WATER CHEMISTRY SURVEILLANCE FOR MULTI PURPOSE REACTOR 30MW GA SIWABESSY, INDONESIA

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Abstract

As part of the water chemistry surveillance program for Multi Purpose Research Reactor (MPR) G.A. Siwabessy 30 MW, the effects of primary water on homogeny, galvanic and crevice corrosion have been studied using various coupons in order to better control the corrosion in the reactor system. [4,5] The main objectives are to establish standard procedures for corrosion monitoring and surveillance, and provide technical guidelines for continued wet storage of spent fuels. After having defined the current water chemistry profile, experiments were conducted using the coupons made of the same grade materials as used for the construction of the fuel cladding (aluminium) and reactor tank (aluminium), and fuel storage racks (stainless steel). The test coupons were made of a series of discs (ϕ95 mm with ϕ15 mm centre hole; 1 mm thick for stainless steel and 5.5 mm thick for aluminium) put together as an assembly using a stainless steel centre pin and insulated with a ceramic bushing and 5 mm thick spacers between the discs. The coupons are also assembled in two orientations to allow vertical and horizontal installations in the pool. The first batch of six coupon assemblies were strategically positioned in the service pool in January 2007 and are due to be withdrawn in stages for inspection after 1, 2, and 3 years of exposure. This paper describes the current water chemistry and surveillance program.

1. INTRODUCTION

There are three research reactors in Indonesia, all operated by BATAN. The major and the largest one is the 30 MW Multi Purpose Research Reactor (MPR) G.A. Siwabessy located in Serpong, about 30 km from Jakarta. It is an open-pool type reactor cooled and moderated by light water and fueled by 19.75% enriched U_3O_8Al/U_3Si_2Al yielding averaged neutron flux of $1x10^{14}$ n/cm^2 s. [1] The reactor construction began in 1983 and completed in July 1987 when the reactor reached its first critically, however, its full power of 30 MW was reached in March 1992. The reactor cooling system comprises primary and secondary systems. The primary coolant is subjected to gamma and neutron irradiation by the core, producing radiolysis species, such as oxidator O_2 and H_2O_2 which induce oxidation reactions of dissolving substances within them. This causes corrosion in the reactor tank components and other undesirable effects like forming compound deposits inside the cooling system, in particular, inside the heat exchanger cores, thereby adversely affecting its performance and life-span. As such, it is imperative to monitor, control and maintain the primary water chemistry to the required specifications at all times in order to ensure longevity and performance of the reactor system.

The in-service inspection of the tank liner and secondary pipes were carried out by using an under water camera and ultrasonic equipment. The results show progressive deterioration in the structure probably due to inadequate control of water chemistry. [3]

2. COOLING SYSTEMS

The research reactor G.A. Siwabessy consists of primary and secondary cooling system. As shown in Figure 1.

