

CATHODIC PROTECTION OF CASSAVA GRATING MACHINE WITH MAGNESIUM ANODE

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ABSTRACT

A small-scale cassava grating machine optimized by attachment of magnesium anode to the hopper, grating chamber and pulp outlet was developed using magnesium as the sacrificial anode. The bedding of the magnesium anode was (1ft wide and 1ft deep). The sacrificial anode was sustained ahead of usage by wrapping up the sack containing the anode with charcoal in an air-tight polythene bag. A detailed soil analysis within the premises of the Engineering Research Unit, National Root Crop Research Institute, Umudike, was established which confirmed the presence of conditions necessary for corrosion to take place. The quantity of Anode required to protect a small-scale cassava grating machine was assembled and packaged. The design parameter for the developed cathodic protection system was; total current; anode current; protection voltage; soil pH; and the soil resistivity test. At the end of ten weeks, potential readings of -1080 mV were obtained; pipe protection current was 0.0076mA; Anode and Anode weight of 7.5kg; Anode current of 0.0096mV; the soil PH and soil resistivity test values(s) were 5.77 and 21.51 Ω m respectively. The protection potential of (-890mV to -1080mV) obtained is in the range of (-850mV to -1150mV) for a protected stainless steel pipe. From the results, it can be concluded that SACP is an effective and efficient means of corrosion control. CP systems are best used in areas of average rainfall per year. The coastal states (Rivers, Bayelsa and environs) are the most favoured as their rainfall statistics are relatively high. All materials used for the cassava grating machine CP system were sourced locally, and the estimated cost of this work is one hundred and two thousand, nine hundred and fifty naira (₦102, 950.00)

Key Words; Cathodic Protection, Electrochemical, Corrosion, Cassava Grater, Small Scale

1.0 INTRODUCTION

The wastage of metal due to rusting has become an important engineering problem. Corrosion is a chemical or electrochemical reaction between a metal and its environment which involves the removal of the metal or its conversion to an oxide or other compound. Corrosion occurs in different forms such as in construction industries, industrial process equipment and allied industries (Abiola and Oforkar, 2002). Corrosion was also represented from global perspective as a tremendous economic loss and there is much to be done to combat it (Amuda *et al*, 2006).

Adetunji, *et al* (2011) evaluated the electrochemical properties of mild steel, galvanized steel and aluminium sheets exposed to cassava fluid using the weight loss technique. The weight loss of each sample for specific periods of immersion was determined on average of two samples exposed under the same cassava fluid in different plastic containers. It was found that aluminium

samples had the highest corrosion resistance followed by mild steel then galvanized steel. Also, corrosion rates for all metallic samples decreased over the immersion durations.

According to Baghdachi, (2010) corrosion can be mitigated using acrylic coatings, sol-gel materials and their combinations, and aluminium and magnesium powder. He notes that modification of acrylic resins with food-contact-approved silicon-containing materials shows high protection potential. Baghdachi adds that the adoption of newer corrosion protection coating technologies by the food processing industry, such as nanotechnology is advised.

Cathodic protection (CP) is a technique used to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell. This is achieved by placing it in contact with another more easily corrodible metal to act as the anode of the electrochemical cell.

Cathodic protection systems are most commonly used to protect steel, water or fuel pipelines and storage tanks, ships, offshore oil platforms and onshore oil well casings. Cathodic protection can be, in some cases, an effective method for preventing stress corrosion cracking (Kroon, D.H and J.G. 2001).

The methods used in the control of corrosion are coating, cathodic protection, material selection, environmental modification, and design practices. Control of underground corrosion is primarily achieved by two methods: coating and cathodic protection. An effective external coating can provide corrosion protection to over 99% of the exposed pipe surface (Kuhn, R.J. 1928). The protective coating is usually applied to the pipe or vessel as a preparation for the sacrificial metal. The coating serves as a thermal insulator for the metal from the soil. If the metal could be completely isolated, the establishment of corrosion cells would be prevented and no corrosion current would flow (Kroon, D.H and J.G. 2001). However, no coating can be considered a perfect coating. Damage to the coating as a result of handling, transportation, installation, thermal stresses and soil stresses will eventually create defects or “holidays” that expose the underlying steel to the environment.

To a large extent, the economic impact of corrosion control on any society can be seen in terms of its effect on the GNP. It is estimated that between 3-5% loss of the Gross National Products (GNP) in industrialized countries is attributed to corrosion damage. Corrosion of metals costs an average economy of almost \$300 billion per year and it is estimated that one-third of this value could be saved if a better selection of corrosion prevention techniques including cathodic protection were adopted (Schwerdtfeger, W.J. 1952).

Nonetheless, to ensure a high level of safety and reliability, it is essential to have cathodically protected metals to ensure zero iron interference while processing food. It is also important to have a system of inspection and maintenance for steel that forms other parts of the grating machine and their ancillary equipment (Kuhn, R.J. 1993).

