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Research Article

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Application of Compost Gel for Treatment of Anode Beds of Onshore Pipelines in High Resistivity Soils

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Abstract
The construction of onshore pipelines often occurs in places that are difficult to access or in non-ideal conditions due to logistical and economic needs or due to design errors. Occasionally, the anode bed of the impressed current cathodic protection system, for protection against external soil corrosion, can be installed in high resistivity soils, making it difficult to efficiently inject enough electrical current to polarize and protect the pipeline. In the present work, soil treatments were carried out with a gel composed of copper sulfate, aluminum silicate and calcium sulfate hydrate in two anode beds with insufficient current injection. The results showed an increase of more than 80% in the current injection and considerable drops in the electrical resistance of the system, consequently, a considerable improvement in the polarization and protection potential of the pipelines to which these systems were interconnected. All this combined with a very low cost compared to other techniques.

Keywords Pipelines Cathodic Protection. Soil Corrosion. Anode Beds.

1. Introduction

The oil industry is greatly affected due to the complex characteristics and composition of the fluids present in the reservoirs and spends a lot of resources investing in maintenance, inspection and technologies to combat internal and external corrosion in pipelines. The oil and gas fields possess produced water (natural water from the reservoir with several dissolved compounds) and other corrosive agents such as O_2, CO_2, H_2S and sulfate-reducing bacteria (BRS) that internally attack steel pipes, in addition to the soil and atmosphere that can cause external corrosion in equipments. Soils can contain moisture, acids, reducing microorganisms (bacteria, algae and fungi), O_2 and other contaminants that, influenced by factors such as pH and electrical resistivity, cause corrosion on the external wall of the pipelines [1].

One way to avoid contact between the metal wall of the pipeline and the ground (avoiding electrochemical corrosion) is to use an external coating on buried pipelines as a form of anti-corrosion barrier. Despite being efficient, the coating has a service life and also suffers damage during maintenance and actions by third parties, which makes its integrity control quite difficult for equipment with kilometers of extension, such as land pipelines [2].

To avoid failures and leaks due to external corrosion, impressed current cathodic protection is used as a second anti-corrosion technique to protect buried pipelines in case of coating failures. Impressed current cathodic protection consists of using a direct current electric power source (rectifier) connected to a bed of anodes on the positive pole and to the pipeline on the negative pole of the system, as shown in Figure 1. This current will cause a polarization in the pipeline leaving it in an electrochemical immunity condition in the corrosion condition of the soil in which the pipeline is buried [3].

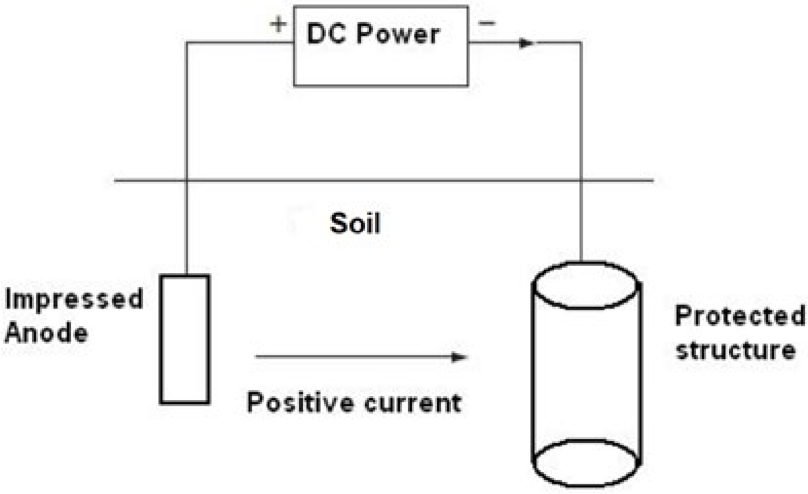

Figure 1: Schematic of impressed current protection method [4]

Due to logistical conditions, costs or even design errors, the impressed current cathodic protection system can be installed in regions with high resistivity soil. This high resistivity in the soil will act as resistance to the passage of ground current and make it difficult for the pipeline to be polarized for protection, which is of more negative electrochemical potentials than -0.85 V for the $Cu/CuSO_4$ reference electrode. In these cases, the company operating the pipeline may be forced to relocate the system to regions with soils with better resistivity, generating significant investment to make the cathodic protection system efficient and avoid possible failures due to corrosion [3].In order to avoid high expenses with relocating the cathodic protection system with high resistivity soils, it was proposed in this work, the soil treatment of two anode beds with high resistivity soils, through the use of a compound of copper sulfate, aluminum silicate and calcium sulfate hydrate. After soil treatment, electrochemical potential measurements were made and confirmed that soil treatment can be more efficient and cheaper than relocating the complete cathodic protection system.

2. Methodology

2.1 Procedure

For the treatment of the soil with the compound gel, two rectifiers called RF-A and RF-B were chosen, connected to a cathodic protection system by impressed current with anode beds installed in high resistivity soils (above 1000 Ω.m). These rectifiers had low current injection and did not keep the electrochemical potentials within the protection criterion that is more negative than -0.85 V [5].Figure 2 shows a photo of the RF-A anode bed before treatment.

