



## STRATEGIC ASSET MANAGEMENT

Project No: P. 03743

### CATHODIC PROTECTION DESIGN REPORT:

ZB Sludge Bypass

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## **EXECUTIVE SUMMARY**

This report covers the procedure followed to design a Cathodic Protection System for the 750m, 800mm diameter sludge steel pipeline from central sludge no. 2 to the cross connection chamber.

The proposed sludge steel pipeline will run in parallel with the Rand Water B01, B06 and B17 pipelines for a short length.

The pipeline will be permanently protected by the installation of an ICCP System. SACP system will be installed as soon as the new pipeline is laid to protect the new pipeline from corroding during construction. Sacrificial Anode Cathodic Protection System shall be provided by 10kg Hi-potential magnesium anodes, surrounded by 70% gypsum, 25% bentonite and 5% sodium sulphate backfill in cloth bag.

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## 1 General

The proposed sludge steel pipeline will run in parallel with the Rand Water B01, B06 and B17 pipelines for a short length.

## 2 Field Survey

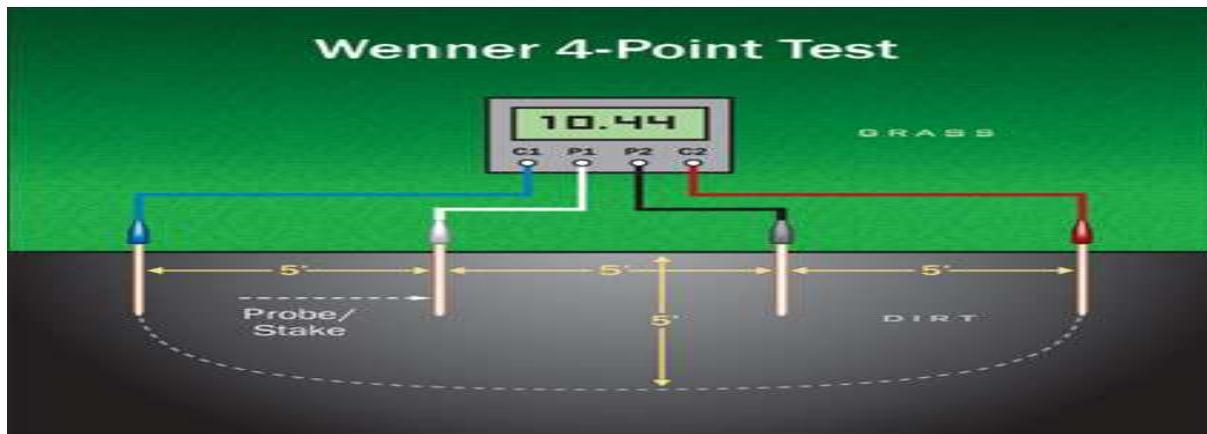


Figure 1: The Wenner 4-point test

$$\rho \text{ (ohm-m)} = 2\pi \times R \times a$$

Where:

$\rho$  - Soil resistivity in ohm-m ( $\Omega$ -m).

$R$  - Resistance in ohms ( $\Omega$ ).

$a$  - Distance between the pins in m.

Soil Parameter Resistivity ( $\Omega$ -m)	Degree of Corrosivity
0 – 20	Very Corrosive
20 – 50	Corrosive
50 – 100	Mildly Corrosive
100 – 200	Generally Non-Corrosive

Table 1

It is worth noting that the soil's resistivity is a function of its moisture content. Soil which has a high resistivity when it is dry can have substantially lower resistivity when it is wet or saturated depending on factors such as the pH and chemical content.

It should be stressed that the above classification for soil resistivity above 100 $\Omega$ m holds only if stray currents are not present, since the latter can cause corrosion in soils of any resistivity.

