DEGRADATION MONITORING OF G.A. SIWABESSY RESEARCH REACTOR'S SECONDARY COOLING PIPE

R. HIMAWAN, SUWOTO, SRIYONO, A. TRIYADI
National Nuclear Energy Agency (BATAN),
Center for Reactor Technology and Nuclear Safety,
Banten,
INDONESIA

Y. YUSI EKO
National Nuclear Energy Agency (BATAN),
Center for Multi Purpose Reactor,
Banten,
INDONESIA

Abstract

Visual inspection, flaw detection and wall pipe measurement have been performed on secondary cooling system of G.A. Siwabessy reactor in order to evaluate the integrity of pipe structure as the implementation of ageing management programme. Visual inspection for internal surface was performed using CCD camera. The measurement was conducted using ultrasonic method and measurement locations were determined according guidelines in NPP. Measurement results show that wall thinning slightly occurred in secondary cooling system. Due to chemical element analysis of scale deposited on internal surface, it is known that wall thinning was caused by corrosion, by means of homogenous and pitting corrosion. No errosion-corrosion phenomenon was observed. In order to retard the wall thinning, it is needed to improve water quality to prevent the corrosion on the pipe.

1. INTRODUCTION

G.A. Siwabessy Multi Purpose Research Reactor with thermal power rating of 30 MW in Puspiptek Area Serpong is one of research reactor operated by National Nuclear Energy Agency (BATAN). G.A. Siwabessy reached the first criticality in July 1987 and reached the first maximum power of 30 MW in March 1992. As a Multi Purpose Reactor, this reactor has various facilities such as material testing facility and radio isotope production.

At the beginning of the operation, ageing management had never been considered for G.A. Siwabessy reactor. After 16 years in operation, in 2003, ageing in structure, system and component (SCC) of reactor became a significant issue. This is because of many degradation effects observed on this reactor's SCC. Thus, ageing management started to be considered in order to assure the operation safety.

Under the scheme of IAEA – EBP Programme, Ageing Management Programme for Research Reactor Workshop was run in 2003. In this workshop "The Ageing Management Programme (AMP)" for G.A. Siwabessy Reactor was established. After this establishment, another programmes followed in order to implement that AMP. They were "Inspection for Secondary Cooling System of Multi Purpose Reactor Workshop" and "Surveillance Program on Water Chemistry Control Management Workshop".

Detection and monitoring of ageing degradation is an important element in the Ageing Management Programme to detect an actual status of degradation. Thus, in AMP of G.A. Siwabessy, various non-destructive testing methods were applied to detect various degradation of Reactor's SCC, such as secondary cooling pipe, pool tank liner, heat exchanger, electrical component, etc. This paper will present the inspection subjected to the secondary cooling pipe.

© *International Atomic Energy Agency*

2. DESCRIPTION OF SECONDARY COOLING SYSTEM

As shown in Appendix 1, a secondary cooling system of G.A. Siwabessy research reactor consists of various components such as pipe, filter, pump and valve. There is also cooling tower to release the heat transfered from heat exchanger. The piping system consists of 3 types of pipe, which specifications are shown in Table 1. Pipe #1 and pipe #2 are the original pipe installed in the construction stage while pipe #3 was installed in 2008 to replaced pipes which degraded significantly as result of the first inspections performed in 2004.

TABLE 1: SPECIFICATIONS OF PIPE IN SECONDARY COOLING SYSTEM

	Pipe #1	Pipe #2	Pipe #3
Material	R St. 37 .2	R St. 37 .2	Carbon steel
Standard	DIN 1626 Bl. 3	DIN 2673	ASTM A53-B
Diameter (mm)	813	610	510
Thickness (mm)	8	6,3	9

There is a difference water chemistry condition between primary coolant system and secondary coolant system[1]. Primary cooling water has a higher requirement regarding to the chemical factor such as chemical element dissolved in water compare to the secondary cooling water. In order to fulfill the requirement and to maintain the water condition, cooling water was treated in various ways including addition of chemical agent to suppress the growth of bacteria. Refering to the material of pipe, stainlees steels are used in primary coolant system while carbon steels are used in secondary coolant system. These environment and material differences resulted a different degradation effects of piping system. As mentioned in previous section that after 16 years in operation, a degradation effects already observed in secondary cooling pipe. Therefor, an Ageing Management Programme for G.A. Siwabessy research reactor was established in 2003 and secondary cooling pipe was taken as priority to be inspected.

