Investigation of the Effect on Flow Accelerated Corrosion (FAC) in Plant Power Uprate

Background

In USA, power uprate up to 20%, which can decrease energy cost with no nuclear safety loss, has already been conducted in many nuclear power plants in the world, and it is now under review in Japan. By uprating operation, plant flow conditions such as flow velocity and the temperature of the system are varied, and those change will lead to (or expose) flow induced problems like wall thinning, FIV (Flow Induced Vibration) and so on. In fact, some problems have actually been reported in US power plants.

In those problems, FAC (Flow Accelerated Corrosion), a kind of wall thinning, especially needs to be investigated because FAC cause rapture of piping. Therefore, it is necessary to examine the rate change of FAC before and after the plant power uprate.

Objectives

The objective of this study is to investigate the effect on changing rate of FAC and management planning of wall thinning for Japanese BWR plants on 5% /15% uprate.

Principal Results

BWR5 is selected as model plant because 58% of Japanese NPP is BWR5, and changing rate of FAC in subsystem chosen by the FAC ranking (Table 1) defined in the JSME* technical rules of the pipe-wall-thinning management for BWR (JSME S NH1-2006) are investigated. FAC rate is calculated by Kastner's model (W. Kastner et al., Nuclear Engineering and Design, 119 (1990) 431) which is reported in the open literature, and it shows a similar tendency to the inspection data (Fig.1). The results are as follows;

(1) 5% power uprate (Table 2)

There is no subsystem where the shortest remaining period for fit for service becomes less than 10 years, which means that the change in the remaining period for fit for service is not so large. The remaining period for fit for service becomes short in subsystems 10-2 and 12-2, which are in the extraction systems categorized in FAC-2 from the low-pressure turbine to the third and the fifth feed water heater, respectively. In these systems, the shortest remaining period for fit for service became 80% and 88%, respectively. In other systems, there are a few systems where the remaining period for fit for service becomes slightly shorter, and in some systems, the remaining period for fit for service becomes longer for the high-temperature subsystem because the FAC wall-thinning rate decreases with increasing temperature above 150℃.

(2) 15% power uprate (Table 2)

The remaining period for fit for service becomes 2/3 for subsystems 10-2 and 12-2, which are in the extraction systems categorized in FAC-2 from low-pressure turbine to the third and the fifth feed water heater, respectively. In these subsystems, though we must take care of wall thinning for carbon steel piping, the shortening of the remaining period for fit for service is greatly reduced in the plant where the piping was replaced by a FAC-resistant material such as low-alloy steel and stainless steel including chromium. Excluding subsystems 9-2 (the extraction system from low pressure turbine to second feed water heater), 10-2, and 12-2, the remaining period for fit for service was 15 years or longer, and the shortening of it was quite small and it even became longer in many systems, which means the effect of the power uprate was not so large.

As a result, we can say the effect on FAC management by power uprate is not so large.

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Table 1 FAC Rank for management in the technical rules of the pipe-wall-thinning management for BWR

FAC-1	-Downstream of oxygen injection and small effects of turbulence where oxygen injection decreases the corrosion of the carbon steel. -Part of condensate system and feed water system etc. -Periodic measurement (within 10 years) of wall thickness at representative points
FAC-2	-Upstream of oxygen injection -Part of main steam system and heater vent systems -Remaining period for fit for service to be controlled by wall thickness measurement
FAC-S	-Downstream of oxygen injection & large effects of turbulence (extraction of particularly high wall-thinning-rate points in FAC-1 subsystems (of which wear rate is more than 0.2mm/ 10^4hr)) -Elbow downstream of feed water pump, and other components. -Remaining period for fit for service to be controlled by wall thickness measurement at particular points.

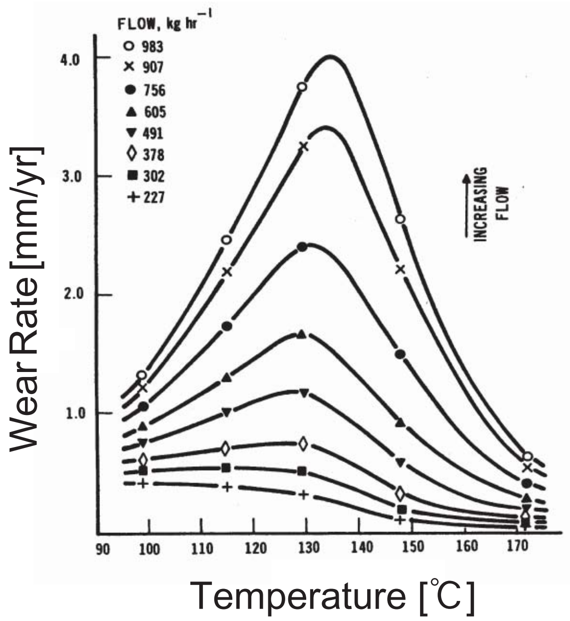

Fig.1 FAC thinning Rate for Carbon Steel vs. Temperature and Velocity (pH 9.05), Ref. : G. J. Bignold, K. Garbett and I. S. Woolsey, in Ph. Berge and F. Kahn, eds., Corrosion-Erosion of Steels in High Temperature Water and Wet Steam (France: EdF, Les Renardieres, 1982) Paper No. 12.

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Table 2 Changing rate R_L of the remaining period before and after the power uprate in piping system where the remaining period is relatively short
(Kastner's FAC model is applied, pH=7, chromium concentration=0.01%)

System No.	Rank of management	Assumed DO[*1] (ppb)	Before power uprating	5% power uprating		15% power uprating	
			Remaining period (yr)	Remaining period (yr)	Changing rate, R_L	Remaining period (yr)	Changing rate, R_L
2	FAC1	15	17.95	18.2	1.01	18.1	1.01
7	FAC2	1	19.32	25.0	1.29	29.5	1.53
8-2	FAC2	1	17.19	20.1	1.17	23.6	1.37
9-2	FAC2	1	10.64	11.6	1.09	13.8	1.30
10-2	FAC2	1	14.42	11.6	0.80	9.5	0.66
12-2	FAC2	1	15.84	13.9	0.88	10.7	0.68
25-1	FAC1/FACS	15	16.92	16.7	0.99	16.3	0.96
105-1	FAC2	1	18.55	18.7	1.01	19.1	1.03
105-2	FAC2	1	15.13	15.3	1.01	15.6	1.03
106	FAC2	1	18.88	20.4	1.08	22.9	1.21
551	FAC1	15	15.02	15.0	1.00	15.0	1.00

: Remaining period is extended. : Though remaining period is shorten, it is more than 10 years

*1 : Dissolved Oxygen

Note : Line No. in table 2 corresponds to the Line No. noted in JSME technical rules of the pipe-wall-thinning management for BWR (JSME S NH1-2006)