Cassava is a widely grown root crop which accumulates two cyanogenic glucosides, linamarin and lotaustralian (J.A. Montagnac, C.R. Davis, S.A. Tanumihardjo. 2009). Linamarin produces the toxic compound hydrogen cyanide (HCN) which can be toxic to processing machinery components. The different primary processing operations of cassava into any food products (gari, lafun, flour etc) include peeling, washing, slicing, grating, dewatering/fermentation, sifting, drying/frying, post-grinding, packaging and storage. All these operations involve the use of the machinery of varying sophistication through which corrosion problems are likely to be encountered, corrosion problems in cassava become more

pronounced as the cassava tubers are broken into pulps and thereafter left to ferment naturally by yeasts and other microorganisms in which the sugars in the mash are hydrolysed. The critical issue is the presence of the two cyanogenic glucosides released during cassava processing.

This paper describes the basic principles of cathodic protection being best for corrosion inhibition in cassava grating machines, the areas of use and the general factors to be considered in the choice and design of food processing equipment CP systems. It gives a basic introduction and simple technical data on cathodic protection. It further provided the basis for a common strategy for meeting the above objectives, allowing efficient and cost-effective corrosion prevention. To this effect, this study provided a basic understanding of corrosion inhibition on cassava grating machines and suggest methods of controlling it.

From the result conducted, it was discovered that most of the cassava graters in the research area are usually corroding (reducing service life) due to the acidic nature of the cassava fluid and material used for the fabrication. To ensure all cassava products are free from any unwanted/offensive taste, odour or infected the iron content of parts (food poisoning) which may affect the quality of the food after processing (FAO 2001) hence the need for corrosion control and a greater need for appropriate materials for fabrication of all cassava processing machine., particularly, cassava grating machine that involves the use of water which comes in contact with the metal used for framing the machine and that of the grater. The acidic cassava fluid is also of great concern as it promotes surface pitting of metals.

The combination of SaCP and Mild steel for the fabrication of cassava grating machine, is affordable compared to the use of stainless steel. Though the rural settlers because of lack of funds predominantly fabricate food processing machines with mild steel, seeing that mild steel contaminates food during processing, it is important to look at alternative corrosion prevention measures hence, Cathodic protection of cassava grating machines.

The cassava tuber spoils after about 2-3 days of harvesting, hence the need for processing into safer stable products. Because of the abovementioned problem and the overall importance of the cassava products, the following objectives are required to address the shortcomings of the grater.

1. To design a 25kg of the sacrificial anode which will give protection to the hopper perforated grating chamber metal and the pulp outlet (all made of mild steel as is seen in most rural areas of Nigeria).

2. To reduce the degree of surface contamination during cassava grating/processing.
3. To promote healthy consumption of cassava products.
4. Coat the external parts of the cassava grating machine with the use of polyethylene tape after painting. The external part of the machine, which has no interference with the cassava to be grated, required protection also. In this study, we coated and also cathodically protected the external part of the cassava grating machine. This was done to give holistic protection to all metallic components of the machine. Its significance is to leave no stone unturned since no one knows where the corrosion may creep in from.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

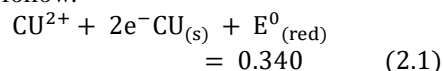
The following materials were used in cathodic protection of the cassava grating machine with a sacrificial anode (SACP) method, they include: mild steel (which was used for the fabrication of the hopper, perforated grating chamber and pulp outlet), Single packaged magnesium anode (with chemical backfill), Polyethylene tape (with coal tar enamel), Test post, PVC-PVC cable, Multi-meter, Bolt and nut, CADweld mould and CADweld powder, CADweld disc, Copper-copper sulphate reference electrode (CU/CUSO₄)

1. **Cassava Grating Machine:** contains the Hopper, Shaft, Drum, Discharge, Pulley, Electric Motor, Bolts, Belts, mild steel frames, Rivet Pins, Bearings, perforated Mesh, Cover and Handle. This study is interested in the use of sacrificial anode to protect the metallic members of a cassava grating machine as such will only mention the parts that come in contact with the cassava and cassava pulp.
2. **Magnesium anode:** Magnesium anodes come in all shapes and sizes. The magnesium in a packaged anode weighs from 0.454kg to 22.680kg. The most commonly used anode in the United States weighs 7.711kg. The backfill consists of 75% powdered gypsum, 20% powdered bentonite clay and 5% sodium sulphate. This mixture is a low-cost, non-hazardous, electrically conductive earth backfill. Based on the length of the structure to be considered for this project, a minimum packaged anode of 5-7.5kg will be needed.
3. **Polyethylene tape:** Polyethylene tape is a type of tape which has a polyethylene backing with a rubber adhesive. This is used for all purpose applications, including; Sealing, Colour coding, Protecting and Moisture proofing

Polyethylene tape consists of two types;

Adhesive: (Inner layer of butyl rubber)