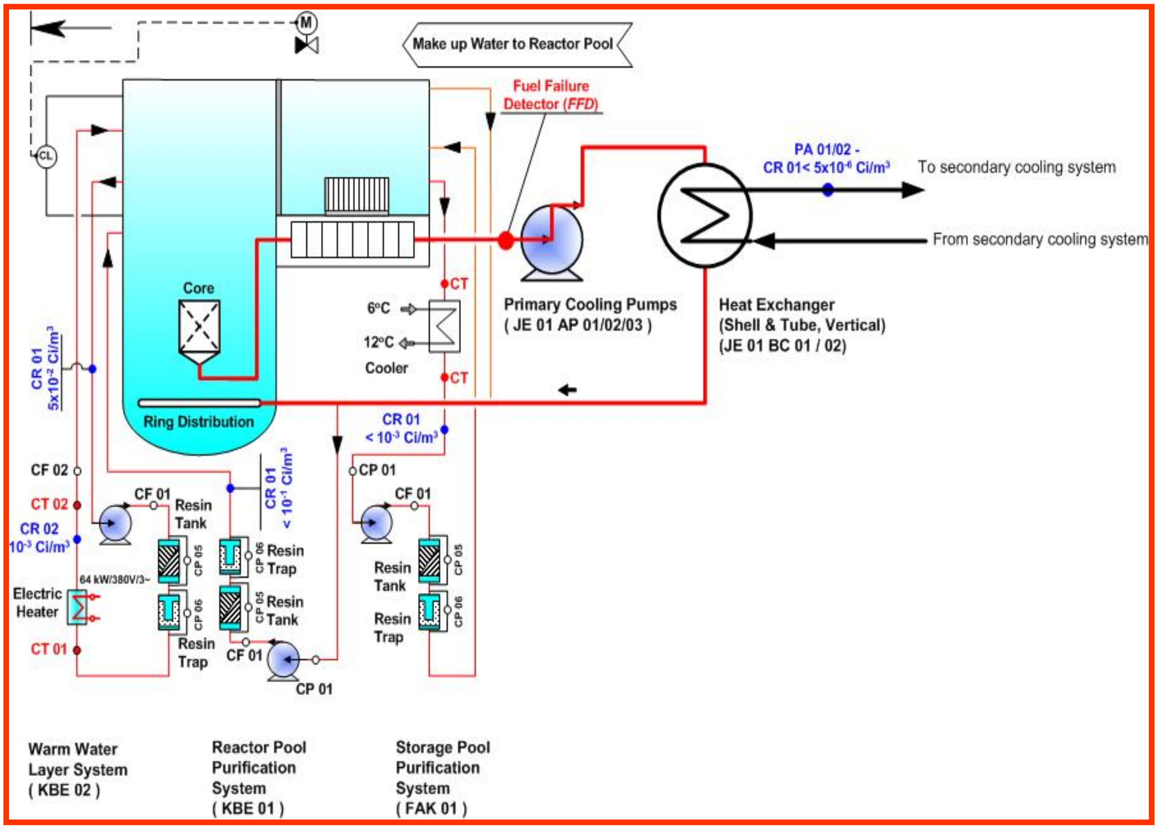

Figure 1. The water system in G.A.Siwabessy Research Reactor.[1,6]

2.1. Primary Cooling System

The primary cooling system contains 330 m^3 of demineralised water, of which 220 m^3 is in the reactor pool, 80 m^3 in the delay chamber and 30 m^3 in the piping system. The flow rate is about 800~860 kg/s.

The tank liner and pipework inside the reactor tank are made of $AlMg_3$, whereas rest of the primary cooling system is made of stainless steel.

The main systems connected to the primary coolant are (1) warm layer; (2) water purification, (3) emergency coolant, and (4) water make up system.

Warm Layer. The main function of the warm layer in the reactor pool is to keep any radioactive products, such as N16, well below the surface level. The warm layer is about 1.5 m deep from the top surface level and heated to maintain its temperature about 8 to 10^{o}C above the primary water below it. This water is purified continuously by mixed bed and resin trap.

Water Purification. The main function for water purification system is maintaining the water quality by filtering the impurities and radioactive products such as Na24, Co58 and Co60. The ion exchanger used is an anion and cation ion exchanger type with a resin trap. The mass flow rate is about 40m^3/hr. Once saturated, it is sent to Center for Development Management Radioactive Waste Management for treatment.

The primary cooling system comprises: (see Fig. 1) :

- Purification system for pool (KBE 01)
- Purification system for warm water layer (KBE 02)
- Purification system for spent fuel storage (FAK 01)

KBE 01 maintains the water quality and suppresses the radiation exposure level in the Operation Hall by eliminating the activated substances and dissolved or undissolved mechanic impurities in the primary water. This system is consisted of an ion exchanger filter and a mechanic filter. The ion exchanger filter contains 750 liters of anion OH^- resin of Lewatite M500Kr/OH^- type and 750 liters of cation H^+ resin of Lewatite S100Kr/H^+ type. The mechanic filter collects residues from the resin and fine mechanic impurities from the ion exchanger filter.

In theory, the resin can treat the primary water at a rate of 40 m^3/hr or about 12% of the primary coolant flow rate. The saturation level of resin is indicated by the differential pressure across the medium.

KBE 02 is designed to continuously purify and provide warm water to the pool surface. It also supplies water to the neutron beam tube. This system consists of mix-bed filters and a mechanic filter rated at 20 m^3/hr. The ion exchanger filter consists of 200 litres of anion OH-resin Lewatite M500KR/OH^- and 200 litres of cation H^+ resin Lewatite S100KR/H^+. The mechanic filter is made of a resin trap that can be opened and closed remotely to avoid operator exposures to high radiation. The saturation level of Mix-Bed filter is indicated by pressure differential across the resin. The other indication is its radioactivity that is equal to > $5x10^{-2}$ Ci/m^3 for the incoming stream and > 10^{-3} Ci/m^3 for backwashing.