Figure 2 – RF-A anode bed before treatment.

Author.

Each bed anode was excavated in an area of 1 m^3 and part of the natural soil was removed, while the rest was mixed with water and 60 kg of gel composed of copper sulfate, aluminum silicate and calcium sulfate hydrate, as shown in Figure 3. The treatment stages can be seen in Figures 2, 4 and 5. The cost of the reducing gel was about U$ 50 per anode and the exact values of the chemical composition of the gel will not be disclosed for reasons of industrial secrecy.

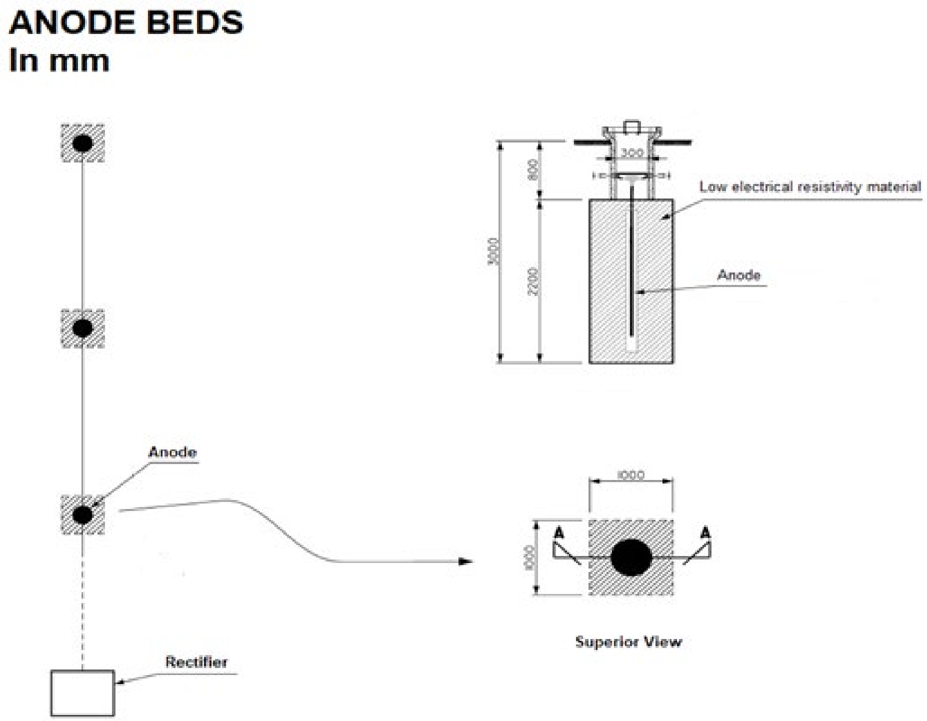

Figure 3: Scheme of bed treatment at each anode.

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Figure 4: Excavation of the anode bed.

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Figure 5: Application of the compound gel and mixture with water and natural bed soil.

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Figure 5: Bed with soil treatment completed.

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2.2 Data survey

After completing the treatment of the two beds, several monthly measurements of the electrical variables of the rectifiers were made, as well as measurements of the electrochemical potential with a multimeter and using a $Cu/CuSO_4$ reference electrode (Figure 6). Random months of the years 2020 and 2021 (before treatment) were chosen and compared with the same months of 2022 (after treatment), in order to avoid seasonality and rainy periods by comparing different months. The objective of this stage is to verify if there were improvements in the polarization and current injection of the systems.

Figure 6: Measurement of electrochemical potential.

Author.

3. Results and Discussions

3.1 Rectifier A

Table 1 shows the results of the RF-A tests in the months of January, February and December. It is possible to see that there was a great improvement in the protection potentials that went from the condition outside the protection criterion to within the protection criterion. As can be seen in Figure 7, the current injection also had an incredibly high increase of fourteen times in 2022 compared to the average of 2020/2021 (before treatment). This was due to the drop in the electrical resistance of the system with the compound used in the soil.

Potential OFF (V)	Month 1	Month 2	Month 3	Average
2020	-0.60	-0.77	-0.64	-0.67
2021	-0.59	-0.57	-0.62	-0.59
2022	-2,28	-1,54	-2,45	-2,00

Current (A)	Month 1	Month 2	Month 3	Average
2020	1.20	8.00	1.30	3.50
2021	1.00	1.00	1.10	1.03
2022	30.20	18.40	50.40	33.00

Resistance (Ω)	Month 1	Month 2	Month 3	Average
2020	73.00	31.44	66.69	57.04
2021	82.00	82.00	74.09	79.36
2022	2.54	4.40	1.43	2.79

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Table 1 – RF-A measurement results