4. **Test post:** The test post is the signboard which displays the connections between the structure to be protected and the magnesium anode. It can either be made of wooden material or plastic.
5. **PVC-PVC wire cable:** This is a double coated wire cable which is specially produced for cathodic protection works. It is made of copper wire and it is thermally conductive. PVC is commonly used as the insulation on electrical cables; PVC used for this purpose needs to be plasticized.
6. **Multimeter:** A multimeter or a multitester, also known as a VOM (volt-ohm meter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter would include features such as the ability to measure voltage, current and resistance. DT-9205A will be the model of the multimeter needed to calculate the current flow between the metal and anode.
7. **Bolt and nut:** Bolt and nut are tools used to hold two ends (be it joints, elbow etc.). For this project, bolts and nuts will be needed to fasten the PVC wire cable to the signboard (Test Post).
8. **CADweld mould:** CADweld mould as a tool is used (with the aid of gun powder) called CADweld powder for sealing the exposed region on the structure where the PVC wire cable was connected directly to the mild steel pipe
9. **CADweld disc and powder:** CADweld disc is a conically shaped metal disc which melts alongside CADweld powder in an effervescence manner. The disc acts as a timing device to allow the welding powder to heat to a proper temperature suitable to cause metal fusing. Technically, it is called exothermic welding.
10. **Copper-copper sulphate reference electrode:** It is used for measuring electrode potential and is the most commonly used reference electrode for testing cathodic protection corrosion control systems. The corresponding equation 2.1 is presented as follow.



This reaction is characterized by reversible and fast electrode kinetics, meaning that a sufficiently high current can be passed through the electrode with the 100% efficiency of the redox reaction.

The potential of a Cu/CuSO_4 electrode is + 0.314 volt for the standard hydrogen electrode.

2.2 METHODS

Cathodic protection of cassava grating machine with a galvanic anode method was achieved by:

1. Carrying out detailed soil analysis within the premises of the Engineering Unit, national Root Crops Research Institute, Umudike.
2. Having a detailed understanding of the quantity of anode needed for the small structure (Cassava Grater Metal) to be protected.
3. Preparing for ASTM and NACE standards, the bedding of the CP system.
4. Burying a carbon steel pipe connected to sacrificial anode cathodic protection with readings taken on intervals to ascertain proportionality. Relevant data will be collected at each interval.
5. Data collected from SACP will be analysed. Graphs will be plotted to show the threat of corrosion for anode-assisted cassava grater.

2.3 SOIL ANALYSIS

A detailed soil resistivity survey was carried out within the premises of the works and services department of the National Root Crops Research Institute, Umudike.

This was done to know the physio-chemical and microbial properties of the area under study

2.4 Laboratory Testing

1. **PH:** For a given resistivity, acid soils, (pH less than 7) are more conducive to steel corrosion. At a pH value below 4, the rate of corrosion accelerates rapidly. At pH values above, 10, the environment tends to inactivate the steel.
2. **Chloride ion:** Chloride ions destroy the passive film on steel and cause pit corrosion.
3. **Sulphide ion:** Sulphide ions present in the soil are indicative of anaerobic conditions. Under these conditions, sulphate-reducing bacteria can greatly accelerate the rate of corrosion.
4. **Moisture content:** The moisture content is a significant parameter in determining the degree of corrosiveness of the environment under consideration. When soil samples are collected, they are immediately protected from environmental interference and the escape of moisture content.

2.5 Equipment/tools used for the survey

The equipment used for the soil analysis of the cassava grating machine permanent site are Soil resistivity meter (DETS5/4R and DET5), Test

cables (0.025m flexible cable), Measuring tape, Hammer, Screwer, Cutlass, Pegs and lines.

2.6 Cassava Grater Surface Preparation

For economic reasons and due to the size of the pipe, it was not cleaned by sandblasting which is one of the best standards. The pipe was first cleaned with a wire brush and emery paper (Coarse and fine) to a silver mirror finish and then was washed with detergent with water and allowed to dry thoroughly. This is to ensure that the pipe surface is free from dirt, oil, chemical, rust or any other foreign body that will aid corrosion. At the end of the cleaning exercise, visual inspection was used to ensure that the surface is defective free.

2.7 Coating the External Metal of the Cassava Grating Machine

The coating material used is a polyethylene field coating material called polythene tape. The polyethylene tape is of two types; the thicker but soft black type and the stronger white. The white type is to protect against mechanical damage which may likely occur due to handling. Before priming, the metal body was exposed to sunlight to be heated at least 5°C above room temperature. A primer was used to prime the surface of the metals and thereafter polyethylene tape wrapping was used to wrap the surface of the metal diagonally, ensuring the appropriate overlap of 50% on each other. After the black tape was wrapped over the metal, the white tape was also applied in the same manner. At the end of the coating, a visual inspection was conducted on the coated metal to ensure a near-perfect bonding between the grater frames and the adhesive. No cracks, holes, gaps or voids were observed.

2.8 Cable attachment

Two points 0.10m apart on the coated cassava grater were scrapped, and cleaned with a wire brush and emery paper to make it free from sand, moisture and earth materials that may weaken the bond between the cable and cassava grater. Only a small area of the sacrificial anode coating was removed for the connection of the 10mm² PVC-PVC cable to the grater.

2.9 Purpose of SACP

The magnesium anode is used to apply for cathodic protection by using a direct electric current to drive a rather non-spontaneous metal. The magnesium anode with its high resistivity to corrosion is used to rather elongate the life span of easily corrodible metals. The sacrificial anode cathodic protection are used to protect the metallic frame of all kinds of equipment and/or oil pipelines.

