



**TRANSNET PL 685 - SPECIALIST ENGINEERING SERVICES
FOR THE OPTIMISATION OF THE MPP CATHODIC
PROTECTION SYSTEM**

**CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON
THE MPP PIPELINE.**

Report No. – P0084/REP001

June 2021

Prepared By:
Cathtect Cathodic Protection (Pty) Ltd
27 Yaron Avenue,
Lea Glen,
Roodepoort,
1709,
South Africa.

Contact: Garreth Raath
c: +27 11 674 1502
e: garreth@cathtect.com

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

DOCUMENT TITLE : CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

PROJECT REFERENCE : TRANSNET PL 685 - SPECIALIST ENGINEERING SERVICES FOR THE OPTIMISATION OF THE MPP CATHODIC PROTECTION SYSTEM

DIRECT CLIENT : TRANSNET PIPELINES



CLIENT REPRESENTATIVE : MR TEBOGO MAHASHA

CATHTECT PROJECT No. : P0084

DOCUMENT No. : P0084/REP001

FIELD WORK : N/A

DISTRIBUTION LIST : TEBOGO MAHASHA, GARRETH RAATH, DAVID RAATH, ROSS MAHAFFEY, PRAVIN NADRAJAH, LUCAS MOLEMI, SHELDON MOONUSAMY, KOBUS STEYN

Revision	Date	Revision Description	For Issue	
0	28 June 2021		Author	Reviewer
		Name	Ross Mahaffey	Garreth Raath
		Signature		
Revision	Date	Revision Description		
			Author	Reviewer
		Name		
		Signature		
Revision	Date	Revision Description		
			Author	Reviewer
		Name		
		Signature		

CLIENT SIGN OFF

Designation	CP Manager			
Name	Lucas Molemi			
Signature				

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

TABLE OF CONTENTS

1	INTRODUCTION.....	4
2	REVIEW OF EXISTING TPL CP ASSESSMENT CRITERIA	5
3	REVIEW OF NERSA REPORT NO. PR0680	6
4	DEVELOPMENT OF NEW TPL MPP CP ASSESSMENT CRITERIA	8
4.1	IR FREE/POLARIZED POTENTIAL – THE KEY PARAMETER FOR CORRECT CP EFFICACY ASSESSMENT	8
4.2	APPLICATION OF CP COUPONS.....	9
4.3	AC POTENTIALS AND RISK OF AC CORROSION.....	9
4.4	USE OF ER PROBES.....	10
4.5	TPL MPP CP ASSESSMENT CRITERIA.....	10
4.5.1	<i>TPL MPP CP Assessment Criteria 1 – IR Free Corrosion Potential less than -0.85 V_{CSE}</i>	<i>10</i>
4.5.2	<i>TPL MPP CP Assessment Criteria 2 – DC Current Density Magnitude and Direction.....</i>	<i>11</i>
4.5.3	<i>TPL MPP CP Assessment Criteria 3 – AC Current Density</i>	<i>11</i>
4.5.4	<i>TPL MPP CP Assessment Criteria 4 – AC DC Corrosion Risk Relationships.....</i>	<i>11</i>
4.5.5	<i>TPL MPP CP Assessment Criteria 5 – Corrosion Rate Less Than 0.1mm per Year (Preliminary).....</i>	<i>12</i>
4.6	MONITORING AND REPORTING	12
5	CONCLUSION.....	13

Annexures

None

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

1 Introduction

The following scope of work items are covered under this Memorandum and are referenced according to their appropriate BoQ item number:

- Item 96 – Review existing TPL CP assessment criteria (inadequate for MPP)
- Item 97 – Develop new criteria to align TPL monitoring system with international best practice and latest applicable SANS standards.
- Item 102 – Implement the recommendations and contents particularly the measurements and assessment methodology of NERSA REPORT No. PR0680 entitled INTEGRITY REVIEW OF THE SOUTH AFRICAN GAS INFRASTRUCTURE – TRANSNET PIPELINES

No further detail of the scope of these items is provided in the Transnet PL 685 Scope of Works Document and this deliverable was developed on available information provided by TPL.