3. INSPECTION METHODS

Due to the operation condition and environment condition of the secondary cooling pipe, corrosion was considered to be a major degradation mechanism of the pipe. Among types of corrosion, homogeneous corrosion, pitting corrosion, and erosion corrosion were assumed occurred in the cooling pipe system. Thus, two inspection methods were used to inspect the degradation; they are visual inspection and ultrasonic inspection. Visual inspection was performed by naked eyes for external surface and CCD camera was used to inspect internal surface. Ultrasonic inspection was performed in order to :

— Detect the presence of flaw in welding part;
— Measure the wall thickness;
— Create thickness mapping.

3.1. Determination of inspection part

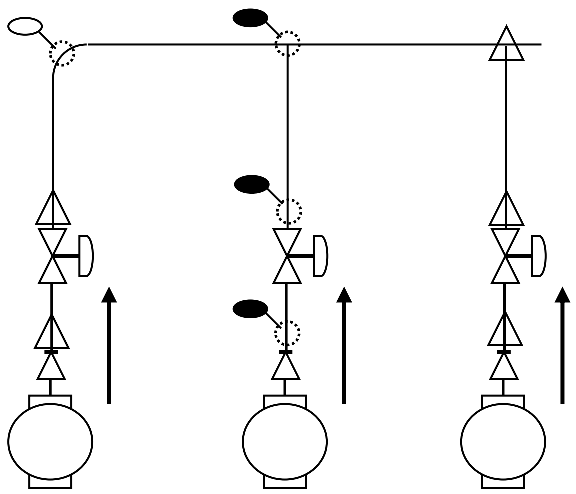
Secondary pipe system is composed by many section of pipe which the total length is more than several kilometres. Due to this reason, the detection of the flaw in welding part, the measurement of wall thickness and thickness mapping are in-efficient if to be performed to whole part of the pipe. The inspection to the whole part of pipe was performed by visual inspection (by naked eye) only. The other inspections were performed by selecting a specific location in the piping system.

In the piping system, there are valves, orifices, elbows, T-joints and other geometrical discontinuities which results a disturbance in the fluid flow inside the pipe. This condition may be contribute to the corrosion rate. Furthermore, a redundant design was applied to this secondary cooling system. For example, as shown in the Appendix 1 that in this secondary cooling system there are three pumps to supply water into the heat exchanger. However in the operation two pumps were being used and another one is stand-by. Considering this matters, the location should be selected to provide an effective and efficient inspections.

In the determination of inspection location, there are two considerations as mentioned below.

— Location close to the valves, orifices or other geometrical discontinuities were choosed;
— For the same configuration such as a redundant lines, just one line was selected as a representative;
— If in one line there are more than one geometrical discontinuities but has a same type, just one location was selected as a representative.

Figure 1 shows an illustration of location selection in this inspection.



Inspected location

Inspected location (representative location)

△ Represented location

Fig. 1. Location selection method.

3.2. Visual inspection

Visual inspections were intended to perceive the condition of both internal and external surface. Visual inspections were performed by naked eye for the external surface and CCD camera was used for internal surface.

