

EFFECT OF CHLORIDE AND COPPER ION FOR REACTOR TANK MATERIAL INTEGRITY OF RSG GAS PRIMARY COOLING SYSTEM

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ABSTRACT

EFFECT OF CHLORIDE ION AND COPPER ION FOR TANK MATERIAL INTEGRITY OF RSG GAS PRIMARY COOLING SYSTEM. RSG GAS as Multipurpose Reactor designed to operate for 30 years, now RSG GAS has been operating for approximately 29 years. Al_2Mg_3 as a reactor tank material has a weakness in its use, that is not resistant for environment that contains of chloride ions and copper ion. The purpose of this research was to know the impact of Cl^- and Cu^{2+} for tank material integrity of the RSG GAS primary cooling system. The analysis is done by simulation on Al_2Mg_3 corrosion in Cl^- and Cu^{2+} solution using Potensiogalvanostate IG & G. The results showed that the concentration of chloride ion in the primary cooling water that greater than 6 ppm have potentially to degrade the integrity of reactor tank material. The existence of copper ions in the primary cooling water will accelerate the damage to the reactor tank. Material integrity of RSG GAS reactor tank can be maintained by limiting the concentration of chloride and copper ions in each of the primary cooling water in accordance with the standard requirement.

Keywords: integrity, the reactor tank material, the primary cooling water, RSG-GAS.

ABSTRAK

PENGARUH ION KLOORIDA DAN ION TEMBAGA TERHADAP INTEGRITAS MATERIAL TANGKI PADA SISTEM PENDINGIN PRIMER REAKTOR RSG GAS. Reaktor Serba Guna G.A. Siwabessy (RSG GAS) dirancang untuk beroperasi selama 30 tahun, sampai saat ini RSG GAS telah beroperasi selama kurang-lebih 29 tahun. Al_2Mg_3 sebagai bahan tangki reaktor mempunyai kelemahan dalam penggunaannya yaitu tidak tahan dengan lingkungan yang mengandung ion klorida Cl^- dan ion tembaga Cu^{2+} . Penelitian ini bertujuan untuk mengetahui pengaruh Cl^- dan Cu^{2+} terhadap integritas tangki Reaktor RSG GAS. Analisis dilakukan melalui simulasi uji korosi Al_2Mg_3 dalam lingkungan ion Cl^- dan Cu^{2+} menggunakan Potensiogalvanostate IG&G. Hasil penelitian menunjukkan bahwa pada konsentrasi ion klorida dalam ATR lebih besar dari 6 ppm berpotensi mendegradasi integritas tangki reaktor. Keberadaan ion tembaga dalam ATR akan mempercepat kerusakan tangki reaktor. Integritas tangki reaktor RSG GAS dapat dipertahankan dengan membatasi konsentrasi ion klorida dan ion tembaga dalam air pendingin primer masing-masing tidak melebihi standar yang dipersyaratkan.

Kata Kunci : integritas, tangki reaktor, air pendingin primer, RSG-GAS.

INTRODUCTION

Multipurpose Reactor G.A. Siwabessy (RSG GAS) designed to operate for 30 years, now RSG GAS has been operating for approximately 29 years. Because of aging process, very possible that the condition of systems, structures and components (SSCs) of the reactor will degraded the function of reactor material. Degradation of system functions and components can disrupt the continuity of the operation of the reactor and interfere the reactor operation safety. Operation safety of RSG GAS should be maintained so that the operation of reactor can be extended for 10 years. Therefore, it is necessary to monitor the reactor safety, by predicting the strength of the reactor tank material [1]. Aging management is one program that must be done to get a reactor operating life longer [2]. Monitoring of the reactor material is very important to do, especially for Al_2Mg_3 as the RSG GAS reactor tank