The following concerns related to MPP CP Assessment Criteria were identified in the Reignite Report (TGC2017041601 rev 04 – 9 July 2018):

- Coupon direct current density measurements strongly support the need to reduce the amount of current being supplied to the NMPP pipeline in a number of locations. (Pg. 8, Item 2.5)
- Due to the excessive stray current interference on the NMPP we are of the opinion that the only sound technical method of determining whether or not the NMPP is adequately protected is by assessing the coupon current density and the instant off potential of the coupon, as the ON potentials are misleading at these locations when applying the “more negative than -0.85V_{cse} criteria”. (Pg. 8, Item 2.6)
- Existing blue data loggers in service with TPL are inadequate in terms of measuring: DC Current Density, AC Current Density, DC potentials more electronegative than -20V. (Pg. 9 and Pg. 10, Item 2.17)
- In some instances, TPL assessments of protected ON pipe-to-soil potentials are in fact erroneous. SANS 53509:2009 (Pg. 10 Item 3.1)
- Corrosion at coating defects where current discharges to foreign pipelines (or other steel structures) with more electronegative potentials than the NMPP. SANS 50162:2010. (Pg. 10 and Pg. 11, Item 3.2)
- Disregard for detailed IR Drop and coupon current density assessment which provide an indication pick up or discharge. SANS 53509:2009. (Pg.11 Item 3.3)
- During 2012 TPL received NERSA REPORT No.: PR0680 entitled INTEGRITY REVIEW OF THE SOUTH AFRICAN GAS INFRASTRUCTURE – TRANSNET PIPELINES (Lily Gas Pipeline) that was authored by PPT. This report essentially sets out the remedial action TPL should take to align their Cathodic Protection monitoring systems with international best practice. (Pg.11 Item 6)
- TPL should adopt national and international standards (Pg.16 Item 6.5)
- AC and DC current density data should be used in conjunction with AC and DC pipe-to-soil potentials to assess the likelihood of AC and DC induced corrosion in terms of SANS 50162:2010, SANS 53509:2009, ISO 18086:2015 and NACE SP0169:2013. (Pg. 17 Item 8).

A detailed technical paper on the International Benchmarking of National and International Cathodic Protection (CP) and Alternating Current Mitigation (ACM) Standards was submitted to Transnet under Annexure 5.1 of the July 2018 Reignite Report). This paper presents and compares commonly referenced CP and ACM monitoring specifications

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

and their associated protection/assessment criteria. The conclusions of this paper are presented in the latter parts of this memorandum, but it is noted that a large number of concerns identified in the July 2018 Reignite report relate to the conclusions presented in this technical paper.

The purpose and scope of this Memorandum is therefore to address the shortcomings identified in the Reignite Report and in the NERSA Report and includes the following objectives:

1. Review the Existing TPL CP assessment criteria.
2. Review the recommendations presented in the NERSA Report (No. PR0680).
3. Develop new TPL CP assessment criteria, which are based on national and international standards and their recommendations.

2 Review of Existing TPL CP Assessment Criteria

The TPL internal policy document relating to their assessment and monitoring of the CP system was requested as part of this task. The following document was provided by TPL:

1. TPL-TECH-CP-POL-001 – Policy – 03.pdf – Cathodic Protection Policy

This document presents the requirements for *Monitoring of CP System (Pg. 8 to Pg. 9 Item 7 & Item 8)*:

- *Cathodic protection Transformer Rectifier Unit equipment for forced drainage, impressed current and natural drainage systems, failure of which would seriously jeopardize the protection of the structure, should be checked weekly. At sites where a remote monitoring device has been installed, and no fault is reported, such sites should be checked as determined by the CP Field Technician. All Cathodic protection rectifiers and test points must be registered on the local Transnet Pipelines SAP maintenance system. A job card must be developed and scheduled with the equipment maintenance frequency. The SAP system will generate, at the pre-determined frequency, the job card, prompting the maintenance of the equipment.*
- *The efficiency of the Cathodic Protection schemes should be monitored at regular intervals. The overall protection will be monitored by measuring the pipeline to Copper/Copper sulphate ½ cell potential over a 24-hour period. A spot reading between the pipe and ½ cell on the AC volt scale must be taken and recorded at each test point before the recording instrument is connected.*
- *Transnet Pipelines will conduct a bi-annual potential survey at all test points. The survey will consist of:*
 - *Summer survey - 01 November to 30 June. A report is to be submitted to the Electrical Manager by 01 September,*
 - *Winter survey – 01 July to 30 October. Test points that need to be surveyed, must include but are not limited to, marshy areas, river, road and rail crossings, all sleeves, block valves, insulating flanges / joints, cross bonds with foreign services and all points surveyed during the summer survey and identified by the Cathodic Protection Field Technician. A report is to be submitted to the Electrical Manager by 05 January.*
 - *All lightning arrestors fitted to test points must be checked before the recording instrument is connected. Defective lightning arrestors must be replaced as this can have an adverse effect on the survey results.*