3.3. Ultrasonic inspections

i. Flaw detection

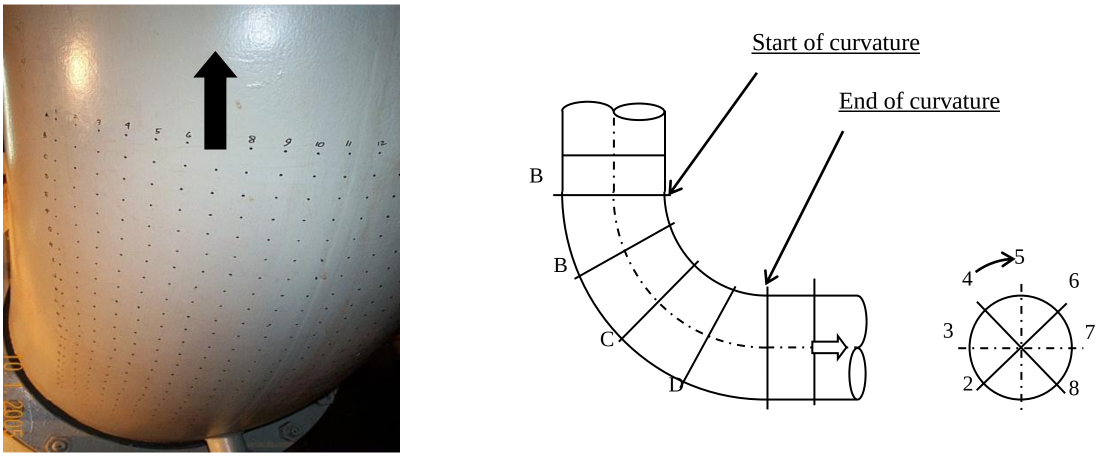
Flaw detections were performed in order to detect whether the flaw exists in the welding joint or not. These inspections were performed to small number of welding joint selected by considering the above considerations. USK7S of ultrasonic flaw detector was used in these inspections. 60 degree of angle probe having 4 MHz of frequency was used.

ii. Wall thickness measurement

Wall thickness measurements were performed using ultrasonic thickness gauge and subjected to selected locations by some considerations as mentioned in previous section. The purpose of this inspection is to know wall thinning of the pipe due to corrosion-errosion phenomenon. In one location, the measurements were performed to many points. Points of measurement were determined in two ways.

- Mesh of measurement determine on the surface which has a high potential of errosion-corrosion;
- Measurements were performed according to NISA Guidelines [2].

Figure 2 shows the point measurements in (a) and (b) method, respectively.



(a) (b)

Fig. 2. Measurement point determination.

Figure 2.(a) shows point measurements which has 2 cm distance in horizonatal and vertical. This method was applied in the first measurement in 2004 [3]. Due to the lack of measurement coverage in circumferential direction, in second measurement performed in 2009, the measurement point for T-joint section of pipe with diameter more than 5 inches, were determined as shown in Figure 2.(b). For another section such as orifice, elbow and others, the measurement points were determined in the similar way[2].

iii. Thickness mapping

Thickness mapping was performed in order to perceive the corrosion distribution in the internal surface of pipe. This inspection was performed using Ultratek Inc. product namely UltraScan 5. This equipment is able to create a thickness mapping with a minimum pitch up to 1 milimetres. By performing this inspection the presence of pitting corrosions in the wall pipe were expected to be detected. Locations to be inspected were selected depend on visual inspection results.

4. RESULT AND DISCUSSIONS

After performing flaw detection to the welding part of pipe, it is confirmed that no defect detected. Piping in secondary cooling system is not experiencing a big load/pressure or high temperature. Therefore, even the reactor already 24 years in operation, the integrity of welding joints is being maintained.

Figure 3 shows the condition of internal and external surface of pipe in secondary cooling system. It is seen that corrosion occurred almost entire of internal surface. This type of corrosion is homogenous corrosion. Besides, a spots of corrosion were also observed. They were considered as pitting corrosion. Concerning to the external surface, there is diffence corrosion occurrence between the sections of pipe installed inside the building and the ones installed outside the building. Figure 3(b) shows pipe section installed inside the building. It can be seen that only minor corrosion occurred on the surface. An external surface is protected by paint layer. In case of pipe section installed outside the building, corrosion attack more serious compares those installed inside the building. Differences in enviroment condition between inside and outside of building, affected corrosion attack on the pipe.

