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Degradation Mechanisms for Alloy 690 Steam Generator Tubing in Nuclear Power Plants

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1. Introduction

Material of steam generator tubing in nuclear power plants has been replaced by Alloy 690 in many countries because of its corrosion resistance. In Korea, alloy 690 tubing has been installed in newly built nuclear power plants such as Shinkori plants and some old steam generators were replaced by alloy 690 tubes such as Hanul #1 & 2, Hanbit #3, 4, 5, 6 and Kori #1, etc. Also, some NPPs in the USA have replaced original steam generators with alloy 690 tubing steam generators. However, degradation mechanisms for alloy 690 tubing are different depending on steam generator models. South Texas Nuclear Power Plant (STNPP) #1 and #2 in the USA are Westinghouse(W) delta 94 models and Shinkori #1 and #2 are Combustion Engineering(CE) system 80 models. In this paper, the existing and potential degradation mechanisms for alloy 690 tubing were compared between the STNPP #1, #2 and the Shinkori NPPs #1, #2.

2. Alloy 690 Tubing Steam Generators

In this section, the W-delta 94 model steam generator in the South Texas NPPs and the scale-downed CE system 80 model steam generator in the Shinkori NPPs are described. Dimensions of tubing, tube support plates, flow distribution baffle plates, and anti-vibration bars, etc., are addressed in detail.

2.1 W-Delta 94 Model

Each of the current South Texas Unit 1 and 2 plants contains four W-Delta 94 model steam generators designed by Westinghouse Electric Company, respectively. Unit 1 steam generators were manufactured in Pensacola, Florida while Unit 2 steam generators were manufactured by ENSA, in Spain. Each steam generator contains 7,585 tubes made of Alloy 690 Thermally Treated Material 0.688" O.D. with a nominal wall thickness of 0.040"[1]. There are nine trefoil support plates that are composed of A-240 Stainless Steel. All support plates 1 through 9 are 1.12 inches thick. A flow distribution baffle plate (FDB) is located between the first support plate and the top of tubesheet. The nanofoil FDB plate is composed of 0.75 inches thick A-240 Type 405 Stainless Steel. Dimensions for the structure are as follows: 25.43" of tube end to top of tubesheet, 20.38" of top of tubesheet to center of FDB, and 19.53" of center of FDB to center of tube support plate 1 (TSP1). Distance of each TSP (center to center) is 40.47", as shown in Fig 1. A maximum of sixteen anti-vibration bars (AVB's) may be detected in the U-bends. The AVB's material is 405 stainless steel bars, 0.16" x 0.48" with chamfered corners.[1]

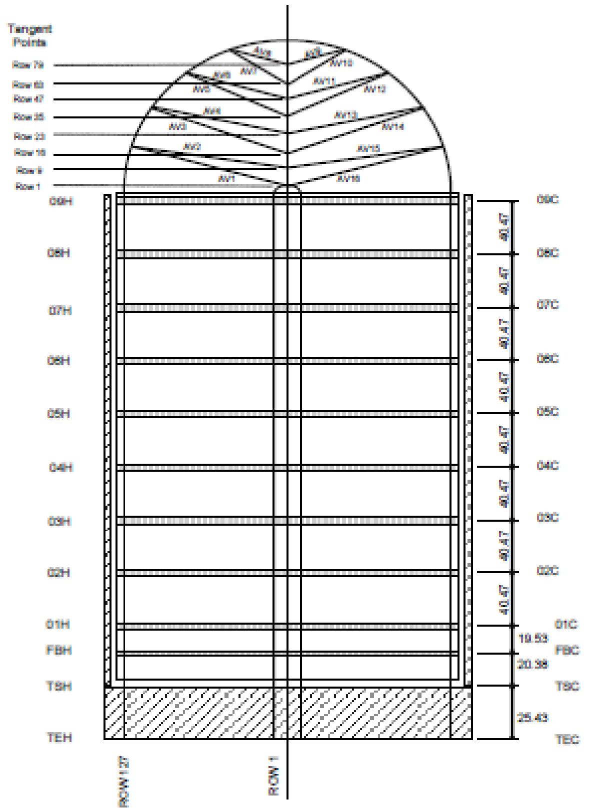
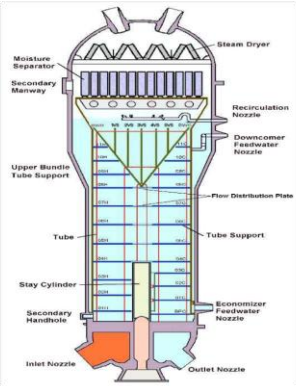


Fig. 1. Support Structure Nomenclature and Measurements of W-Delta 94 Model.