2.1.0 The components of a packaged anode

A standard sacrificial anode consists of the following items which make up a fortified anode:

- i. Coke breeze which in some books is referred to as chemical backfill
- ii. Highly conductive electrode
- iii. PVC-PVC cable attached to the electrode

- iv. An “all in one” sack is used to package and carry the Anode as a whole.

2.1.1. Monitoring and evaluation of the SACP system

In this project work, the monitoring technique will be the pipe-to-soil potential. This is because the pipe length

involved is very small and other monitoring techniques like Pearson survey, signal attenuation, coating survey and close-interval-potential survey used for long lengths of pipelines cannot be applied. Table 2.1 shows the statistics of the pipe under study:

Table 2.1: Pipe type and dimension

Pipe Type	Mild Steel Pipe (API 5L-X65)
Pipe length	2m
Metal sheet diameter	0.16m
Metal sheet thickness	0.01m
Metal sheet coating material	Polyethylene tape

Procedure: The soil resistivity meter gives the value of the soil resistance R (Ω), directly. The grass around the survey area was cleared, and four (4) probe rods/spikes are pushed into the ground using a hammer. With aid of a peg, line and tape, the spikes were in a straight line and equidistant from each other with the spikes' depth equal to spacing “a” divided by twenty (20m) as recommended in the manual of the soil resistivity meters used.

Resistance R (Ω) at different depths are taken and their resistivity calculated using equation 2.2. (Michael *et al.*, 1994)

$$P = 2\pi aR \quad (2.2)$$

Where P = Soil resistivity (ohm-m)

a = distance between spikes/probes

R = Soil resistance (Ω) (instrument reading)

$\pi = 3.142 = \text{constant}$

If the soil is sandy, loose or muddy, the top layer should be scrapped to ensure that the probe spikes are driven into firm soil to guarantee close contact with the group. The test was conducted two times and an average value for each depth was taken to determine the depth that gives a minimum of $15\Omega\text{m}$ and a maximum value of $20\Omega\text{m}$ resistivity which is ideal for magnesium anode. The installation was made at a depth of 1.3m which gave the desired value.

2.1.2. Calculation of corrosion rates

The corrosion rate depends on the kinetics of both anodic (oxidation) and cathodic (reduction) reactions. There is a linear relationship between the metal

dissolution rate (m) and corrosion rate (CR), and the corrosion current. (Corrosion rate conversion) between the mpy and the equivalent in the metric unit in (millimetre per year) (mm/yr)

$$(1 \text{ mpy} = 0.0254 \text{ mm/yr} = 25.4 \text{ microm/yr})$$

To calculate the corrosion rate from metal loss equation 2.3 was used;

$$CR = 87.6 \times \left(\frac{W}{DAT} \right) \quad (2.3)$$

Where:

W = weight loss in kg

D = metal density in g/m^3

A = area of sample in m^2

T = time of exposure of the metal sample

in hours

CR = corrosion rate in mm/yr.

To derive the design calculation, these parameters must be known:

Data for design calculation;

Pipe material; Carbon Steel, API 5L –X65

Length of Metal, L

Metal diameter, D

Wall thickness, W_o

External radius, R

Over-protection potential “off” (E_o)

Protection potential “off” (E_p)

Natural pipe-to-soil potential, (E_n)

To know the degree of protection of the grating machine, it is important to calculate the cross-sectional area of the pipe is given in equation 2.4;

Cross-sectional area of the pipe,

$$A = \pi r^2 = (R - W_0)^2 (m^2) \quad (2.4)$$

Where R = external radius

W_0 = wall thickness

The total surface area of the bedding space is given in equation 2.5;

Total surface area,

$$S_A = \pi DL (m^2) \quad (2.5)$$

Where: D = pipe diameter

L = length of pipe

The total current required to protect the desired metal is given in equation 2.6;

The total current required to protect the pipe, I_T

$$I_T = (S_A \times I_D \times FS) \quad (2.6)$$

Where:

I_D = current density

FS = factor of safety

S_A = surface area

To know the mean current, the coating efficiency must be known and

The mean current is given in equation 2.7;

4. **Mean current for pipe protection, I_M**

Where:

CE = Coating efficiency

$$I_M = I_D \times S_A \times \frac{100 - CE}{100} \quad (2.7)$$

Statistically the anode required current should be small. This will refuse the anode

a quick reaction with its environment, the Anode required current is given in equation 2.8;

5. **Anode required current,**

$$I_A = S_A \times I_D \times FS \quad (2.8)$$

Where;

S_A = surface area of sheet metal

I_D = current density

FS = factor of safety

The anode weight is calculated mostly to be sure the anode has enough weighty protected insulators to help control the anode diminishing speed. The anode weight is given in equation 2.9;

6. **Calculation of the derived anode weight, W_{AD}**

$$W_{AD} = \frac{I_{AT} \times A_c \times D_L}{U_{AF}} \quad (2.9)$$

Where;

