on elongation at break is set to 70%, and service duration is estimated for the actual operation period to reach this value.
*4 A methodology to estimate the material lifetime from the relation between the operation period and wear-out time to reach the criteria.
*5 N. Fuse et al., IEEJ Tech. Meeting on Dielectric and Electrical Insulation, DEI-14-42, Tokyo, 2014.

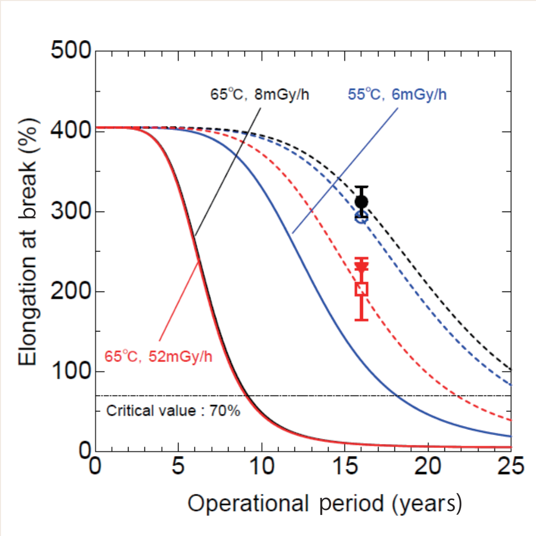

Fig. 1: Comparison of aging trends in service-used cables and aging prediction by the ACA project

Several instrumental analyses were conducted on service-used cables in order to evaluate their integrity. Discrepancies between the prediction by the ACA project (solid curves) and the actual aging trend (broken curves) are clearly shown.

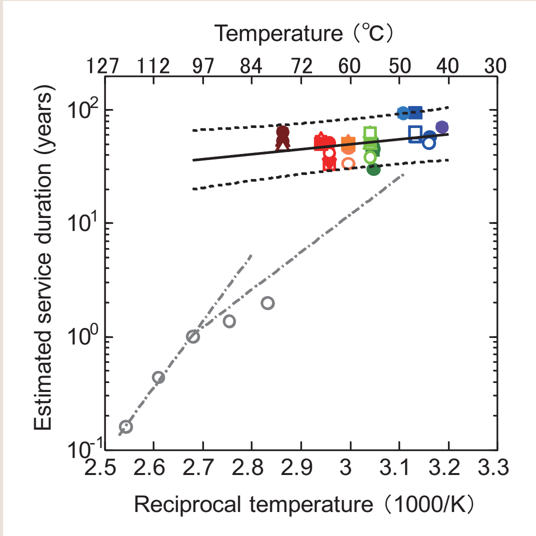

Fig. 2: Service duration estimated for cables used in nuclear power plants and their temperature in an Arrhenius plot

Colored plots are the duration estimated for each service-used cable. Their regressed result is shown in a black solid line, and the two broken curves represent 95.4% prediction band. Gray open symbols are the result of an acceleration aging test performed by the ACA project.

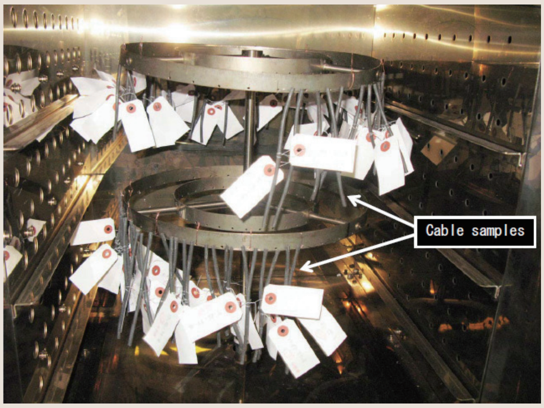

Fig. 3: A thermostatic oven during the wear-out additional aging test

Additional heat aging is performed on service-used cable insulations at 110°C. The test meets the Japanese Industrial Standard to use a gear oven with air ventilation every hour. Conductors are removed from the samples prior to the test.

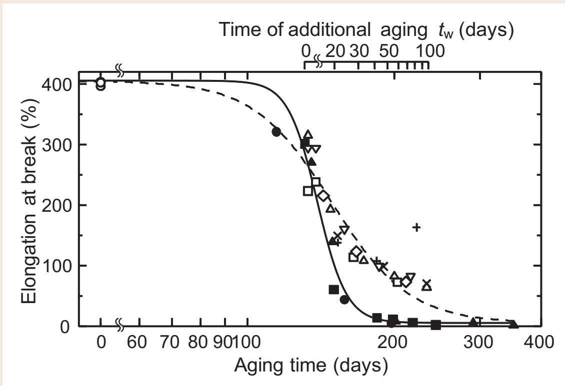

Fig. 4: Comparison of the mechanical aging trend during the wear-out test to that predicted based on the ACA project result

The solid plotting with a regressed curve indicates the prediction based on ACA project result. The open circles are the value for un-degraded samples. The other open symbols and their regressed curves represent the wear-out testing result of service-used cables.