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

- *The cathodic protection system shall be capable of polarizing all parts of the pipeline to potentials more negative than 000Mv¹ or more negative = 100% of the time, -500Mv or more negative = 99% of the time and -850Mv or more negative = 95% of the time per Copper/copper sulphate reference cell and to maintain such potentials throughout the design life of the pipeline.*

These monitoring requirements are regarded as overly simplistic, especially considering the complexity of the MPP pipeline and its interaction with various other pipelines, traction systems and overhead high voltage (AC and DC) powerlines. These requirements are also not aligned with National and International standards and associated best practices and principles. **The use of “On Potentials” for monitoring the CP system is not aligned with the National and International Standards and is required to be addressed.** The following additional items are also presented to be considered for inclusion in the TPL monitoring requirements:

- A number of cross bonds are regarded as critical and should be included in the maintenance and monitoring schedules. Critical cross bonds should be included in the remote monitoring systems.
- The inclusion of maximum negative (high negative) pipe-to-soil potentials should be considered for inclusion into the criteria.

This review of the existing TPL CP assessment warrants the definition of new TPL CP assessment criteria which shall be aligned with international best practice and latest applicable SANS standards.

3 Review of NERSA Report No. PR0680

The National Energy Regulator of South Africa (NERSA) appointed Pipeline Performance Technologies (PPT) to conduct a desktop study on the integrity of the South African gas transmission pipeline network in July 2011. PPT concluded their study and submitted a report to NERSA in April 2012. The report titled, *Integrity Review of the South African Infrastructure – Transnet Pipelines (Rev 2, 19 April 2012)* was submitted to Transnet for comment. This report specifically focuses on Transnet’s Lilly pipeline.

Reignite’s 2018 report advises that the NERSA report essentially sets out the remedial action TPL should take to align their Cathodic Protection monitoring systems with international best practices and in particular the CP measurement and assessment methodologies as presented in the report.

The NERSA report presented TPL’s monitoring regime for the Lily Pipeline. It is noted that TPL monitors the Lily Pipeline according to the monitoring requirements described in § Error! Reference source not found. Error! Reference source not found.. This process as summarised in the NERSA report is presented below:

- *Summer Survey: typically, from November to July of the following year i.e., November 2010 to July 2011*
- *Winter Survey: typically, from August to October i.e., August 2010 to October 2010.*
- *Annual Survey: this is typically executed during the Summer Survey period and the aim is to gather pipe-to-soil potential (PS) recordings at every monitoring test point along the Lilly Pipeline.*

¹ It is assumed that this value is a reference to milli volts, which is commonly denoted as mV and not Mv as per the TPL policy. It is recommended that this is corrected to avoid any potential confusion.

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

- *Transformer Rectifier Unit (TRU), Forced Drainage Unit (FDU) and Natural Drainage Unit (NDU) Survey: this is conducted on a weekly basis and the aim is to gather kWhr, PS values, anode potentials, Alternating Current ripple, output voltage and output current.*

TPL gather the information from respective surveys and use proprietary software to download their data loggers to assess the PS recordings. TRU and NDU data is captured manually into MS Excel spreadsheets to form a comprehensive database that forms the basis of historical assessment.

TPL use the approach of determining the percentage time that PS recording data is more electronegative than certain values with respect to a saturated copper/copper sulphate reference electrode. The percentage time approach is determined against the following values: $0.0V_{DC}$, $-0.5V_{DC}$, $-0.85V_{DC}$, $-1.0V_{DC}$, $-2.00V_{DC}$, $-3.0V_{DC}$, $-4.0V_{DC}$ and $-5.0V_{DC}$.