I_{AT} = Total anode current

A_c = Anode consumption rate

A_d = Design life of Anode

U_f = Utilization factor of anode

The anode is designed in a way that it corrodes easily to last up to a given period. The anode is designed as given in equation 2.10;

7. Design life of anode (in years),

The life span of Mg anode

$$= \frac{0.058 \times \text{Anode Wt} \times \text{Efficiency} \times \text{Utilization Factor}}{\text{Current (A)}} \quad (2.10)$$

Anode weight in pounds (lb)

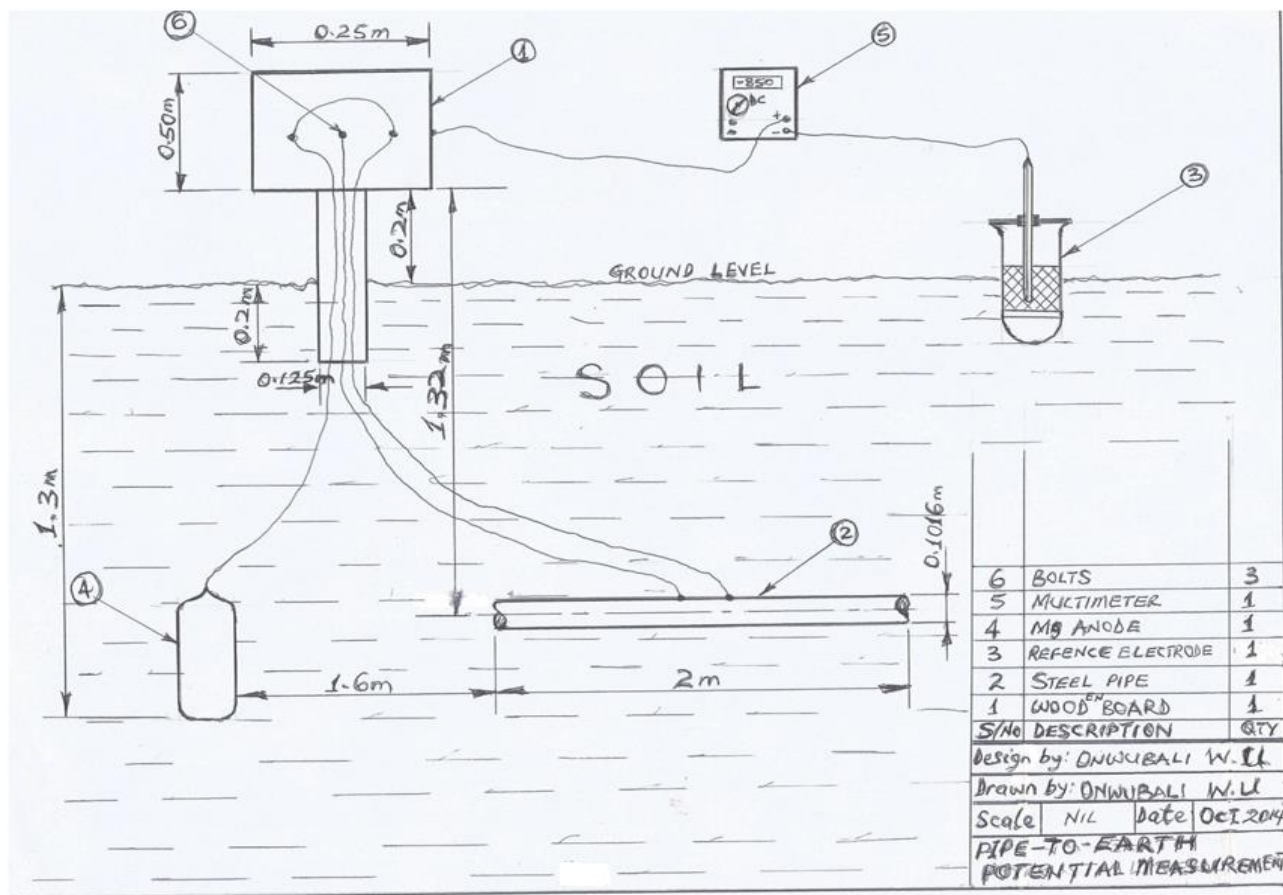
Weight kilogram (kg)

Weight in pound (1b)

Anode efficiency

Utilization factor

Mg Anode constant



3.0 RESULTS AND DISCUSSION

Table A in the appendix shows the chemical and physical properties of the soil at the Engineering Research Unit, NRCRI premises. The soil pH of the “NRCRI Works (A)” is below seven (7) showing that the soil is acidic and very corrosive to the structure under study. This in return means that conditions necessary for corrosion to occur are present in the soil. The PH of the soil at “NRCRI Works (B)” is likewise below seven (7) which indicates that the soil is highly acidic and very

corrosive to the pipe. The sulphide ion of the soil is very high which indicates anaerobic conditions. If chloride ions in the soil are high, it destroys the passive film deposits on the pipe surface which in return, exposes the pipe to corrosion attack. Under these conditions, the sulphate-reducing bacteria greatly accelerate the rate of corrosion of the pipe. The corrosivity of the soil is evidence of possible corrosion attacks on metals. For this work, the soil condition is mildly corrosive and the results obtained are suitable. (Refer to Appendix)