material. Aluminium alloy has a weakness in its use which is not resistant to environments containing chloride ions, especially when there is a copper Cu ion. That will trigger the corrosion process on aluminum alloys. Therefore, there should be analysis of the influence of chloride ion and Cu ion in primary cooling water for RSG GAS material integrity. The use of water as a coolant in research reactors could pose problems for the integrity of structures, systems and components of the reactor, such as the corrosion of the reactor material, the formation of oxide layer in the cladding of fuel elements and heat exchangers pipes so that will reduce the efficiency of heat conductivity, radiation exposure increases due to the activation of particles dissolved in the water, and the emergence of aggressive species generated by radiolysis process [3]. Various mitigation needs to be done to minimize the negative effects arising from the use of water as a coolant. Water treatment is needed to be important in obtaining water quality which low aggressiveness [2] It is necessary to minimize the negative effects arising from the reactor cooling water to the reactor material. Therefore, it is necessary to periodically monitoring system against reactor water chemistry quality conditions so that if any irregularities will be immediately anticipated and reactor water quality will be maintained according to the requirements [4]. Chloride ion and copper ion is very aggressive towards aluminium (Al_2Mg_3) as reactor tank material, so that if the concentration exceeds the concentration required it will damage the reactor tank material and lead operations will shorter. The purpose of this study was to know the impact of Cl^- and Cu^{2+} for material integrity on the RSG GAS primary cooling system. The existence of trace elements in the primary cooling water on RSG GAS especially chlorida ion and copper ion have not been monitored periodically. Monitoring on water quality conditions of the primary cooling water on RSG GAS done on the pH (degree of acidity) and electrical conductivity of water.

ALUMINIUM CORROSION ON WATER

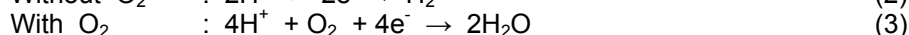
Corrosion degraded the quality of material caused by reactions with the environment [5]. The mechanism of corrosion process in water by electrochemically occurring simultaneously at the anode and cathode regions on the electric current circuit closed [6-7].

1. Reaction on anoda (oxidation)

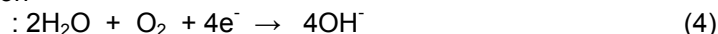


2. Reaction on catoda (reduction)

- a. acidic solution



- b. Alkali or neutral solution



- c. The reduction of the dissolved metal ions



The stages on corrosion process in 4 phases, as follows: [8].

1. Anode, oxidation reaction occurs that releases electrons, so the corrosion process will take place.
 2. Cathode, there will be a reduction reaction that will capture electrons.
 3. The electrolyte as a medium of contact between the anode and the cathode so as to allow the flow of electricity.
 4. The electrical circuit between the anode and cathode which allows the flow of electrons
- Water is a one aggressive substance towards metal which pasted. Because water will be ionized to produce ions H^{+} and OH^{-} ions in 10^{-7} mol per liter ($pH = 7$). H^{+} ions will acts as an oxidant in corrosion process in the structure and components of the material reactor. So the presence of hydrogen ions in the water has a chance to damage the metal, support for the corrosion process such as the occurrence of defects on the surface[9]. Corrosion will occur in the structure and components on the material reactor if water is used in reactor coolant contains aggressive ions such as chloride ion and cupper ion. For example, the aggressiveness of ion chloride and copper ion in form of pitting on aluminum alloy such as Figure 1 [10-12].

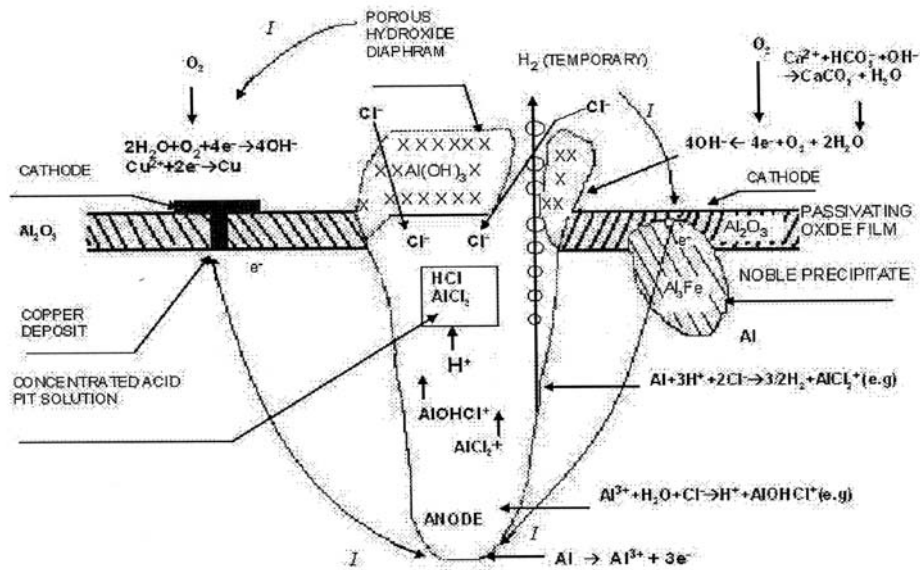


Figure 1. Formation process of pitting corrosion due to the effect of chloride ions and copper ions on aluminum alloy [10].