(a)

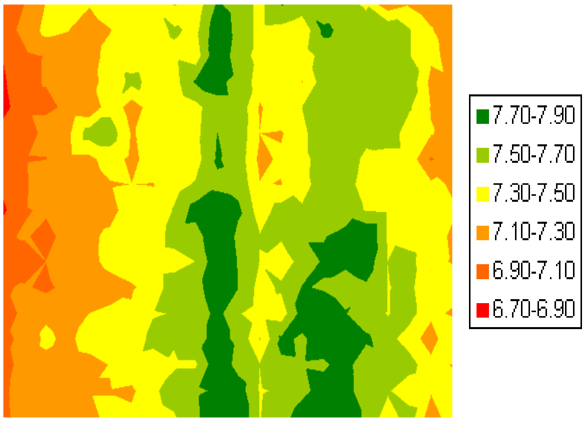
(b)

Fig. 3. Corrosion on internal surface (a) and external surface (b).

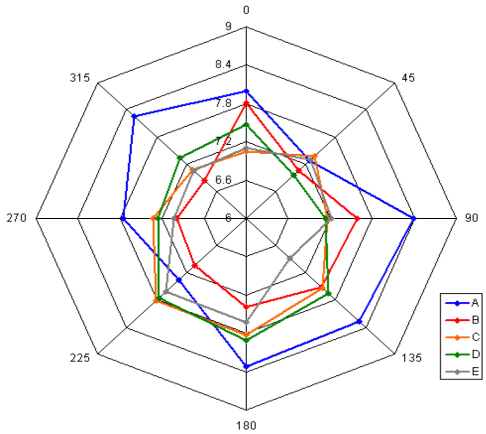
Figure 4.a shows one of thickness measurement results from measurement performed in 2004. This area covers 30 cm height and 40 cm width in pipe surface which has 61 cm diameter (see Figure 2(a)). As shown in Table 1, this pipe has initial wall thickness of 6.3 mm. This figure shows that wall thickness has a range from 6.70 mm to 7.90 mm. In the middle part, the wall thickness is rather thicker compare to the side part. This condition represents the real condition of wall thickness to be measured.

From Figure 4.a it is known that the measurement results are thicker compare to the initial wall thickness. It indicated as if wall thickness became thicker during the reactor operation. In this measurement, paint layer on the surface was not removed. Thus, it is considered that paint layer result to thicker wall thickness. In the other hand, from visual inspection of internal surface using CCD camera, scales were observed in many places on internal surface. The presence of scales should affect the accuracy of thickness measurement.

Figure 4.b shows measurement results from the same part as shown in Figure 4.a, which performed in 2009. The measurement method is shown in Figure 2. This measurement covered along circumferential direction. This figure shows that wall thickness has a range from 6.70 mm to 8.40 mm. Result in Figure 4.a can’t be compared to Figure 4.b directly, due to the difference of measurement points. However, the range of wall thickness indicates a same condition.



(a)



(b)

Fig. 4. Example of thickness measurement result for elbow: (a) first measurement, (b) second measurement.

According to thickness mapping results (performed in 2004), it is confirmed that wall thickness of pipe relatively has a big range. Besides, it is also known that there are several points with small value of thickness. The minimum thickness reached 3 mm. Due to the minimum value which detected on spot point, it could be considered that the thinning proses in this point is a result of pitting corrosion. Based on these results, some replacements were conducted to the pipe which experienced significant thinning.

In order to assure the effect of paint layer and scale on thickness, a measurement were performed on old pipe (replaced pipe) after removing paint layer, scale and corroded part. Corroded part was removed by grinding the surface. However, pitting corrosions were not completely removed. These measurement results show that scale, corroded part and paint layer have a various thickness. These results show that scale is the biggest contributor to the deviation of thicknes result, followed by corrosion layer and finally paint layer. Scale thickness varies from 1 mm to 2 mm, corrosion layer varies from 0.1 mm to 0.3 mm and paint layer has 2 mm thickness. By ignoring these 3 layers, it is known that the pipe experience up to 1.0 mm thinning. However, we should remember, that pitting corrosion still exist. The presences of pitting corrosions were confirmed by thickness mapping.