Table 3.1: Soil resistivity survey results carried out within the premises of NRCRI, Umudike

Spacing “a” (m)	Depth (a/20) (m)	Resistance R (Ω)	Resistivity, ρ ($2\pi \times R$)(Ωm)
1.00	0.050	2.110	13.2592
1.100	0.055	2.120	14.6543
1.200	0.060	2.150	16.4227
1.300	0.065	2.200	17.9722
1.400	0.070	2.250	19.7946
1.500	0.075	2.260	21.3028
1.600	0.080	2.290	23.0246
1.700	0.085	2.330	24.8909
1.800	0.090	2.350	26.5813
1.900	0.095	2.370	28.2969
2.000	0.100	2.390	30.4146

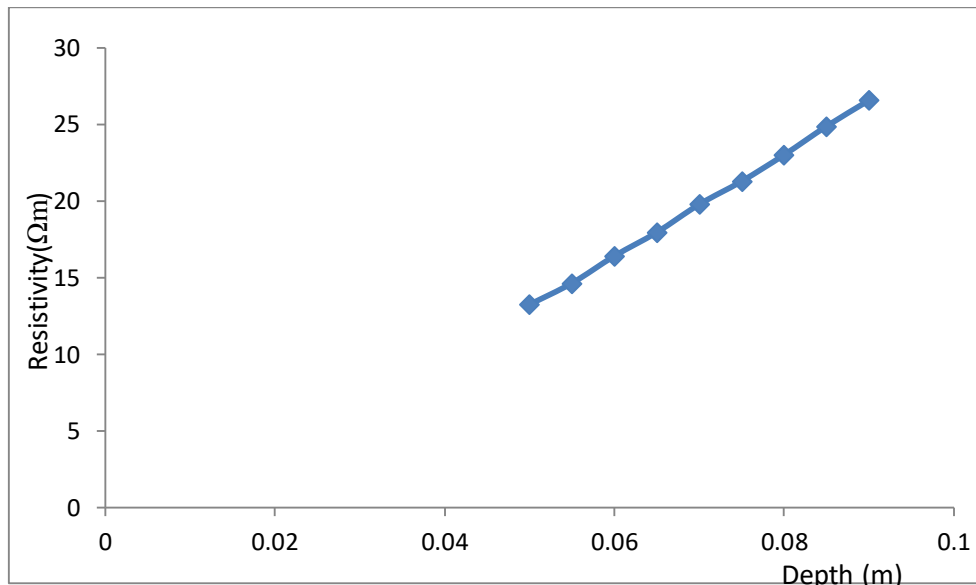


Figure 3.1: Variation of resistivity with depth

The soil resistivity graph above shows that the change in the value of the soil resistivity value was directly proportional to depth. This also applies to the resistance of the soil which shows upward sloping for distance. The resistivity values at 1m, 6m and 11m, were 13.2592, 21.3028 and 30.4146 respectively. From the soil

resistivity and corrosivity relationship table above (Peabody, 2001), it was stipulated that values within (20.00-100.00Ωm) are mildly corrosive. Comparing the results obtained with the stipulated value of (20.00-100.00Ωm), it is evident that the chosen area for CP system installation is conducive.

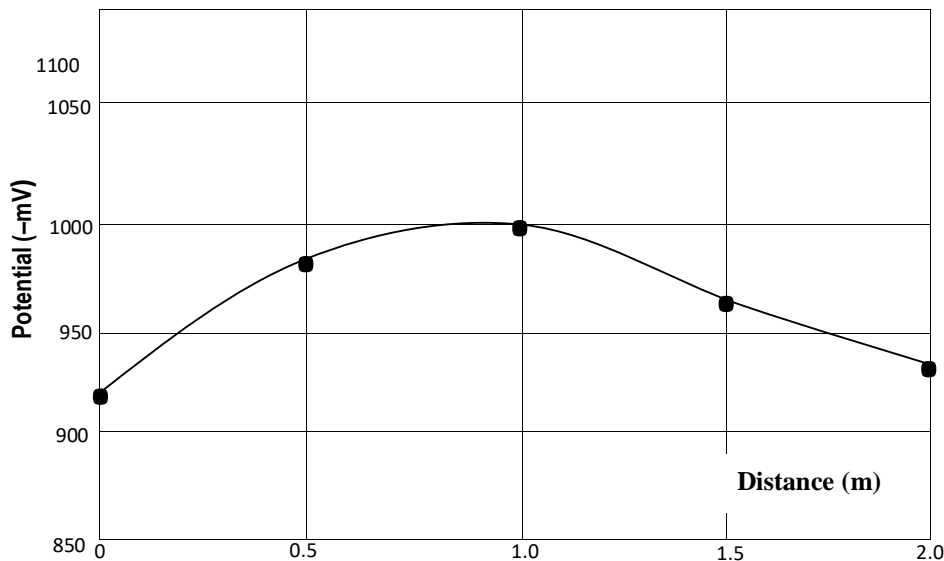


Figure 3.2 Plot of potential (-mV) against distance (m)

Figure 3.1 shows a significant rise in the values of the potential (-mV) readings due to proper watering and rainfall which have helped the uniform polarization of pipe-to-soil potential to occur. It has been observed that burying the anode very close to the pipe affects the performance of the CP system. From the installation of this system, the distance between the anodes was 1.0m

away from the pipe as against the conventional 0.5m. This trial did not only prove effective and acceptable but had further decreased the fears associated with over-codding. The highest value on this plot was achieved because

The following are the results obtained from the cathodic protection system installation using an anode-to-soil

potential survey for 20 weeks with readings taken every 2 weeks.