TPL have set the benchmark for their assessments at 100% time more electronegative than $-0.85V_{DC}$ with respect to a saturated copper-copper sulphate reference electrode. Monitoring test posts along the Lilly Pipeline that deviate from this benchmark, in terms of PS recordings, are scheduled for resurvey within a week or two and in some instances during the next Winter Survey.

It is however noted that the benchmark of achieving potentials that are more electronegative than $-0.85V_{DC}$ 100 % of the time deviates from the Current TPL CP criteria of achieving potentials that are more electronegative than $-0.85V_{DC}$ 95 % of the time. It is unclear if this is a result of revision changes to the TPL Cathodic Protection Policies or if it is a standalone requirement for the Lilly Pipeline.

The NERSA report then proceeded to compare the TPL monitoring policy with prominent National and International standards (in a similar manner to the Annexure 5.1 Technical Paper presented in Reignites report), which are considered as international best practice. The following standards and practices were benchmarked by PPT:

- SANS15589-1 Petroleum and Natural Gas Industries - Cathodic Protection of Pipeline Transportation Systems. Part 1 On-land Pipelines
- NACE SP0169-2007 Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- SANS50162 Protection Against Corrosion by Stray Current.
- SANS53509 Cathodic Protection Measurement Techniques
- TM0497 Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems
- NACE RP0104-2004 The Use of Coupons for Cathodic Protection Monitoring Applications
- NACE International Task Group 210 - Coupon Technology - Technical Report on the Application and Interpretation of Data from External Coupons Used in the Evaluation of Cathodically Protected Metallic Structures
- NACE International Task Group 211 - on Cathodic Protection: Report on the Application of the 100 mV Polarization Criterion. One Hundred Millivolt (mV) Cathodic Polarization Criterion

The Authors of the NERSA report concluded with the following statement: *“Based on the Standards and reports evaluated earlier it is evident that the measurement of purely “on potentials” is out of step with current trends internationally.”* The following recommendations were also extracted from the NERSA report:

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

- *Adoption of a thoroughly planned and executed CP Coupon installation along the length of the Lilly Pipeline. This will be based on numerous variables covered under NACE RP0104-2004.*
- *Adoption of 4 wire current span stations at key locations to permit the measurement of in line current flow and assessment of coating condition. This is a topic of discussion on its own and not covered in detail in this report.*
- *More detailed assessment of IR Drop error included in current "on potential" measurements and the likely impact on historical data validity. This is covered in detail in the specification previously reviewed in this report.*

4 Development of New TPL MPP CP Assessment Criteria

4.1 IR Free/Polarized Potential – The Key Parameter for Correct CP Efficacy Assessment

Criteria for cathodic protection are generally based on the value of the structure to electrolyte potential. Accurate measurement of the potential is therefore necessary in order to assess the effectiveness of the cathodic protection. Generally, structure to electrolyte potentials are measured using a reference electrode placed on the soil surface. The presence of currents in the soil (either intended CP currents or unintended stray currents) between a coating defect or holiday and the reference electrode place on grade will cause errors in the potential measurement. This phenomenon is referred to as IR Drop and may be in the order of a few millivolts to tens of volts and may be positive or negative in magnitude. The magnitude of IR Drop is a function of position of the reference electrode in relation to the pipeline, soil resistivity, burial depth of the pipeline, coating condition and the magnitude of CP current and stray current.

The TPL Cathodic Protection Policy currently calls for the measurement and use of “On Potentials”, which will therefore include IR Drop, which results from the MPP ICCP system, as well as other potential IR Drop resulting from stray currents originating from various/numerous sources. The TPL CP policy does not include any other assessment criteria which may assist in dealing with the IR Drop in the pipe to soil potential measurements.

It is well known and documented in current CP literature, training, and standards that to assess the efficacy of CP, the structure to electrolyte potentials (in this case pipe to soil potentials) should be measured and recorded as IR Free or Polarized Potentials. This requirement is presented in various National and International CP standards, including, but not limited to: ISO 15589-1 (2015), SANS ISO 15589-1 (2009), NACE SP0169 (2007), CSA Z662 (2020) and AS 2832.1 (2015).

It is therefore recommended that IR Free/Polarized Potentials are utilised to assess the efficacy of the CP system and to confirm that the buried pipeline infrastructure is cathodically protected.