#### GB 1

GB Start: -26.678351,28.013696

GB End: -26.678698,28.012902

Distance (m)	2	4	6	8	10	12	14	16	18	20
Resistance ( $\Omega$ )	16.8	4.91	3.87	3.67	1.89	0.89	0.72	0.63	0.53	0.47
Resistivity ( $\Omega$ .m)	211	123	146	185	119	66.7	62.9	62.9	60.4	59.2
Average Resistivity ( $\Omega$ .m)										<b>109.61</b>

Table 2

#### GB 2

GB Start: 26°40'40.50" S 28°00'48.93" E

GB End: 26°40'39.13" S 28°00'45.83" E

Distance (m)	2	4	6	8	10	12	14	16	18	20
Resistance ( $\Omega$ )	10.5	3.95	2.54	1.59	1.11	0.86	0.67	0.55	0.46	0.40
Resistivity ( $\Omega$ .m)	132	99.4	95.6	79.7	69.7	64.6	58.6	55.3	51.6	50.7
Average Resistivity ( $\Omega$ .m)										<b>75.72</b>

Table 3



Figure 2: Proposed GB2

The TRU location is: 26°40'42.78" S 28°0'45.77" E

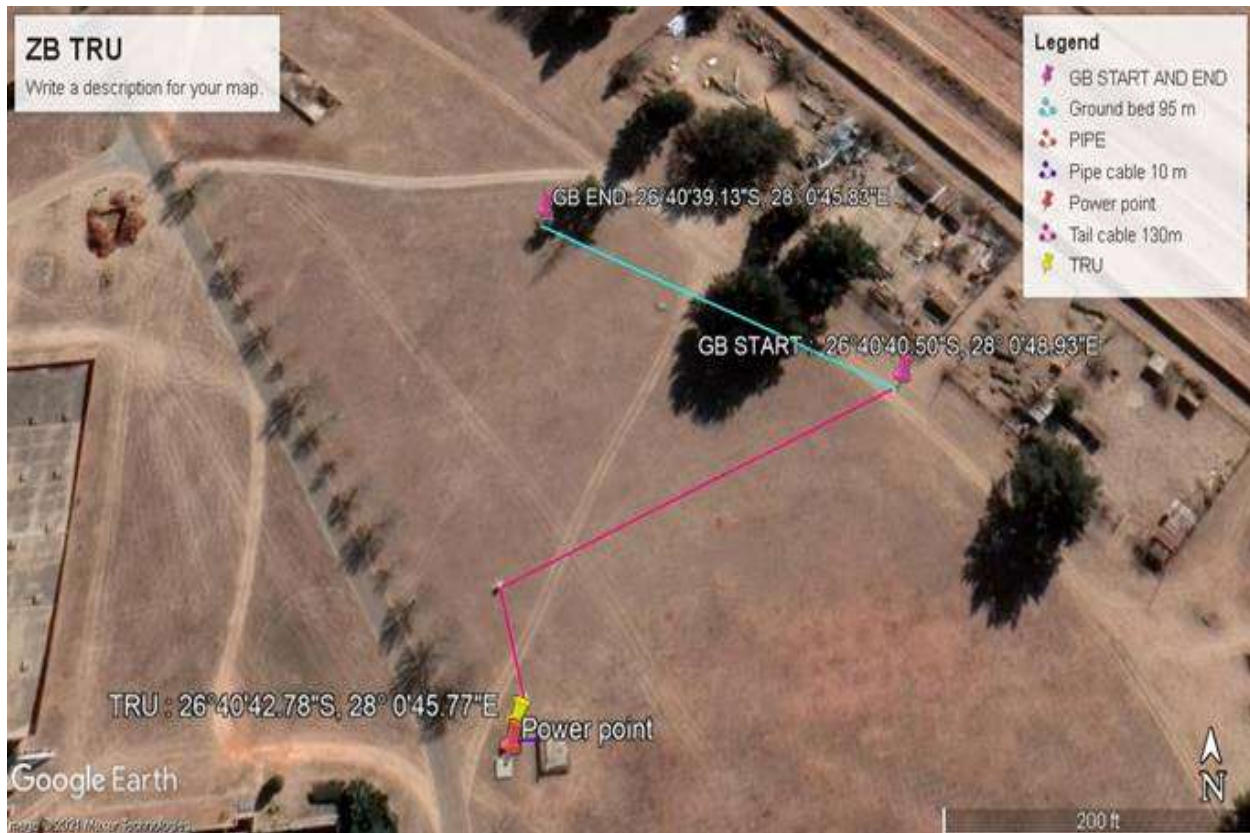


Figure 3: Proposed GB2

### 3 Design Objectives

The objectives for this design are as follows:

- Provide a system design adequate to protect the proposed pipeline against any form of external corrosion on the metal surface.
- Provide a pipeline free of safety hazard to personnel and general public in case where test leads and pipeline appurtenances are accessible.

## 4 Design Codes

According to SANS15589-1:2009, the Cathodic Protection system shall be capable of polarizing all parts of the buried pipeline to potentials more negative than -850mV referred to Copper Sulphate Electrode (CSE).

Document Title	Document No.
NACE international standard practice - Control of external corrosion on underground or submerged metallic piping systems	SP169 - 2007
Cathodic Protection measurement techniques	SANS 53509:2009
Protection against corrosion by stray current from direct current systems	SANS 50162:2010
Petroleum and Natural gas industries – Cathodic Protection of pipeline transportation systems	SANS 15589-1:2009

*Table 4*



## 5 Sacrificial Anode Cathodic Protection

Assumptions:

