

## DEVELOPMENT AND APPLICATION OF INTER-TUBE LANCING SYSTEM FOR WOLSONG UNIT 1 S/G

Woo-Tae Jeong<sup>1</sup>, Jeong-Uk Lee<sup>2</sup>

<sup>1</sup>Principal Research Engineer, KHNP-CRI, Korea

<sup>2</sup>Senior Manager, Chemistry Div., KHNP, Korea

### ABSTRACT

We started a project for developing a waterjet inter-tube lancing and FOSAR (foreign object search and retrieval) system on April 2014. A FOSAR system was developed for removing foreign objects on the tube-sheet and the annulus of the Wolsong unit 1 steam generators. Hot test of the FOSAR system was made on March 2015. The developed FOSAR system was composed of a flexible guide, a hand-hole mount, FOSAR tools, and an endoscope. We trained ANSCO technicians for visual inspection and removal of foreign objects. The developed system was successful in visually inspecting inter-tube region and removing foreign objects.

The inter-tube lancing system for removing hard deposit located between the tubes of the steam generators is also developed. It is going to be hot tested during Wolsong #1 outage scheduled on June 2017. The lancing system is composed of a flexible rail, a flexible lance guide, and a flexible lance. The flexible rail uses permanent magnets to be firmly attached to the annulus wall of the steam generator. It could be installed in almost all types of steam generators. Therefore, even though the technology was developed for Wolsong steam generators, it also could be applied for almost every type of nuclear steam generators.

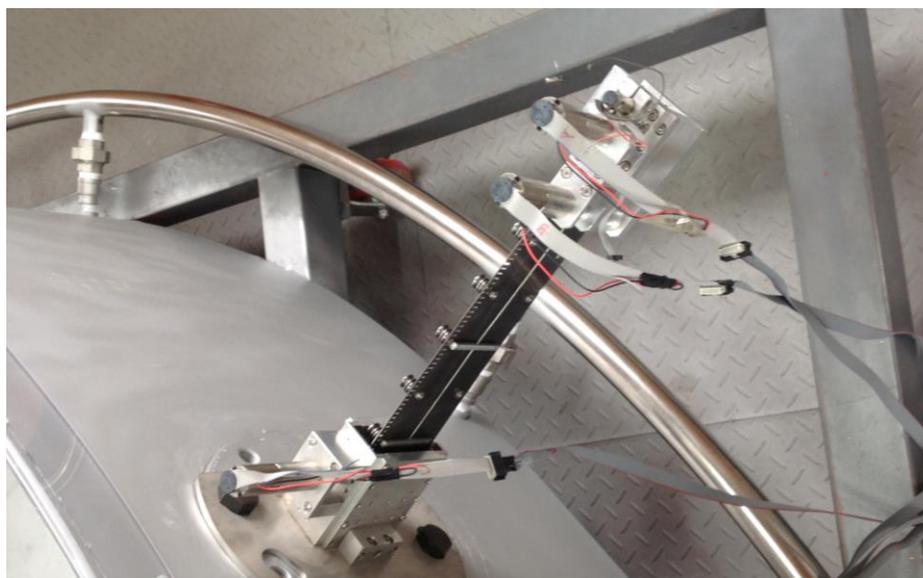


Figure 1. Inter-tube lancing system installed in S/G mock-up

## INTER-TUBE FOSAR SYSTEM APPLICATION

Manual inter-tube FOSAR system was developed and applied for removal of foreign objects during 24<sup>th</sup> Wolsong #1 outage period. Two narrowly cut steel sheet plates were assembled together for coming in and out of the probe and tool. We put some plastic material between the two plate, and assembled them using stainless wire to make a room for the passage of an endoscope and the FOSAR tools. By using the developed tool, we removed 108 foreign objects. Various very thin metal plates were found, and it was retrieval by a magnet tool.



Figure 2. Inter-tube FOSAR system

## INTER-TUBE LANCING SYSTEM

Our previous inspection of inside of the Wolsong steam generators has shown us that hardened sludge existed in some area of the tube bundle. In some cases, inspection camera was not accessible because of the hardened sludge. Therefore, we decided to develop inter-tube water jet lancing system to remove the hardened sludge.

The mechanism of inter-tube lancing system is composed of a flexible rail, a flexible guide, and a flexible lance. The flexible rail is made of a narrowly cut sheet metal. Several miniature rolling carts with four roll bearings are attached to the sheet metal. Friction between the flexible rail and the surface of the annulus of the steam generator are designed to be minimized by small friction of the roll bearings of the rolling carts. Each rolling cart also has permanent magnet to be attached to the surface of the annulus wall.