METHODOLOGY

If the primary cooling water in RSG GAS containing chloride ions and copper ions, the integrity of the material reactor tank needs to be analyzed to ensure the continuity and safety of operation. The analysis was performed through corrosion process using a potentiogalvanostate for Al_2Mg_3 as the reactor tank material on the solution that contains chloride and copper ion. The element content on Al_2Mg_3 as described in the Table 1.

Table 1. Element content on Al_2Mg_3 [13].

Element W (%)	Al	Fe	Mn	Cu
	98.9034	0.4939	0.4189	0.1838

Al_2Mg_3 had cutting with 1.6 cm diameter cylindrical shape as a sample corrosion test. The sample then polishing by using sandpaper with 100, 400, 800, 1200 mesh. Simulations carried out by using a sodium chloride solution with varying concentrations of 0, 2, 4, 6 ppm. Varien concentration of copper solution with 0.02 ppm, 0.1 ppm, 0.15 ppm is add on the sodium chloride solution 2 ppm. The corrosion rate is calculated using the phenomenon of Faraday's law [14]:

Corrosion process on the metal (M), occurs electrochemically by follow the equation such as



M_1 = monovalent metal M_2 = bivalent metal and M_3 = trivalent metal

If in the corrosion test, has result the current (i_{corr}) of 1 Faraday (96500 Coulomb) means there has been a corrosion process on metal as much as 1 equivalent. Faraday formulation to calculate the corrosion rate.

$$Corrosion.rate = \frac{0.13i.eq}{\rho A} mpy$$

corrosion rate = mpy (mili inchi per year)

A = area of the metal (cm^2)

eq = equivalent weight

ρ = metal density (gr/cm^3)

i = current (mili ampere)

RESULTS AND DISCUSSION

The water quality requirements (safety analysis report) on Triga Reactor-Bandung, Kartini reactor-Yogyakarta, RSG GAS-Serpong are shown in Table 2:

Table 2. Safety analysis report of water quality requirement

No.	Parameter	Reactor research		
		Kartini	Triga	RSG GAS
1.	pH	5.5 – 6.5	5.5 - 6.5	5.8 – 7.0
2.	λ ($\mu\text{S}/\text{cm}$)	< 3.5	< 3.5	< 8.0
3.	TDS (ppm)	-	-	-
4.	Ca (ppm)	< 1	< 1	-
5.	Mg (ppm)	< 1	< 1	-
6.	Si (ppm)	< 1	< 1	-
7.	Na (ppm)	< 1	< 1	0.0232
8.	Fe (ppm)	-	-	-
9.	Mn (ppm)	0.004	< 0.1	-
10.	Al (ppm)	-	-	0.0115
11.	Cu (ppm)	-	-	0.0209
12.	Ni (ppm)	-	-	-
13.	Zn (ppm)	-	-	-
14.	Cd (ppm)	-	-	-
15.	Be (ppm)	-	-	-
16.	Cl^- (ppm)	-	-	0.049
17.	SO_4^{2-} (ppm)	-	-	0.0528

Effect of chloride ion to Al_2Mg_3 corrosion rate as RSG GAS reactor tank material is shown in Figure 2. Effect of copper ion concentration of 0.2; 0.10; 0.150 ppm to Al_2Mg_3 corrosion rate on chloride solution as shown in Table 3. We can see that there are the corrosion process on Al_2Mg_3 on concentration chloride ion solution 0 ppm with corrosion rate of 0.0121 mpy (0.000307 mm/year). It is possible there are the corrosion process on Al_2Mg_3 , supported by reaction 1,2 and 3. Water will contribute the corrosion process, in the presence of hydrogen ions from the dissociation process, it is exactly to effect for the corrosion process. If ion concentration at primary cooling water can be maintained under the standard requirement, especially ion concentration 0 ppm, a reduction in the thickness of the reactor tank material for 30 years was 0.363 milli-inch (0.009210 mm). Reduction in thickness due to corrosion of the reactor material tank in these conditions is small relatively so that the integrity of the reactor material tank is still high relatively.

The RSG GAS safety analysis reports of chloride ion concentration on the primary cooling water is 0.049 ppm. Based on the curve of Figure 2, can be determined that the corrosion rate of RSG GAS reactor material tank is 0.0144 mpy (0.000365 mm/year). So, thinning tank reactors over 30 years of age RSG will not exceed 0.432 milli-inch (0.010970 mm). This condition is still safe for thinning reactor material tank still small relatively. So that the integrity of the material tank is high relatively.