SANS (ISO) 53509 (2009) states that: “On Potential measurements are mostly used for monitoring cathodic protection, particularly where stray currents from DC traction systems occur. In this case, in order to obtain meaningful values, on potentials should be recorded over a period of time consistent with the interference level and variation over time” it is therefore noted that these measurements are required in TPL CP monitoring regime to assess interference but should not be used purely to assess CP Efficacy.

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

4.2 Application of CP Coupons

CP coupons are a practical method to determine the level of polarization (level of cathodic protection) of a buried structure and to confirm the IR (voltage) drop in a potential measurement. A CP coupon is used to simulate coating defects (holidays) on the structure being evaluated being evaluated.

The CP coupon is installed near the structure and is connected to the pipeline via a panel located within a test post or bunker. This allows for the coupon to be protected by the CP system as it is connected to the pipeline. The CP coupon can then be temporarily disconnected from the circuit during field inspection and an instant-disconnect potential (also referred to as an instant-off potential) can be measured and recorded². A key advantage of using CP coupons is the ability to record interference-reduced pipe potentials on pipelines affected by stray currents. The primary difficulty of measuring IR free potentials on pipeline which are impacted by stray currents is the inability to simultaneously interrupt all off the current sources.

NACE SP 0169 allows for the use of CP coupons to evaluate the IR drop in a potential measurement, which is required to provide a representative polarized potential.

Furthermore, the coupon's area of exposed steel is generally known and that permits the calculation of the current density (both AC and DC) on the coupon and thereby provides additional useful information regarding the protection level. This can also be used to determine the direction of current flow.

Reproducibility of instant-off and/or instant-disconnect potentials is poor and subjective and varies between field personnel. Automated recorders can be set to record the time between interruption and the recording of the instant-off potential and thereby significantly improve accuracy and repeatability. For this project, a fixed period of 300 milliseconds will be utilised to improve accuracy and repeatability of measurements.

4.3 AC Potentials and Risk of AC Corrosion

The risk of AC corrosion has become prevalent over the past few years, and it is now a well-known fact and is becoming widely accepted that pipelines may be at risk of AC corrosion, even when they have sufficient levels of cathodic protection (i.e., DC potentials less than $-0.85V_{CSE}$). In some cases, an increase in the cathodic polarization can even increase the potential of AC corrosion. There are currently two distinctive approaches to the predication and associated assessment criteria for AC corrosion:

1. Approach presented in NACE SP0169 (2013) where AC current densities are reviewed in isolation and are limited to 30 A/m^2 (limit at which AC corrosion can occur) and 100 A/m^2 (limit at which AC corrosion is expected, even under conditions where CP criteria are met).
2. Approach presented in ISO 18086 (2019) where criteria are presented for both AC potential and AC current densities and are based on the magnitude of DC potentials and DC current densities. Allowance is made for scenarios where the DC potentials are "low" and scenarios where DC potentials are "high" (excessively negative) because of stray current interference.

² The CP coupon polarized potential is not identical to the traditional on grade pipe-to-soil polarized/instant off potential. The traditional measurement is affected by many factors and is represented by a potential field produced by a mixture of holidays, whereas the CP coupon potential is a point source, representative of CP effectiveness in a particular environment.

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

The traditional approach of assessing soil resistivity and AC voltage as general indicators for AC corrosion risk is not recommended and will not be utilised in isolation but could be used to support some findings.

4.4 Use of ER Probes

An Electric Resistance (ER) probe measures the metal loss of an alloy having a similar composition to the pipe and provides an estimated corrosion rate of the pipeline by measuring the change in electrical resistance of the metallic probe. ER probes can therefore provide instantaneous corrosion rate readings.

The primary advantage of this technique is that the average corrosion rate can be followed continuously and used to optimize cathodic protection levels. The primary disadvantage is that the localized corrosion rate is detected with less accuracy until the probe is perforated.

The widespread use of ER probes has not yet been accepted in South Africa and any application of ER probes should first be trialled to ensure that the capital investment can be justified by obtaining accurate and meaningful results.

