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Assessment of a leakage by a water pressurization on a degraded SG tubes

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1. Introduction

Ni based alloy 600 materials have been used a lot for steam generator (SG) tubes which were being installed in Pressurized Water Reactor (PWR) nuclear power plants. Recently the trend is to replace alloy 600 SG tubes with alloy 690 materials because of its excellent corrosion resistance. The installed SG tubes in the existing PWRs have experienced various types of corrosion damage, such as a pitting, wastage and Stress Corrosion Cracking (SCC) on both the primary and secondary side. It is important to establish the repair criteria for the degraded tubes to assure a reactor integrity, and yet maintain the plugging ratio within the limits needed for an efficient operation. The primary coolant leakage to the secondary system is likely to suffer difficulties in the radiation safety management aspects when the steam generator tubes of the currently operating power plant have occurred SCC defects. Therefore, an evaluation of a coolant leakage behavior of the tubes containing stress corrosion cracks is very important under the pressure conditions of a operating or a virtual accident. The objectives of the present work are to develop the various forms of SCC tube defects and to evaluate a coolant leakage from SCC cracks of SG tubings at room temperature.

2. Methods and Results

2.1 Development of OD and IDSCC on SG tubes

High temperature thermally treated (HTMA) alloy 600 tubes were used for the purpose of the present work. The outside diameter (OD) and the wall thickness (WT) of the tubes were 19.05mm (0.75 in.) and 1.07mm (0.042 in.), respectively. Before exposure to the tetrathionate solution, the specimens were heat treated at 600^{o}C for 36-48 hours to produce a microstructure that is susceptible to a cracking. The heat treatment was performed in a tube filled with an argon-nitrogen mixture gas to avoid an oxidation of the tube surfaces. The tubes were internally pressurized with nitrogen gas during the exposure. When a SCC grew through-wall, the internal gas pressure dropped, the SCC process was completed. Chemical compositions of the alloy 600HTMA tubes are shown in Table 1.

Table 1 Chemical compositions of alloy 600MA tube (wt %)

Alloy	C	Si	Mn	P	Cr	Ni	Fe	Co	Ti	Cu	Al	B	S	N
600MA	0.025	0.05	0.22	0.07	15.67	75.21	8.24	0.005	0.39	0.011	0.15	0.001	0.001	0.01

2.2 Leak rate test

Leak rate test were performed for the degraded tubes specimens at room-temperature using a high pressure leak-rupture test facility (Fig.1.). The facility consists of a water pressure pump, a specimen stage and manipulator, and a control system. It has the similar features as described in NUREG/CR-6511 [2]. The inside of the tube was pressurized with water. The water pressure was increased until the tube shows a leakage. The first leak from the tube can be detected visually by the naked eye through a transparent plastic window. The leak rate at a given pressure was measured by weighing the water from the leak. The pressure was held at a certain value for a designated time to measure a leak rate. The measured data of a leak rate were recorded in a storage unit.

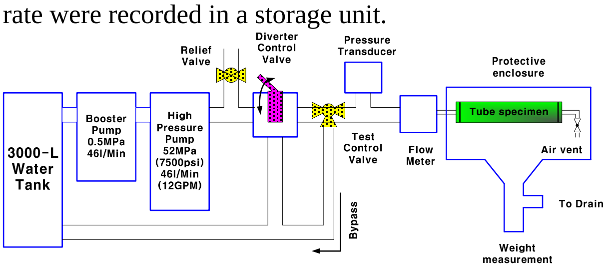

Fig.1. High pressure leak and burst test facility.

Several SG tube specimens with various SCCs were tested for the present investigation. The SCC flaws have a characteristically different flow path through crack surface and a different leak behavior. Fig.2 shows the typical behavior of the pressure and leakage rate during water pressurization on a degraded SCC tube. In case of that specimen, the leak tests were conducted 2 times with the same specimen (KY56088). As the pressure increased, the crack opening area (COA) increased and the leak rate also increased consequently. Because the flow path and the crack width were deformed during the 1st test, the average leak rate in the 2nd test was greater than that of the 1st experiment.

The behavior of the leakage measured and compared leak rates of the ID and ODSCC are shown in Fig.3. As already demonstrated in Fig.2, the leak rate of an ODSCC in the 2nd test was greater than that in the 1st. Despite the low water pressure region and the shorter length of IDSCC than that of ODSCC, the leak rate of the IDSCC was much larger than ODSCC one. This implies that ID side developed cracks are more easily opened than OD side initiated cracks.

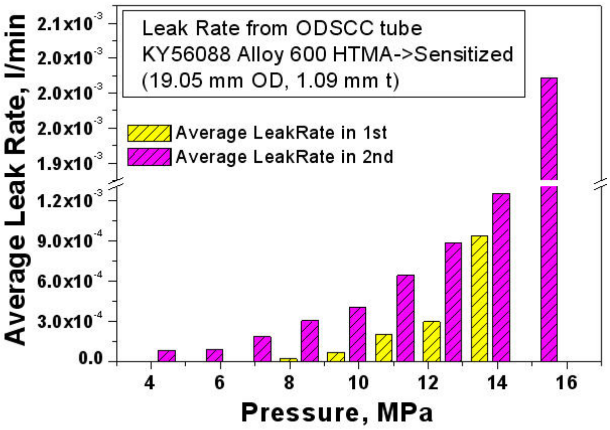

Fig.2. Typical leak behavior for a degraded SCC tube at room temperature.

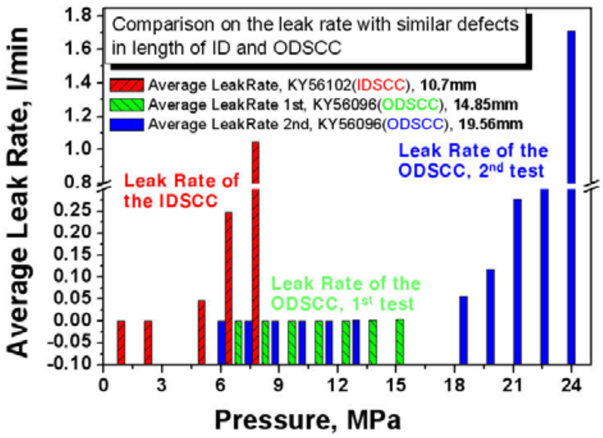

Fig.3. Comparison on the leak rate of the ID and ODSCC with similar crack length.

3. Conclusions

◈ Coolant leakage behaviors were evaluated for the tubes containing stress corrosion cracks.

◈ The SCC flaws had a characteristically different flow path depending on the crack formation side(ID/OD).

◈ The flow path and the crack width were deformed during the 1st test. In other word, because of the elastic deformation of the specimen the average leak rate in the 2nd test was greater than in the 1st experiment.

◈ The leakage rate of an IDSCC crack was larger than that of an ODSCC with the internal water pressure.

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