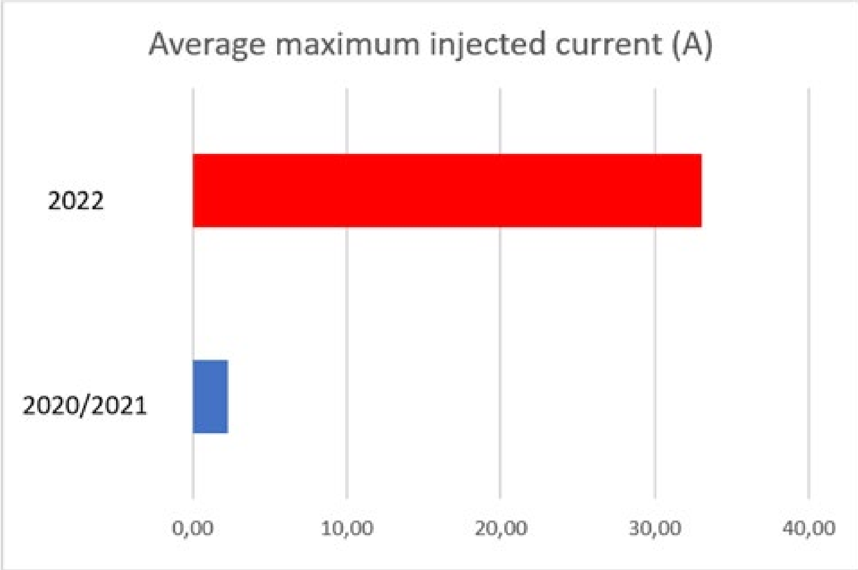

Figure 7: Average increase of injected current of 14 times in RF-A.

Autor.

3.2 Rectifier B

Table 2 shows the results of the RF-B tests in the months of September, November and December. As in the RF-A, it is possible to see that there was a great improvement in the protection potentials that went from the condition outside the protection criterion to within the protection criterion. As can be seen in Figure 8, the current injection also had an incredibly high eight times increase in 2022 compared to the average of 2020/2021 (before treatment). This was due to the drop in the electrical resistance of the system with the compound used in the soil, as well as in the RF-A.

Potential OFF (V)	Month 1	Month 2	Month 3	Average
2020	-0.66	-0.68	-0.63	-0.66
2021	-0.63	-0.63	-0.59	-0.62
2022	-3.13	-3.07	-1.88	-2.69

Current (A)	Month 1	Month 2	Month 3	Average
2020	7.50	4.30	3.80	5.20
2021	5.40	4.10	3.40	4.30
2022	32,00	48,00	33,00	37,67

Resistance (Ω)	Month 1	Month 2	Month 3	Average
2020	12.40	20.30	23.42	18.71
2021	16.20	21.59	26.09	21.29
2022	0.86	0.60	0.68	0.71

Table 2: RF-B measurement results.

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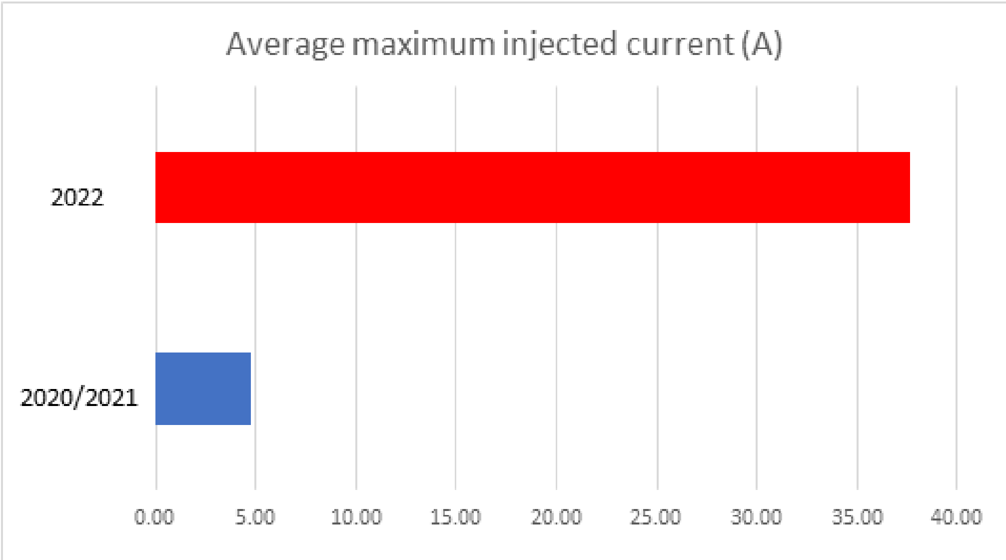

Figure 8: Average increase of injected current of 8 times in RF-B.

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4. Conclusions

From the results of this work, it is possible to verify that the treatment of the anode bed soil with a compound of copper sulfate, aluminum silicate and calcium sulfate hydrate was extremely efficient in increasing the injection of electric current in the rectifiers, with an average increase of up to fourteen times in relation to the electrical conditions before soil treatment.

The location where the anode bed is installed is extremely important for the result of cathodic protection against external corrosion in onshore pipelines and a location with high resistivity can completely compromise the efficiency of this protection. Soil treatment is an efficient and inexpensive alternative to remedy bed problems under these conditions.

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