4.5 TPL MPP CP Assessment Criteria

The recommended approach for the formulation of the TPL MPP CP Assessment Criteria, is to base the CP assessment criteria on locally available SANS (ISO) 15589-1 (2009) and ISO 15589-1 (2015) standards and where there are shortfalls, other international standards and best practices are introduced. It is noted that the ultimate goal in a CP monitoring regime and its associated CP criteria is to find areas on the pipeline that are not adequately protected and are at risk of corrosion. The CP criteria are to be aligned with this ultimate goal.

The proposed criteria are presented below and still include background information which supports the discussion and review of the assessment criteria. Once the final set of criteria have been agreed upon in conjunction with TPL, the description of these criteria will be simplified by removing the background information.

4.5.1 TPL MPP CP Assessment Criteria 1 – IR Free Corrosion Potential less than $-0.85 V_{CSE}$

SANS ISO 15589-1 requires an IR Free pipe-to-soil potential (polarized potential) more negative (less than) $-0.85 V_{CSE}$ (soils and waters in all conditions, excluding soils and waters with increased temperatures (not the case for MPP)). This requirement is increased to $-0.95 V_{CSE}$ in areas where there is a high risk for SRB. A review of the Cathodic Protection Design Reports (2684358-C-PL1-CP-RP-025, and- RP-053) it was noted that the pipelines are designed for a potential more negative than $-0.85 V_{CSE}$, with little to no discussion on the requirement for the requirement to increase the criteria to $-0.95 V_{CSE}$ in order to account for SRB.

The recommended assessment is an **IR Free potential** more negative than $-0.85 V_{CSE}$. In order to measure IR Free readings, it is recommended that the measurements should be focused on Type B test posts, where there is a buried stationary reference electrode installed, which will assist to minimize IR drop and present a more accurate potential measurement.

Internal Transnet protection targets can be set, as per the current TPL CP Assessment Criteria (i.e., 95% of the time more negative than $-0.85 V_{CSE}$ and 99% of the time more negative than $-0.5 V_{CSE}$). It is however noted that this is a target value and the criteria to ensure cathodic protection of the pipelines remains at $-0.85 V_{CSE}$.

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

It is noted that the potentials should be limited to $-1.2 V_{CSE}$ such as to avoid coating damage and to limit the risk of hydrogen embrittlement³. A maximum polarized potential of $-1.1 V_{CSE}$ is a preferred limit, but it is noted that this may not be possible due to the presence of excessive stray currents.

4.5.2 TPL MPP CP Assessment Criteria 2 – DC Current Density Magnitude and Direction

The inclusion of coupons at all the test stations allows for the measurement of DC current density magnitude and direction. The DC current density represents the amount of current being picked up by the pipeline and can be compared to the design current densities and the recommended current densities presented in the ISO 15589-1 standard(s). The direction of the current identifies if the pipeline is picking up current or discharging current. In the event that pipeline is discharging current but is still more electronegative than the IR Free $-0.85 V_{CSE}$ criteria, significant corrosion will not be expected. Areas that discharge current and have potentials which are more electropositive than the IR Free $-0.85 V_{CSE}$ criteria should be flagged as high-risk areas, which are experiencing active corrosion. Areas of discharge should be assessed in more detail utilising the Type E test posts.

The various DC current densities to which the DC coupon measurements can be compared are:

- i. $10 \mu A/m^2$ - Initial Current Density (MPP CP Design Reports)
- ii. $30 \mu A/m^2$ - Adjusted Current Density to Allow for Stray Current Activity (MPP CP Design Reports)
- iii. $47 \mu A/m^2$ ($50 \mu A/m^2$) - Design Current Density to allow for Coating Degradation of 30 Years (MPP CP Design Reports)
- iv. $50 \mu A/m^2$ to $200 \mu A/m^2$ - Current Density for Conservative CP Design (ISO 15889-1 (2015))
- v. $1 \mu A/m^2$ to $20 \mu A/m^2$ - Current Density for Optimized CP Design (ISO 15889-1 (2015))

The DC current density should be in the range of $10 \mu A/m^2$ to $50 \mu A/m^2$ to avoid over protection and excessively negative potentials.

4.5.3 TPL MPP CP Assessment Criteria 3 – AC Current Density

The AC Current Density shall be limited to the AC current densities presented in NACE SP0169-2013 where the following limits are to be measured and reported on:

- i. AC Corrosion may occur where AC Current Densities exceed $30 A/m^2$; and
- ii. AC Corrosion is almost certain where AC Current Densities exceed $100 A/m^2$.