FAK 01 cleans water from the activated compound and any mechanical impurities either dissolved or not in the spent fuel storage pool. It also has a function of removing up to 32kW heat from the spent fuel. This pool contains of 150 m^3 demineralized water and a series of storage racks; 200 fixed positions for spent fuels and control rods and 100 positions for the new fuel elements and control rods.

This system comprises a mix bed filter: 350 litre anion OH^- resin Lewatite M 500KR/OH^- and 350 litre resin cation H^+ Lewatite S100 KR/H^+, and a mechanic filter rated at 15 m^3/hr. The saturation level is indicated by differential pressure across the resin.

Emergency Coolant. The reactor is equipped with an air-cooled emergency cooling system. The function of this system is to remove all the heat after shutting down at normal and emergency condition. The capacity is about 63 kW x 3 units.

Water make-up system. The demineralised water is made from the local town water supply to the specification shown in Table 1. The demineralised water is stored in a $10m^3$ tank.

Table 1. G.A. Siwabessy RR's demineralized water specification

pH	6,5 – 7,5
Conductivity max	2 µS/cm
Ion Chloride max	0,0094 ppm
Ion Copper max	0,0056 ppm

2.2. Secondary Cooling System

The secondary cooling system is capable of dissipating 33MW into atmosphere via cooling towers. The cooling pipework inside the reactor hall is made of stainless steel. The rest of the cooling system outside the reactor hall is carbon steel.

The secondary water is chemically treated to control corrosion, scaling and micro-organism. It is partially blown down and replenished when conductivity reaches 950 µs/cm. The pH control is achieved by adding H_2SO_4. The water chemistry is shown in Table 2.

Table 2. Secondary water coolant specification

pH	6,5 – 8
Conductivity (normal)	850 - 950 µs/cm
Conductivity (max)	1500 µs/cm
Calcium ($CaCO_3$)	>280 ppm
SO_4^{-2} max	320 ppm
Total Hardness max	480 ppm
Total Fe max	1 ppm
Cl^- max	177.5 ppm
Corrossion Rate max	3 mpy
Number of bacteri	10^6 bacteri/ml

2.3. Interim Spent Fuel Storage

The function of this installation is to temporarily store the spent fuel to allow cooling down inside the service pool for about 100 days. The capacity is 1,458 spent fuel assemblies. The water temperatures at normal, 10 days after coolant failure, and the worst case are predicted to be 35, 45 and 100^oC, respectively.

Demineralized water is used as the primary coolant which is cooled by air-cooled chiller units installed outside the building.

3. METHOD

3.1. Analytical, monitoring and specification for water cooling system.

The secondary water chemistry is monitored to the following specifications in Table 3.[1]

Table 3: Specification and monitoring method for cooling water quality.[1]

System	Parameter	Methode	Specification	Frequency
Primary Cooling System	pH	pH meter	Min 5,2	Once a week
	Conductivity	Conductivity	8 μS/cm	Once a week
Secondary Cooling System	pH	pH meter	6,5 – 8	Once a week and online monitoring
	Conductivity	Conductivimetry	Max.1500 μS/cm	Once a week and online monitoring
	Ca^{+2}sbg.$CaCO_3$	Titrimetry	280 ppm	Once a week
	Total Hardness	Titrimetry	480 ppm	Once a week
	SO_4^{-2}	Spektrophotometry	320 ppm	Once a week
	Cl^-	Titrimetry	177,5 ppm	Once a week
	Zn^{+2}	Spektrophotometry	0,3 – 2,5 ppm	Once a week after blowdown
	Orthophosphate	Spektrophotometry	10 –20 ppm	Once a week after blowdown
	Total Fe	Spektrophotometry	1 ppm	Once a week
	Number of bacteria	Dipslide Test	$< 10^5$ bacteria/ml	If needed
Raw Water	pH	pH meter	7 – 7,5	Once a week
	Conductivity	Conductivitimetry	150 μS/cm	Once a week
	Ca^{+2}as.$CaCO_3$	Titrimetry	34 ppm	Once a week
	Total Hardness	Titrimetry	40 ppm	Once a week
	SO_4^{-2}	Spektrofotometri	67,5	Once a week
	Cl^-	Titrimetry	7,1	Once a week
	Total Fe	Spektrophotometry	1 ppm	Once a week
	Zn^{+2}	Spektrophotometry	-	Once a week
	Orthophosphate	Spektrophotometry	-	Once a week
Demine-ralized Water	pH	pH metry	6,5 – 7,5	Once a week or at the time of filling the tank
	Conductivity	Conductivitimetry	2 μ S/cm	Once a week or at the time of filling the tank