- Average soil resistivity: **10  $\Omega$ .m**
- Pipe Diameter: **800 mm**
- Pipe length: **750m**
- Average current density since it's a newly installed pipeline: **0.15 mA/m<sup>2</sup>**
- Fair average specific coating resistance: **1000  $\Omega$ .m<sup>2</sup> @ 10  $\Omega$ .m**
- The soil resistivity around the magnesium anode to be approximately **10  $\Omega$ .m** due to the backfilling composition of **70%** of gypsum, **25%** bentonite and **5%** of sodium sulphate
- Minimum design life **10 years**
- Anode diameter is **200mm** (supplier's dimensions)
- Anode length is **595mm** (supplier's dimensions)

### Method 1:

Calculating the surface area

$$A_s = \pi dL = \pi \times 0.8 \text{ m} \times 750 \text{ m} = 1\,884.95 \text{ m}^2$$

Calculating the current required

$$I_{cp} = i_{cp} \times A_s$$

$$= 0.15 \times 10^{-3} \text{ A/m}^2 \times 1\,884.95 \text{ m}^2$$

$$= 0.282 \text{ A}$$

Resistance of a single vertical anode

$$R_a = \frac{\rho}{2\pi L} \left( \ln \frac{8L}{d} - 1 \right)$$
$$= 5.8 \, \Omega$$

Current Output of a single anode

$$E_p = -1.7V$$

$$\text{Driving potential} = -1.7 - (-0.85V) = -0.85V$$

$$I_{\text{(anode)}} = V/R_a$$

$$= 0.1 \text{ A current output per anode}$$

Calculating the number of anodes

$$= \text{total current required} / \text{current output per anode}$$

$$= 0.282 \text{ A} / 0.1 \text{ A}$$

$$= 2.827 \approx 3 \text{ anodes}$$

## Method 2:

Calculating the amps per year:

$$C_{cp} = I_{cp} \times L = 0.282 \text{ A} \times 10 \text{ years} = 2.82 \text{ A-Y}$$

Calculating minimum weight:

$$W_{ta, \min} = \frac{C_{cp} \times C_{cr}}{U \times E}$$

Where:  $C_{cp} = 2.82 \text{ A-Y}$

$C_{cr} = 3.98 \text{ Kg/A-Y}$

$U$  (utilization factor) = 0.85

$E$  (electrochemical efficiency) = 0.5

$W_{ta, \min} = 26.40 \text{ Kg}$

Calculating the number of anodes:

Number of anodes =  $26.40 \text{ Kg} / 10 \text{ Kg}$

$= 2.64 \approx 3 \text{ anodes}$

Therefore, the average number of anodes:  $\frac{Meth1 + Meth2}{2} = \frac{3+3}{2} = 3 \text{ anodes}$

Therefore, due to un-foreseen circumstances and considering the cross connections on other Rand Water pipelines, a safety factor is included to increase the total number of anodes required to **8 anodes** and to be terminated inside the chamber, of which **4 anodes** shall be installed per chamber.

## Cross bonds

No	Pipe lines	GPS Co-ordinates	Cross Bonds
1.	B17, Old ZB Sludge and the three other 800mm lines crossing the ZB Sludge line @ chainage 100. (RW Lines)	26°40'43.00"S 28°00'21.54"E	X5
2.	Those bunkers from the engine room	Between chainages 200 and chainage 650.	X9

Table 5

## 6 Impressed Current Cathodic Protection

### Design Assumption

- **Potential shift** – A voltage drop of 0.3V between the pipeline and remote earth is required to polarise a coated steel pipeline to an average polarisation potential of 1.15V is required. Potentials more negative than -1.15 V vs Cu/CuSO<sub>4</sub> does not result in any significant increase in protected range (Baeckman & Schwenk pg 266).

$$\diamond -0.85V - (-1.15) = 0.3V$$

- **Pipeline resistance** - Even with a high quality protective coating, the large number of fittings such as valves, blow off and mechanical coupling will produce significant pipe to soil leakage conductance. In 100Ωm average soil resistivity, the effective specific coating conductance would not be expected to be lower than approximately  $g = 1 \times 10^{-3} \text{ S/m}^2$  or  $r' = 1 \times 10^3 \text{ } \Omega\text{m}^2 @ 10\Omega\text{m}$

- **Current required** - Assuming a fair quality coating (Fair quality coating takes into consideration long term coating deterioration and the pipeline is not cathodically protected) with an average specific coating resistance of  **$2 \times 10^2 \Omega \text{m}^2$  @  $10 \Omega \cdot \text{m}$**  will be used for calculations.

**GB 2, is the selected area for a horizontal ground bed installation. Because it has a lower soil resistivity.**

GB Start: 26°40'40.50" S 28°00'48.93" E

GB End: 26°40'39.13" S 28°00'45.83" E

Distance (m)	2	4	6	8	10	12	14	16	18	20
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Resistivity ( $\Omega \cdot \text{m}$ )	132	99.4	95.6	79.7	69.7	64.6	58.6	55.3	51.6	50.7
Average Resistivity ( $\Omega \cdot \text{m}$ )										<b>75.72</b>

*Table 3*

Calculating the Ground Bed resistance:

The anode bed resistance is calculated by means of Dwight's formula for a horizontal electrode and using the average resistivity value at 4m depth as follows:

$$R_h = \frac{\rho}{2\pi L} \ln \frac{L^2}{td}$$

Where;

$R_h$ = Resistance, in ohms, of horizontal anode to earth

$\rho$ = Resistivity, in ohm-cm, of backfill material (or earth)

$L$ = Length of anode in metres

$t$ = Depth below grade

$d$ = Diameter of anode in metres

As the pipe coating deteriorates more current will be required to protect the pipe.