2.2 CE System 80 Model

Each of the Shinkori Unit 1 and 2 plants contains two scale-downed CE system 80 model steam generators manufactured by Doosan Enerbilty Co., Ltd. Each steam generator contains 8,340 tubes made of Alloy 690 Thermally Treated Material 0.75" O.D. with a nominal wall thickness of 0.042"[2]. Top of tubes has two types in this model. One is U-bend and the other is square bend according to the row number of tubes. Tubes of row number 1 to 17 are U-bend type and 18 to 138 are square bend. There are eleven eggcrate support plates that are composed of A-176 Type 409 Stainless Steel as shown in Fig. 2. The range of distances for each TSP to TSP is from 27.75 to 39.68 inches. In the U-bend region, there are vertical strips and batwings to prevent vibration of tubes. A maximum of five vertical strips and two batwings may be detected in the U-bend and square bend. The material of vertical strip and batwing is A 176 Type 409 stainless steel. A flow distribution baffle plate is located between the first support plate and the top of tubesheet in the cold leg side.



Intervals	H/L	C/L
TE-TTS	21.50	21.50
TSC-BPC	-	16.00
TTS-01	19.00	47.75
01-02	37.08	30.25
02-03	37.08	30.25
03-04	37.09	22.00
04-08	39.68(39.69)	39.68(39.69)
08-11	27.75	27.75

Fig. 2. Support Structure and Locations of Scale-downed CE System 80 Model.

2.3 Degradation Mechanisms of Alloy 690 Tubing

The eddy current testing (ECT) is widely used for the inspection of steam generator tube integrity because it offers an approach for high speed, large scale testing of metallic materials in high pressure and temperature engineering systems. The ECT technology uses electromagnetic induction to detect flaws in conduct materials. Two types of eddy current probes are normally used for the inspection of steam generator tubes: the bobbin probe and the rotating probe [3]. During the outage period, steam generator tubes are inspected using the ECT technologies according to the steam generator management program (SGMP). In the SGMP, degradation mechanisms for the steam generator tubes are normally classified with existing and potential degradation mechanisms according to the inspection history of steam generator tubes in various NPPs with the same tubing material.

In the South Texas NPP Unit 1, the existing degradation mechanisms are foreign object wear, tube wear at TSP intersections and pitting under hardened TTS (Top of Tubesheet) sludge deposits. The potential degradation mechanisms in the STNPP Unit 1 are tube wear at AVB intersections and tube-to-tube wear. In the STNPP unit 2, the existing degradation mechanisms are tube wear at TSP intersections and pitting under hardened TTS sludge deposits. The potential degradation mechanisms in the STNPP Unit 2 are foreign object wear, tube wear at AVB intersections and tube-to-tube wear. During the 1RE19 inspection in the STNPP Unit 1, a volumetric indication was identified in one location under hard sludge at the top of the tubesheet. The cause of the indication is not certain. However, the direct cause investigation has found that two causes are more likely than other possibilities. These more likely causes are: 1) Pitting Corrosion or 2) False Call [4].

In the Shinkori Unit 1, the existing degradation mechanisms are foreign object wear and tube wear at tube support plates, batwings and vertical strips[2]. The potential degradation mechanisms in the Shinkori Unit 1 are stress corrosion cracking (SCC) at top of tubesheets, SCC at U-bends and SCC due to dent or ding at free spans and tube support plates. In the Shinkori Unit 2, the existing degradation mechanism is tube wear at tube support plates, batwings and vertical strips[5]. The potential degradation mechanisms in the Shinkori Unit 2 are foreign object wear, SCC at top of tubesheets, SCC at U-bends and SCC due to dent or ding at free spans and tube support plates.

3. Conclusions

This paper describes the existing and potential degradation mechanisms for Alloy 690 steam generator tubing in some nuclear power plants. Alloy 690 tubing has been used in newly built nuclear power plants and in replaced steam generators from old steam generators because of its corrosion resistance. Material of steam generator tubing in the South Texas NPP Unit 1 & 2 is Alloy 690 TT which is the same as Shinkori NPP Unit 1 & 2. However, degradation mechanisms are different between them. Particularly, the AVB wear in the U-bend region has not been detected in the STNPPs that is normally detected in Shinkori NPPs. The cause of the difference may be from the tube support structures. Numbers of the AVB in the STNPPs are more than Shinkori NPPs. However, pitting identified in the STNPP unit has not been detected in the Shinkori unit 1 & 2. The cause of pitting indication in the STNPP is not certain. Two causes, which are pitting corrosion under sludge pile or false call from eddy current response, are more likely than other possibilities. Further studies or additional examinations by eddy current testing should be needed to find the valid causes.

REFERENCES

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