3.2. Coupon Racks

The coupon rack was designed to allow studying the effect of water chemistry quality on homogeny, galvanic and crevice corrosion and to provide technical guidelines for continued wet storage of spent fuels. The test coupons were prepared from the same grade materials as used for the constructions of the reactor structure, e.g. aluminum alloy used for fuel cladding, reactor tank and stainless steel (SS) for fuel assembly storage rack. The service pool and interim spent fuel facility are chosen to be the subject of study. The exposure duration is planned for 1, 2 and 3 years.

4. RESULTS AND DISCUSSION

4.1. Water Chemistry Analyses

The analyses of pH, conductivity and total dissolved solid were done for both in service pool and Interim Storage for Spent Fuel (ISSF). The analyses method and frequency are as shown in Table

3. The level of pH fluctuated between 5 to 7, conductivity between 2 to 2.5 μS/cm and TDS between 1 to 1.5 ppm.[7] ISSF has a conductivity of 0.5~5 μS/cm and Cl^- around 0.01~0.03 ppm.

4.2. Coupons

The test coupons were made of a series of discs (ϕ95 mm with ϕ15 mm centre hole; 1 mm thick for stainless steel and 5.5 mm thick for aluminium) put together as an assembly using a stainless steel centre pin and insulated with a ceramic bushing and 5 mm thick spacers between the discs. The coupons are also assembled in two orientations to allow vertical and horizontal installations in the pool. The coupons are also assembled in two orientations to allow vertical and horizontal installations in the pool. The first batch of six coupon assemblies were strategically positioned in the service pool in January 2007 and are due to be withdrawn in stages for inspection after 1, 2, and 3 years of exposure.

Before installation, both sides of the samples were photographed and weighed for future comparisons.

The cleaning of the samples was conducted using alcohol and then rinsed by demineralized water. After drying in warm air, the coupon was placed at its designated located in the pool and suspended by a stainless wire. The exposure started in January 2007 for both service pools of RSG and ISSF (Figure 4.a and b, respectively). The final analyses of the coupon are planned in January 2008 for both locations and both shapes (vertical and horizontal).

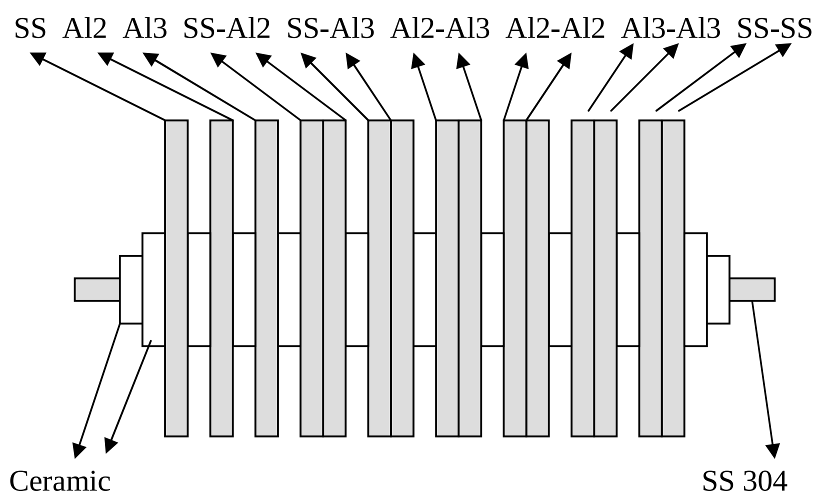

Figure 2. Setting coupons in rack.(SS=SS 304, Al2=Aluminum for fuel cladding, Al3=Aluminum for tank)

(a) (b)

Figure 3. Coupons horizontally (a) and vertically (b).

(a) (b)

Figure 4. Immersion place in service pool (a) and ISSF (b).

5. CONCLUSION

The analyses of pH, TDS and conductivity for both service pool and ISSF were done. The values are still within the acceptable limits. To understand the effect of the primary water quality on the reactor structures, a series of coupons were designed, fabricated and placed in test locations in January 2007.

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