The surface of the roll bearing touches the surface for the annulus. The permanent magnet is attached to the cart, but it is actually not attached to the surface of the annulus. In this way, the flexible rail could move along the surface of the annulus by the magnetic force between the magnet and the annulus surface.

The flexible guide is composed of two sheets of narrowly cut sheet metal. It has several rollers with groove. Two grooved rollers of the flexible guide moves along the flexible rail. The endmost part of the flexible guide is attached by a stainless wire for adjusting the bending radius of the tip. By using a electrical stepping motor, the bending radius of the flexible guide is designed to be adjusted remotely just by winding or releasing the stainless wire.

The flexible lance is made of urethane, several tubes, and a very small camera. The thickness of the flexible lance was designed to be 4 mm which is a little smaller than the 4.7mm gap between the S/G

tubes of the Wolsong unit 1. In case of the lances with smaller thickness such as 2.8mm, we observed water jet may hit directly to the S/G tubes.

Urethane lance showed very diverse characteristics. Some were excessively flexible, and others were very rigid. We found an optimal mixture for our purpose of appropriate rigidity and flexibility. When highly pressurized water was discharged to the hardened deposit, reaction force is created to the opposite direction of the discharge. To remove this reaction force, we designed the discharge direction to three ways of forward, upper rear, and down rear. The forward discharge may hit the hard scale between the tubes, and down rear discharge might be used to remove hard deposits on the tube sheets.

## **COLD TEST**

The developer, the manufacturer, and the users gathered together at the test set-up site for evaluating the performance and suggest ideas for further successful hot test for Wolsong S/G lancing which are scheduled to start on 28<sup>th</sup> of May. S/G mock-up was made and used for the experiment.

During several times of cold test, pressurized water of 250 bars was used to test the performance of the lancing system. As was expected, the evaluation of the performance made us to expect the successful application of the equipment. However, several modification ideas were also suggested for improvement.

One idea was about the thickness of the flexible lance. The gap between the tubes of Wolsong S/G is 4.7mm. Our lance was 2.7mm thick. Because of the 2mm clearance between the S/G tube and the flexible lance, we observed that the pressurized water directs exactly to the tube surface. Even though it is not very dangerous in actual cases, we decided to modify the thickness of the flexible lance to remove possible danger.

The other idea was about the lance camera. The lance camera was headed to the front. Therefore, only the front view could be seen when we insert or extract the flexible lance. Tube pattern need to be identified for the calibration of the control system. To solve the problem, we decided to attach a kind of mirror in front of the flexible lance.

Other minor suggestions were proposed. Installing a new camera for barrel spray at the no tube lane was proposed and accepted by the developer and the manufacturer. A miniature camera with LED light was selected and installed for identification of barrel spray head position. This camera also enables the operator of the system to identify whether the pressurized water directly head toward the gap between the tubes..

## **HOT TEST**

All the equipment is scheduled to be transferred to Wolsong NPP on around 28<sup>th</sup> of April 2017. Training of the service personnel will be made afterwards. Equipment installation and operation procedures will be registered. The personnel from the KINS and plant higher managers will come and see the equipment. When everything about the safety and performance about the system is cleared, the hot test is scheduled from 28<sup>th</sup> of May 2017 for two weeks.

When we present at the conference on August 2017 at VEXCO, we expect it would be possible to present in more detail about the results of actual hot test.



Figure 3. The flexible guide moving along the flexible rail

## CONCLUSION

We developed a water jet lancing system specifically targeted for removal of hard sludge in tube bundles. This system is designed specifically for Wolsong NPP unit #1. However, we could identify the concept could be used for cleaning hard deposits for all types of nuclear steam generators.

Flexible rail system was developed to be easily installed along the surface of the annulus of the steam generators. The magnet attached to the flexible rail enables the flexible rail to travel along the annulus which is made of carbon steel. The rail is attached strongly to the annulus surface. However, it also is free to move along the surface of the annulus.

Flexible lance design was made of urethane. Various water tubes and camera lines may be inserted in the molten urethane. The thickness of the flexible lance may be easily adjusted according to the specific type of the steam generator. It is easier to make. Furthermore, less or no problem may be created by the surface scratch by abrasion between the steam generator tube and the flexible lance.

## REFERENCES

Jeong, W. T. and Lee, K. H. (2016). "Search and Retrieval of Foreign Objects for the Steam Generator of Wolsong NPP Unit 1," *Transactions of the Korean Nuclear Society Autumn Meeting*, Gyeongju, Korea.