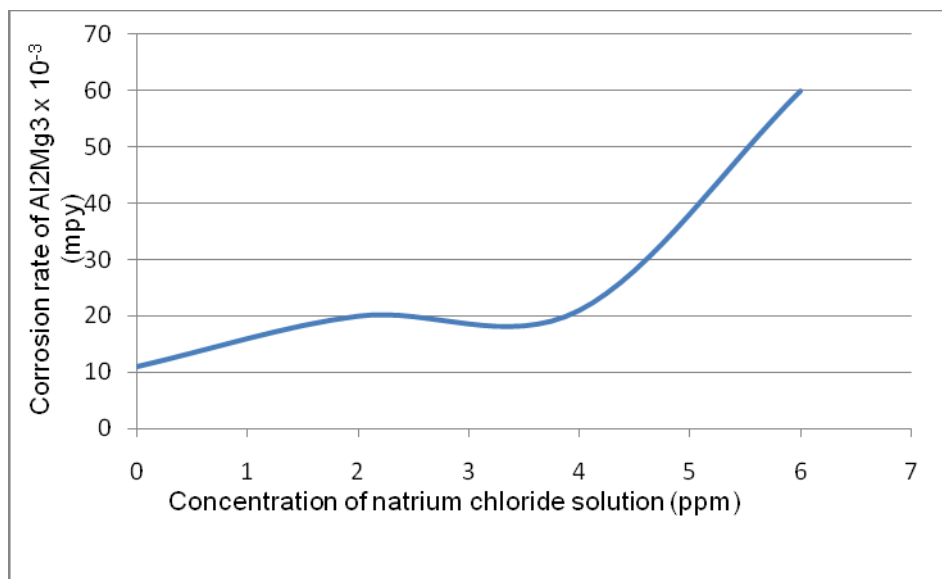


Figure 2. Effect of chloride ion to Al₂Mg₃ corrosion rate

Table 3. Effect of copper ion to Al₂Mg₃ corrosion rate

Konsentrasi Cl ⁻ / Cu ²⁺ (ppm)	0,00/0,00	2,00/ 0,00	2,00/0,02	2,00/0,10	2,00/ 0,15
Corrosion rate (mpy)	0,0121 mpy (0,000307 mm/year)	0,0213 mpy (0,000541 mm/year)	0,0639 mpy (0,001623 mm/year)	0,0958 mpy (0,002434 mm/year)	0,1478 mpy (0,003754 mm/year)

The corrosion rate of Al₂Mg₃ at 2, 4 and 6 ppm chloride ion concentration, is 0.0213 mpy (0.000541 mm/year), 0.0258 mpy (0.000655 mm/year) and 0.0609 mpy (0.001546 mm / year). So can be expected the possibility of thinning material for 30 years is 0.639 milli-inch (0.016230 mm), 0.774 milli-inch (0.019650 mm), and 1.827 milli-inch (0.046400 mm). On the condition of the chloride ion concentration below 6 ppm, thinning of the reactor tank is small relatively so that the integrity of the reactor material tank at these concentrations can still be maintained. It can be seen table 3, that the corrosion rate of Al₂Mg₃ in the chloride solution with concentration of 2 ppm add the copper solution with 0.150 ppm is 0.1478 mpy (0.003754 mm/year), much higher than the corrosion rate of Al₂Mg₃ in the chloride solution with concentration of 2 ppm with and without copper solution is 0.0213 mpy (0.000541 mm / year). We can see that increase of the corrosion rate is 7 times. It can be confirmed that the presence of copper ions in the primary cooling water would be able to trigger an increase in the corrosion rate of Al₂Mg₃.

Monitoring of primary cooling water quality especially chloride ions and copper ions as periodically should be done so that the integrity of the reactor material can be maintained. If there are symptoms of increased ion is then immediately do a more intensive refining primary cooling water thus further corrosion of the tank can be avoided.

CONCLUSION

A concentration of chloride ions in primary cooling water is greater than 6 ppm potentially degrade the integrity of the material reactor tank. Presence of copper ions in the primary cooling water would accelerate damage to the material reactor tank. Monitoring of primary cooling water quality especially chloride and copper ions should be done periodically so that the integrity of the reactor material can be maintained. If there are symptoms of increased ion is then immediately do a more intensive refining primary cooling water thus further corrosion of the tank can be avoided. Monitoring of primary cooling water quality especially chloride ions and copper ions as periodically should be done so that the integrity of the reactor material can be maintained.

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