According to chemical analysis on scales, it is known that scales are formed by the corrosion product of pipe and deposition of inhibitor (chemical agent) added to the cooling water[4]. It indicates that chemical agent added to the cooling water couldn’t dissolve homogenously and perfectly into the entire of cooling water. In this time, the method of chemical agent injection was by poured out a large volume of chemical agent into the water basin in cooling tower. That’s why the chemical agent couldn’t dissolve homogenously. Based on this chemical analysis result, it is recommended to improve injection method of chemical agent into the water. Automatic injection directly to pipe line along the operation of reactor could be considered.

Figure 5 shows one of thickness measurement results fro new installed pipe which the measurement were performed in 2009. As indicated in Table 1, this new pipe has 9 mm wall thickness. This figure shows that according to the measurement result, the wall thickness of pipe varies from 9.2 mm to 9.4 mm. Considering the paint layer, measurement results are close to the initial wall thickness. According to these results, it is confirmed that scale and corrosion product on the internal surface of pipe affect the measurement.

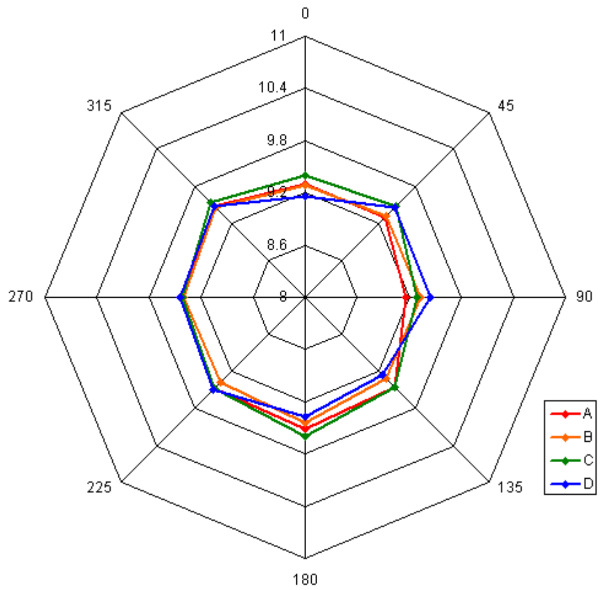


Fig 5. Example of thickness measurement result for new installed pipe.

5. CONCLUSIONS

The series of inspection has been done to the secondary cooling system of G.A. Siwabessy Research Reactor. They are; visual inpection, flaw detection, and thickness measurement. According to the results, it can be concluded that errosion-corrosion haven't occurred in secondary cooling pipe. Corrosion occurred in these piping are homogenous and pitting corrosion. The effect of pitting corrosion to the wall thickness is more serious compare to the homogenous corrosion.

REFERENCES

[1] SENTOT, A.H., "Safety Principal, Water Chemistry System and Current Facing Problem for GA Siwabessy Research Reactor", Proceeding of Training Course on Water Chemistry of Nuclear Reactor System 2, 2005.

[2] NUCLEAR AND INDUSTRIAL SAFETY AGENCY (NISA), "Requirements of Pipe Wall Thinning Managements for Nuclear Power Stations," Ministry of Economy and Industry, NISA-163a-05.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, EBP Report on Secondary Cooling System Inspection of RSG-Siwabessy, IAEA, Vienna (2005).

[4] "Analysis of Wall Thickness of RSG-GAS Secondary Cooling System", Scientific Magazine of Reactor Safety Technology "Sigma Epsilon," **12** 3 (2008) p 64-70.

Appendix 1 Schematic of Secondary cooling system