Therefore, the Current required will be **20 A**.

$$R_t = R_{\text{cathode}} + R_{\text{GB}} + R_{\text{wire}} \quad (\text{but the value of } R_{\text{wire}} \text{ is negligible})$$

$$R_{\text{GB}} = R_t - R_{\text{cathode}}$$

Rand Water's Transformer Rectifier Unit is rated at 100V/100A

$$\begin{aligned} R_{t(\min)} &= V/I - R_{\text{cathode}} \\ &= (100V - 2V)/100A \\ &= 0.98 \, \Omega \\ &\approx 1 \, \Omega \end{aligned}$$

$$\begin{aligned}
 R_{t(max)} &= V/I - R_{cathode} \\
 &= \frac{(100V-2V)}{20} A \\
 &= 4.9 \, \Omega
 \end{aligned}$$

$$\begin{aligned}
 R_{t(aver)} &= (0.98 + 4.9)/2 \\
 &= 2.95 \, \Omega \\
 &\approx 3 \, \Omega
 \end{aligned}$$

Therefore:  $1\Omega < R_t < 3 \, \Omega$

$$\begin{aligned}
 \text{Pipe Resistance} &= \text{Specific Coating Resistance @ } 2 \times 10^2 \, \Omega m^2 \text{ @ } 10 \Omega m \\
 &= 0.021 \Omega
 \end{aligned}$$

However,  $R_t = R_p + R_{gb}$

$$\begin{aligned}
 \text{Therefore, Ground-Bed Resistance (R}_{gb}\text{)} &= R_t - R_p \\
 &= 3 \, \Omega - 0.021 \, \Omega \\
 &= 2.97 \, \Omega \\
 &\approx 3 \, \Omega
 \end{aligned}$$

$L$	100 m
$d=$	0.3 m
$R_H$	<b>3 ohms</b>

Table 7: Groundbed Resistance Calculation value for a horizontal configuration

The Anodes to be used for the permanent ICCP System conform to Rand Water's RW ELS 00001 TS with a design life of 20 years. Due to the fact of un-foreseen circumstances, the ground bed over rated or increased to cater for the 100V/100A TRU and so that it can withstand the effects of stray current in the vicinity.

## **ICCP installation:**

The ICCP installation shall essentially entail the supply and installation of the following:

- Install a three phase 100V/100A, automatically controlled TRU next to AC Distribution Board. An AC isolation box for the incoming supply shall be installed next to the TRU enclosure.
- A maximum 10 ohm (low impedance) TRU earthing system shall be installed around the TRU.
- TRU shall be connected to a single 3m deep, 0.5m diameter, and 91m long horizontal Groundbed.
- The anode groundbed shall consist of 30 by 2m canisters containing MMO anodes and coke breeze and 31 by 1m spacer canisters filled with coke breeze. The bottom 300mm of the groundbed shall be filled with coke breeze, such that the actual groundbed dimension will be 0.3m x 0.5m x 91m. The anode canisters will be buried in the coke breeze.
- The anodes shall be connected individually to a ring main cable consisting of a single-core 35mm<sup>2</sup> PVC/PVC cable, such that there is redundancy built into the system. Each connection to the ring main shall be individually made, using suitable line taps and a Y-type epoxy splicing kit. Sufficient time shall be allowed to allow the epoxy to cure, before backfilling of the Groundbed commences.

## **7 Conclusion and Recommendations**

The Cathodic Protection System for the ZB Sludge shall be as follows:

- SACP system shall be installed as protection on the pipeline and a total of 8 high potentials magnesium anodes shall be installed along the pipeline. 4 anodes shall be installed per chamber along the pipeline.
- All Rand Water pipelines in the area are to be cross bonded with the new ZB Sludge Pipeline, the quantity and location is stated on the BOQ.



- A total of 2 chamber monitoring points shall be installed along the pipeline route for testing and maintenance purposes.
- This same chambers will also be used to terminate the sacrificial anodes and the IR Free reference electrodes will be used to measure IR Free potentials.
- One Cross Bonding Bunker with a link panel for the B17 and the old ZB sludge.
- Two IF kits shall be installed at the start and end point of the pipe.
- The meter X1 (400mm Magflow meter) @ chainage 260, and
- Two IF Kits shall be installed on both sides of the Magflow Meter
- 14 Insulating Flange (IF) kits shall be installed on both sides of the actuator valve.