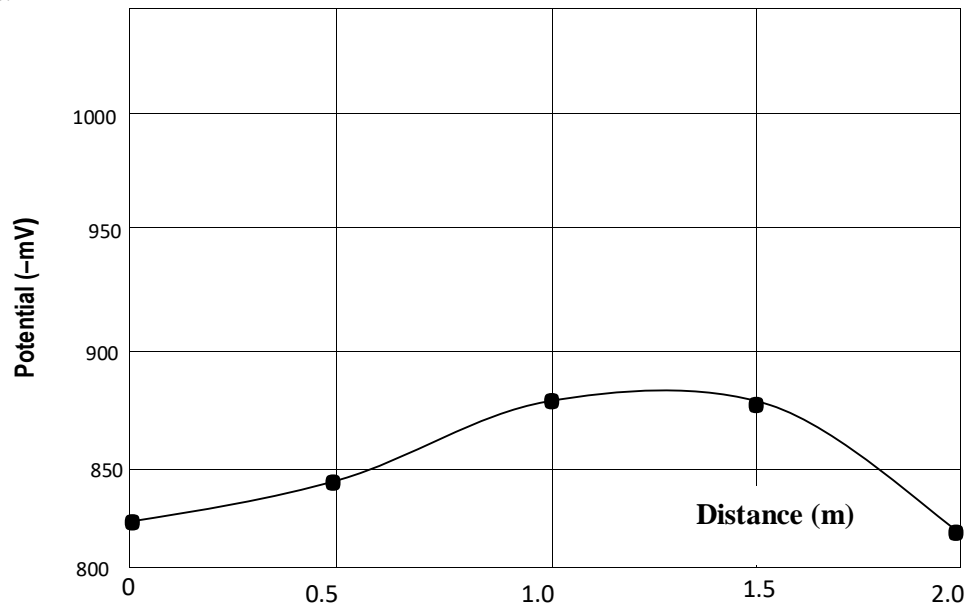
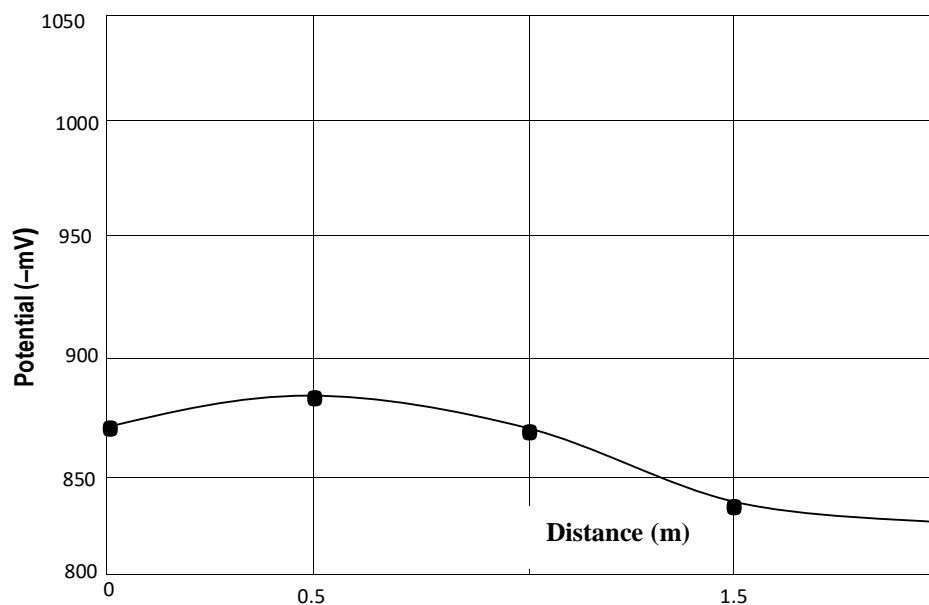


Fig. 3.3: Plot of potential (-mV) against distance (m)

Fig 3.3 shows the instability of protection potentials as a result of the non-homogenous flow of protective current, caused by dispersed polarization. It is, therefore, imperative to always allow the installed CP system a minimum of 2 weeks to attain full polarization before readings can be taken. The graph shows also a failing slope like that of the stress-strain curve. This is a result of the distance of the reference electrode to that of the buried anode.

Figure 3.4 shows fluctuation in the potential (-mV) values due to the non-availability of adequate moisture content in the soil. Microorganisms present in the interiors of the anode can induce localised changes in the aqueous environment which can alter the concentration of the electrolyte components) leading to localised corrosion known as microbiologically influenced corrosion.