4.5.4 TPL MPP CP Assessment Criteria 4 – AC DC Corrosion Risk Relationships

ISO 18086 (2019) presents a two-step approach to assess the levels of AC Interference:

- i. AC Voltage on Pipeline – General requirement is to reduce the voltage to 15 V rms (Average over 24 hour)
- ii. Meet Assessment Criteria 1 (IR Free Corrosion less than $-0.85 V_{CSE}$) and
 - a. Maintain the AC average current density (rms) over a representative period of time (e.g. 24 h) to be lower than $30 A/m^2$ on a $1 cm^2$ coupon or probe; or
 - b. Maintaining the average cathodic current density over a representative period of time (e.g. 24 h) lower than $1 A/m^2$ on a $1 cm^2$ coupon or probe if AC average current density (rms) is more than $30 A/m^2$; or

³ The MPP pipeline is an API 5L X60 PLS2, which has a design yield strength of 415 MPa to 565 MPa. Material at risk of hydrogen embrittlement have yield strengths higher than 550 MPa. There is therefore a risk that the MPP pipeline is at risk of hydrogen embrittlement at excessively negative potentials.

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

- c. Maintaining the ratio between AC current density (Ja.c.) and DC current density (Jd.c.) less than 5 over a representative period of time (e.g., 24 h).

It is noted in ISO 18086 that current density ratios between 3 and 5 indicate a small risk of AC corrosion. However, in order to reduce the corrosion risk to a minimum value, ratios of current density smaller than 3 would be preferable. The requirement in Item C listed above, **is therefore recommended to be decreased to 3 for the MPP Assessment Criteria.**

4.5.5 TPL MPP CP Assessment Criteria 5 – Corrosion Rate Less Than 0.1mm per Year (Preliminary)

SANS ISO 15589-1 requires a pipe-to-soil potential that results in a corrosion rate less than 0.1mm/year. The only realistic way in which to monitor corrosion rates on the MPP pipeline is the use of ER Probes (or similar methods such as Electrochemical Impedance Spectroscopy or Linear Polarization Resistance). One of this project's tasks (Item 106 - Investigate the use of ER probes to determine corrosion rate and other variables in real time and the use of suitable monitoring algorithms to manage TRU, NDU and crossbonds to foreign pipelines.) is to review the potential application for ER probes on the MPP. If this is found feasible, it will be added to a revised version the MPP CP Assessment Criteria.

4.6 Monitoring and Reporting

The introduction of the criteria listed above introduces complexity into the monitoring regime currently executed by TPL. The current logging equipment utilised by TPL cannot record all the parameters discussed above and it was therefore agreed that project specific loggers will be developed to provide a platform capable of monitoring the pipeline according to the assessment criteria presented above (excluding Criteria 5, which will be a standalone system).

The project specific TPL loggers currently under manufacture can measure and log the following items:

- i. Coupon On Potential – DC & AC
- ii. Coupon Instant Disconnect Potential – DC
- iii. Coupon Current Density – DC & AC
- iv. Coupon Current Direction – DC
- v. TRU & FDU monitoring and logging capabilities.
- vi. Crossbond current monitoring and logging capabilities

The logged data will be post processed and presented in PDF and CSV reports. The layout and content of the reports will be developed in consultation with TPL management. The data will also be accessible on an FTP server, and it is intended to present the data graphically as well.

CP ASSESSMENT CRITERIA TO BE UTILIZED BY TPL ON THE MPP PIPELINE.

5 Conclusion

The assessment criteria discussed and presented in this memorandum covers the following items:

1. Concerns regarding TPL's assessment criteria presented in Reignite Report (TGC2017041601 rev 04 – 9 July 2018) are addressed.
2. Measurements and assessment methodologies presented in the NERSA REPORT No. PR0680 are included in the assessment criteria.
3. Develop new criteria to align TPL monitoring system with international best practice and latest applicable SANS standards.

These proposed new TPL MPP assessment criteria will be implemented during the optimisation project and will be formalised in consultation with TPL during the project optimization and handover phases. Any feedback on the criteria and the implementation thereof is encouraged.