Sludge Lancing and Visual Inspection of Steam Generator for KORI Nuclear Power Plant Unit 3

Woo-Tae Jeong [a*], Sang-Tae Kim[b], Jae-Yung Hong [b], Yun-Soon Jeong [b]
[a]*Korea Hydro & Nuclear Power Co., Ltd., Central Research Institute, 1312-70 Yuseongdaero, Yusung-gu, Daejeon, Korea 305-343*
[b] *Sae-An Engineering Corporation, Rm910, Byucksan Digital Valley II, 481-10, Gasan-dong, Geumcheon-gu, Seoul, Korea 153-803*
[*]*Corresponding author: wtjeong77@khnp.co.kr*

1. Introduction

Cleaning of the deposits on tube-sheet of the KORI Nuclear Power Plant Unit 2 steam generators started on August 28 and ended on September 28, 2012. Total 428 kg of sludge was removed during the deposit removal operation. Annulus, tube-lane, and in-bundle area of the steam generators were searched for possible foreign objects. No new foreign objects were found. Two foreign objects which were found during previous outage were impossible to remove. Mock-up training before the operation was helpful to finish the service as scheduled.

2. Scope of the Service

The scope of the lancing and FOSAR service includes the followings:
- Inspection of the lancing equipment.
- Bringing the equipment in the containment vessel and install it.
- Removal of sludge deposit on the tube-sheets.
- Withdrawal of the equipment and clean the area around the steam generator.
- Check spare parts and make a list for procurement for the next operation.

3. Lancing and FOSAR

3.1 LANCING

Lancing equipment, which is called FOLAS-I, is consisted of the lance robot, the rail assembly, and the take-up assembly as shown in Figure 1. The lance robot has two DC servo motors for locomotion and rotation. Locomotion motor drives pinion gear which rotates on rack gear on the rail assembly.

Eight barrel spray nozzles spout water with 200 bars on each side of hot and cold leg simultaneously. A DC motor with encoder was used to control tilting movement of the nozzles.

A rigid lance spouts water of about 1,000 bars for hardened sludge removal. The length of the rigid lance is fixed, therefore it could not move deep into the tube bundle.

Hard sludge removal efficiency of the rigid lance is very limited. Pressurized water jet of 1,000 bars has bigger momentum compared to that of barrel spray water jet. Experimental results showed us that water jet of higher pressure tends to diverge even though the pressure and momentum is big. When water leaves the high pressure nozzle, the water quickly changes into spray. When the water stream moves about 200 mm from the nozzle, most of water becomes spray of small droplet. Therefore, it quickly looses momentum because of the resistance of surrounding air.

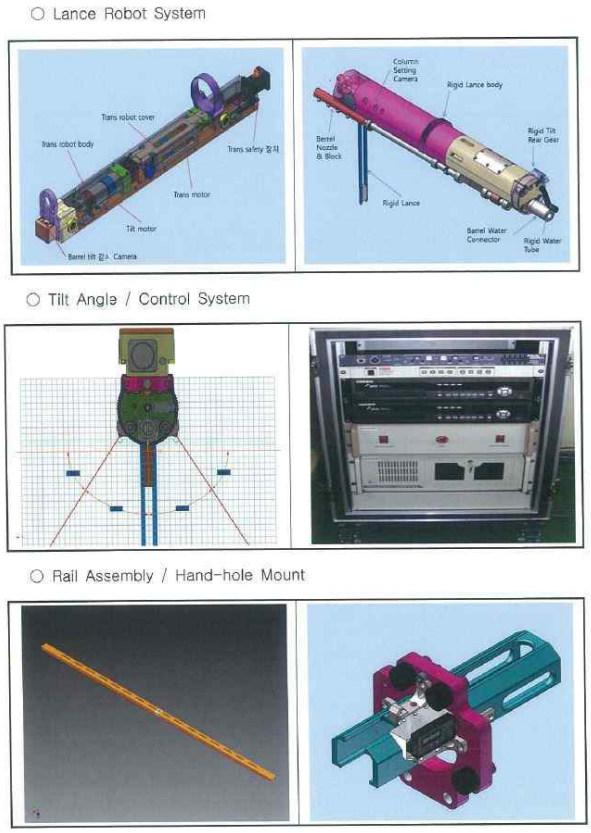

Fig. 1. Lancing Equipment Used for Hanul Unit 2

The hand-hole mount fixes the rail to the flange of the hand-hole. Total 6 bolts were used to fix the mount plate the flange.

The control system of the lancing equipment is composed of an industrial computer, a digital video recorder, and two motion controllers for four DC motors.

A camera is attached to the front region of the cylindrical part of the robot is used to align the barrel spray nozzles with the tube gap. Correct arrangement is very important for acquiring barrel spray efficiency.

When it is badly aligned, water spray could not clean sludge deposits between the tubes.

Another camera is attached to the rear part of the robot. This camera shows images of cylindrical parts of the robot. Using the image, operators could check whether the barrel spray nozzles swing as it is commanded.

Figure 2 shows the weight of sludge removed during the outage. Net sludge weight from SG 'A', 'B', and 'C' is 177 kg, 134kg, and 117 kg respectively. Bag and cartridge filters used for SG 'A', 'B', and 'C' is (53, 414), (75, 243), and (61, 171) respectively.