1.0
Fig. 3.4: plot of potential (-mV) against distance (m)

2.0

The bio-film found on steel surfaces affects the kinetics of cathodic and/or anodic reactions. The sacrificial anode goes through this rapid corrosion circle to protect the desired metal. At this point 0, the protection was adequate. This is because the reference electrode was placed at the point where the Mg anode was buried. At that, uniform polarization was achieved.

3.1 Experimental Observations

1. It was observed that about 2 weeks after installation, the protection potentials stabilized. This happened when the system became well polarized and this showed that installed CP systems should be allowed for at least two weeks to polarize before taking the reading.
2. Burying the anode very close to the cassava grating machine affects the performance of the CP system. From the installation of the system, the distance between the anode and cassava grating machine was 1.0m instead of the conventional 0.5m
3. In the course of this experiment, it was observed that the soil must be moistened for uniform polarization of metal-to-soil potential to occur. Therefore adequate watering is required for polarization to occur.
4. We observed as well that the lead cable otherwise known as the PVC-PVC cable can lose current from any nakedness or damage along the cable chain. This was observed and corrected by replacing it from the point it got damaged.
5. Much has been said about hydrogen embrittlement, cathodic disbandment, over protection, cable failures, etc. In the cause of this project, we realised that many (during experimentation) pretended to have obeyed NACE specifications on material selection, coating and cathodic protection, the variance between 4m pipes and that of 2m and the quantity of anode that is expected to protect them. We realised also that other students buys cheaply made cables, which does not transmit current as dissipated by the anode. Since the price of the anode varies according to their kilograms, some student tends to go for anodes which are cheaper but will end up not protecting the pipe as required.

4.0 CONCLUSION

The result as obtained from the development of cathodic protection of mild steel metal using the galvanic anode method is as follows; Anode current of 0.0096mA; Pipe protection current of 0.0076mA; current density of

0.01mA/m²; maximum potential reading of -1080mV; soil pH of 5.77; soil resistivity value of 21.51Ωm. From the values above, it can be deduced that the results agree with the NACE standard requirement for pipe protection criteria of (-850mV and - 1150mV). Comparing the results obtained with the stipulated value of -850mV, it is evident that managing corrosion of mild steel metal for cassava grating machines using sacrificial anode cathodic protection is an effective means of corrosion control.

RECOMMENDATIONS

This study recommends that;

1. Corrosion can be economically and effectively mitigated by using a combination of coating and cathodic protection systems on pipes, tanks and pressure vessels to be buried or submerged.
2. Pipe-to-soil potential measurement using the -850mv criterion is adequate to evaluate the cathodic protection performance of any structure under such test or protection.
3. Submerged steel structures' corrosion can be curbed and hence environmental hazards are controlled by applying systematic corrosion prevention measures.
4. The instrument used for data collection or for taking readings should be cleaned after use. This is to ensure accuracy when taking subsequent readings. For example, the half-cell reference electrodes gather soils at the tip immediately after it touches the earth. It is then advisable that it should be kept neat especially if it is not to be used frequently.
5. Installing the anode very close to the pipe affects the performance of the CP system, the distance between the anode and pipe was supposed to be (0.5m). If this standard is not obeyed, potential readings will not conform to expected results.
6. The installed sacrificial anode cathodic protection system should be allowed a minimum of 2 weeks for the system to be fully polarized without which definite values will not be achieved.
7. In the cause of installation, the researcher should be careful to know if the cable(s) were still attached to the pipe and/or damage to the PVC-PVC cable. This is important when experimenting with small structures (as this implies in this project).
8. During the dry season, it is advisable to water the SACP zone for optimum values(s) to be achieved. To achieve set objectives, more attention needed to be paid to the purchase and

handling of the following materials: The polyethylene tape, Handicap, PVC-PVC Cables, Anode quantity and Site preparation.

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Appendix

Table A: Soil sample survey test carried out within the premises of NRCRI, Umudike, Abia State

Location	Physio-chemical Properties					Microbial Properties			
	PH	Cl ⁻ (mg)	SO ₄ (mg)	Moisture content (%)	Fe (mg)	H ₂ S (mg)	Zn (mg)	Sulphate red. Bact (SR/mg)	Hydrocarbon degrading bacteria
ERU NRCRI (A)									
Point A (0-0.15m)	5.73	43	36	8.11	317	1.09	94	5	0.0175
((0.15 – 0.30m)	6.13	106	76	11.21	416	3.96	49	7	0.0278
(0.30-0.45m)	5.27	101	40	9.23	324	2.09	103	3	0.0150
(0.45 – 0.60m)	5.96	109	76	12.02	497	2.28	69	2	0.0118
ERU NRCRI (B)									
Point A (0-0.15m)	4.19	103	57	12.38	603	0.89	58	5	0.0965
0.15 – 0.30m	5.22	113	69	15.24	608	0.68	63	12	0.00971
0.30 – 0.45m	4.36	115	90	13.71	613	0.27	38	9	0.0184
0.45 – 0.60m		134	93	14.90	677	0.42	43	8	0.0194

