Corrosion Inhibitor Use in the Gland Seal Water System of a Greenfield Alumina Refinery

Mireille Wonoredjo[1], Howard Johnson[2] and Lawrence Smit[3]
1. Senior Process Engineer
2. Senior Chemist
3. Senior Manager – Reliability Engineering
Emirates Global Aluminium - Al Taweelah alumina refinery, Technical Department, Abu Dhabi, UAE
Corresponding author: mriveralaguado@ega.ae

Abstract

Gland Seal Water (GSW) systems in alumina refineries are essential for safe operation of gland sealed slurry pumps. Keeping a closed loop system with integrity intact is key to protecting both the pumps themselves, as well as the personnel operating in the vicinity of these pumps. Over the short years of operating the Al Taweelah alumina refinery, there have been observations of premature pinhole failures in the GSW pipework. To mitigate this problem, the potential effects of chemically treated water on the pipework was studied. The research team conducted laboratory tests to identify suitable chemical treatments before implementing a field trial to evaluate the efficacy of the selected corrosion inhibitor. This paper provides a comprehensive evaluation of the results obtained from both the lab tests and field trials, offering insights into the effectiveness of the chemically treated water in preventing GSW pipework failure. The findings have significant implications for improving the safety and efficiency of alumina refineries.

Keywords: Corrosion inhibitor, Corrosion rate, Gland seal water, Mild steel coupon.

1. Introduction

Steel is unstable in contact with oxygen and water and will undergo reactions that result in a variety of iron oxides, hydroxides and oxyhydroxides. The oxides are favoured at high pH and can impart some protection against further corrosion. Refineries and factories consist of a network of connected metal pipework that are easily susceptible to corrosion. To minimize and/ or prevent this from occurring, several techniques can be applied. These can be by installing galvanized pipework, clamping or replacing parts of failed pipework, by adding chemical(s) in the water (corrosion inhibitors), amongst others.

The objective of this study is to demonstrate the efficacy of chemically treated water, which will form part of the evaluation of the treatment selection on the GSW pipework integrity in the near future.

2. Rusting and Mechanism of the Selected Chemical

Rusting is a redox reaction that occurs when iron comes into contact with air and/or water. Iron is oxidized to Fe^{2+} and Fe^{3+} ions, with the oxygen undergoing reduction in the presence of water to form hydroxyl ions, as follows:

$$O_{2(g)} + 2H_2O + 4e^- = 4OH^-_{(aq)} \quad (1)$$

$$Fe_{(s)} = Fe^{2+}_{(aq)} + 2e^- \quad (2)$$

The ferrous ion is unstable in the presence of oxygen and undergoes further oxidation:

$$Fe^{2+} = Fe^{3+} + e^{-} \quad (3)$$

The ferric ions react with hydroxyl ions to form a loose precipitate of ferric hydroxide, which then undergoes dehydration reactions to produce oxyhydroxides and oxides:

$$Fe^{3+}_{(aq)} + 3OH^{-}_{(aq)} = Fe(OH)_{3(s)} \quad (4)$$

$$Fe(OH)_{3(s)} = FeO(OH)_{(s)} + H_2O \quad (5)$$

$$2FeO(OH)_{(s)} = Fe_2O_{3(s)}.+ H_2O \quad (6)$$

In an alumina refinery, the oxide layer is quite compact and acts as a partial passive layer (except at very high free caustic concentrations). However, this passivity can be lost in the presence of chloride ions, leading to pitting corrosion. In addition, crevice corrosion at joints and seams, and galvanic corrosion through poor material selection can sometimes result in early failure. The selected chemical works both as an anodic inhibitor (using orthophosphate to form a passive film) and a cathodic inhibitor using zinc.

3. Experiments

3.1 Laboratory Experiments

For the laboratory experiments, an NCM100 Corrosion Monitor 400 - NCM100.88 was used. A corrosion probe attached to this device is inserted in the water samples for measurement and recording of corrosion rates. The tested water samples were taken from the main distribution tank which feeds the GSW (gland seal water) tanks across the refinery. Corrosion rates were measured over a period of a few days at room temperature, using 500 mL water samples in 1 L plastic beakers with a magnetic stirrer, where the chemical was added using 50 mL syringes. This was done on untreated and chemically treated water samples. Different corrosion inhibitor products with varying dosages were tested to select a suitable chemical to be trialed in the field.

3.2 Field Experiments

The duration of the field trial was 5 months, commencing with 150 ppm dose rate based on the laboratory outcome. This had to be lowered after one day as this caused blockages in the discharge pump strainer affecting gland seal water flowrates to the slurry pumps.

The main distribution tank (Process Water tank) feeds the GSW systems and other applications across the refinery. This water is a mixture of generated hot process condensate from the digester units and imported water (average ratio 25:75). To measure the corrosion rates of the untreated water, mild steel coupons were installed on the discharge line of the Process Water tank via a PVC rack on a recirculation line.

The field test of the chemical addition was in the Precipitation facility GSW tank. The chemical was pumped by a solenoid-driven metering pump via a 25.4 mm plastic tube from an Intermediate Bulk Container (IBC) into the top of the GSW tank, near the inlet of the water feedline for proper mixing. The treated water was then pumped off by a GSW pump to the slurry pumps. A 38 mm hose was installed to recirculate the treated water from a drain valve at the discharge of the GSW pump, back to the GSW tank, to allow online corrosion and mild steel coupon measurements via a PVC rack. The NCM device was attached to the corrosion probe for data storage. Figures 1–3 represent a simplified overview of the field setup.

5. References

1. V.A. Chukhin and A.P. Andrianov, Formation mechanism of iron tubercles during corrosion of water supply pipes, *Int. J. Corros. Scale Inhib., 2022, 11, no. 2, 812–830*, Moscow State University of Civil Engineering (National Research University), Yaroslavskoe shosse 26, 129337 Moscow, Russian Federation, 1
2. A. Jannifar, T. A. Ichsan, Hamdani Nurdin, Fakhriza Mukhtar, Wahdania Wahyudi, Welding current effect of welded joints of base metal st37 on characteristics: corrosion rate and hardness, *International Conference on Sustainable Energy and Green Technology,* 2018, Indonesia, 1
3. Alexey Andrianov and Evgeny Orlov, Explanation of tuberculation scales formation in steel and iron pipes using the theory of wave motion of a liquid, *MATEC Web of Conferences 178, 04002, 2018,* Moscow, Russia, 5- 6.