증기발생기	Filter 종류	소요량(EA)	무게(kg)	공 Filter(kg)	포장비닐(kg)	순수 Sludge
'A'	Bag	53	103.2	39.75	1.5	61.95
	Cartridge	414	340.65	219.42	5.75	115.48
	소 계	**467**	**443.85**	**259.17**	**7.25**	**177**
'B'	Bag	75	125.15	56.25	2	66.9
	Cartridge	243	199.1	128.79	3.5	66.81
	소 계	**318**	**324.25**	**185.04**	**5.5**	**134**
'C'	Bag	61	131.9	45.75	1.75	84.4
	Cartridge	171	125.7	90.63	2.5	32.57
	소 계	**232**	**257.6**	**136.38**	**4.25**	**117**
TOTAL	Bag	**189**	**360.25**	**141.75**	**5.25**	**213**
	Cartridge	**828**	**667.7**	**438.84**	**14**	**215**

Fig. 2. Filters Used and Weight of Sludge Removed

Figure 3 shows the lancing equipment used for each outage of Kori Nuclear Power Plant Unit 3. Jet Cleaner was used for outage number 1 and 2. Booy Clean was used for outage number from 3 to 9. Cecil unit 1 was used for outage number from 10 to 20. Folas-1 was used for outage number 21.

The amount of sludge when the steam generator was new was very little. Only 1.98 kg and 3.62 kg of sludge was removed during outage number 1 and 2. However, the amount of sludge at outage number 20 and 21 is 103.35 kg and 428 kg respectively. It shows us that as the operation time of the steam generators increases, sludge deposit also increases.

주기	Sludge 제거량(kg)				사용장비	비 고
	S/G 'A'	S/G 'B'	S/G 'C'	계		
K3R1	0.54	0.54	0.90	1.98	Jet Cleaner	
K3R2	1.25	1.13	1.24	3.62	Jet Cleaner	
K3R3	4.70	4.90	4.40	14.00	Booy Clean	
K3R4	2.35	2.76	3.09	8.20	Booy Clean	
K3R5	4.20	3.10	3.50	10.80	Booy Clean	
K3R6	8.00	7.20	5.60	20.80	Booy Clean	
K3R7	11.30	8.70	6.80	26.80	Booy Clean	
K3R8	7.80	10.90	10.80	29.50	Booy Clean	
K3R9	5.80	6.80	7.10	19.70	Booy Clean	
K3R10	56.00	45.50	49.80	151.30	CECIL Unit 1	
K3R11	23.85	18.10	11.00	52.95	CECIL Unit 1	
K3R12	13.00	11.40	8.20	32.60	CECIL Unit 1	
K3R13	11.80	9.20	12.30	33.30	CECIL Unit 1	
K3R14	16.70	15.40	13.40	45.50	CECIL Unit 1	
K3R15	13.00	20.30	16.80	50.10	CECIL Unit 1	
K3R16	17.20	10.80	11.70	39.70	CECIL Unit 1	
K3R17	15.30	24.10	17.50	56.90	CECIL Unit 1	
K3R18	260.2	215.95	634.25	1,110.4	CECIL Unit 1	
K3R19	82	57	42.5	18.1	CECIL Unit 1	
K3R20	21.25	36.95	45.15	103.35	CECIL Unit 1	
K3R21	177	134	117	428	FOLAS-1	

Fig. 3. Lancing Equipment Used and Sludge Remove During Each Outage for Hanul Unit 2

3.2 FOSAR

FOSAR (Foreign Object Search and Retrieval) activities were made for the annulus, the no tube lane, and the in-bundle area of steam generators 'A', 'B', and 'C'. No foreign object was found during the search procedure.

Two foreign objects which were found in the previous outage remained at the same location. The size of the two objects was 13 mm x 11 mm x 3 mm, and 10 mm x 7.4 mm x 1 mm respectively. Both were assumed to be metal objects. Its locations are column number 15/16 with row number 1, and column number 70/71 with row number 44 as shown in Figure 4. It was impossible to retrieve the two objects because they were firmly fixed to the steam generator.

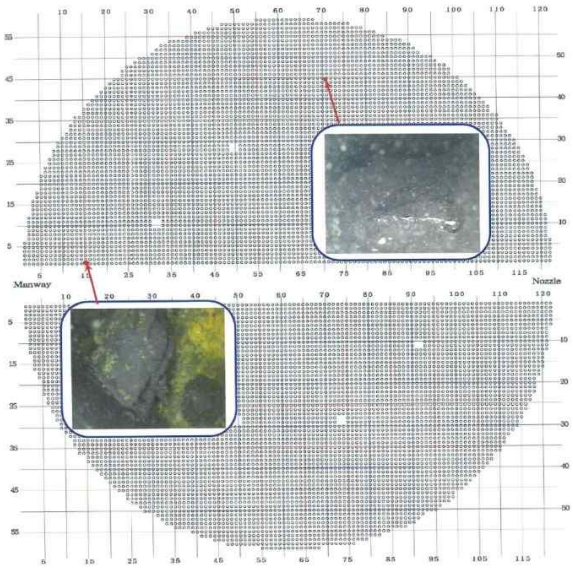

Fig. 4. Location of Foreign Objects

4. Conclusions

Sludge lancing of the three steam generators was made using FOLAS-I lancing system. FOSAR operations were done using video probe and special tools of Sae-An Engineering Cooperation.

The weight of sludge removed from SG 'A', 'B', and 'C' was 177kg, 134kg, 117kg respectively. Bag filters for and cartridge filters consumed for SG 'A', 'B', and 'C' was (53,414), (75,243), and (61,171) respectively.

Foreign object search operation for the annulus, the tube lane, and in-bundle area of the steam generators found nothing. Retrieval of the two remaining foreign objects from the previous outage was tried but failed.

REFERENCES

[1] Suk-Chul Kang et. al., 21th of KORI Nuclear Power Plant, Unit 3 (Steam Generator Secondary Lancing/FOSAR), Sae-An Engineering Co., December 2012.