AusNet Gas Services Pty Ltd

Gas Access Arrangement Review 2018–2022

Appendix 6H: Corrosion Protection Strategy – Public

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Corrosion Protection Strategy

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Executive Summary

AusNet Services utilises Cathodic Protection, and associated systems, to actively defend against corrosion of buried steel assets within its gas transmission and distribution networks.

The gas transmission and distribution system features 183 active cathodic protection units of various current outputs that protect 2,683km of steel pipeline and mains. All 183 km of the transmission network is cathodically protected however, approximately 15% of steel main cannot be effectively cathodically protected. Network cathodic protection is also aided by approximately 851 magnesium sacrificial anode bed sites, stray current drainage sites, earthing sites, and numerous surge protection devices.

The performance of these systems is monitored via test point boxes dispersed throughout the network and routine maintenance is performed to meet regulatory obligations and ensure the systems effectively protect the steel assets. Capital programs are established to replace assets that have reached the end of their effective life and require replacement. These programs aim to achieve the following four key objectives:

- Maintain network Safety in accordance with AusNet Services' Gas Safety Case through ensuring its gas pipelines and mains networks are adequately cathodically protected to the prescribed levels. This ensures minimal corrosion, reduced leakage and hence improved public safety.
- Maintain top quartile operating efficiency and the general integrity of the network through the mitigation of corrosion. Reduced corrosion rates improve asset life, ensuring the integrity of the networks.
- Undertake prudent and sustainable network investment to ensure the maximisation of asset life.
- Delivery of services valued by our customers through the reduction of both planned and unplanned works required for leakage repair and mains renewal works.

The following capital projects are planned over the 2017 to 2022 period:

Table 1: Financial Year Capital Expenditure to 2022

Program		2017	2018	2019	2020	2021	2022	Program Total 2018-22
New CPU Installation	Units	3	4	4	4	4	4	20
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
Small Anode Bed Replacement	Units	6	2	2	3	3	3	13
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
Large Anode Bed Replacement	Units	1	1	1	1	1	1	5
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
New sacrificial anode	Units	3	3	3	2	2	2	12
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
Replace Expiring Sacrificial Anode	Units	4	4	4	4	4	4	30
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

Program		2017	2018	2019	2020	2021	2022	Program
CP UNIT Remote Monitoring	Units	40	19	19	19	19	19	95
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
City Gate Remote Potential survey	Units	0	5	5	5	5	5	25
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
Critical Test point on Lic Networks remote potential survey	Units	0	10	10	10	10	10	50
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
Miscellaneous CPS	Exp ('000)	$80	$84	$84	$84	$84	$84	$422
TOTAL Expenditure ('000)		**$359**	**$401**	**$401**	**$403**	**$403**	**$403**	**$2,010**

1 Document Overview

1.1 Purpose

This document articulates AusNet Services' approach to the management of its corrosion protection assets. The document is for use by:

- Internal staff and senior management; and
- Regulators – Economic, Technical and Safety.

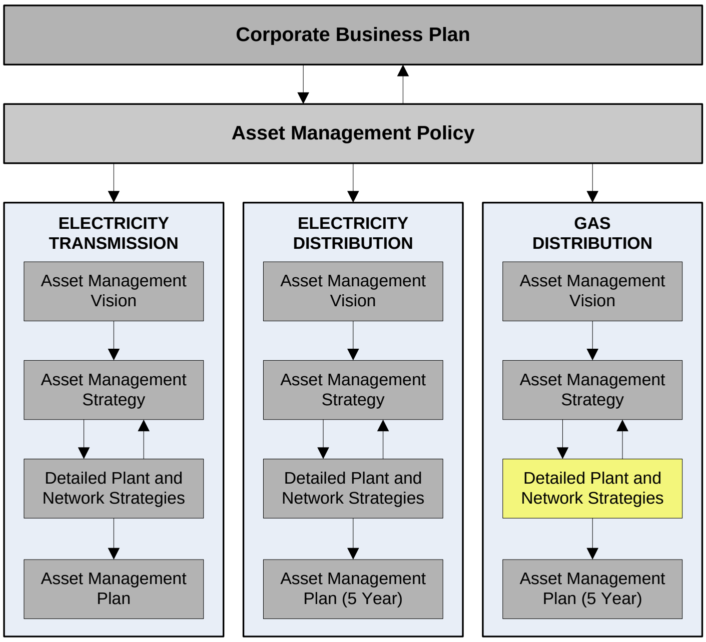
The Cathodic Protection Strategy is one of several plant strategies developed and maintained for the management of AusNet Services' Gas Distribution Network. It has the following objectives:

- It articulates the key areas of focus in relation to asset management, key risks, key programs, costs and service standard outcomes for the asset group.
- It defines the linkages of the asset group to the overarching asset management strategy and underpinning asset management plan.

1.2 Relationship with Other Management Documents

The Corrosion Protection Strategy is one of a number of asset management related documents developed and published by AusNet Services in relation to its gas distribution network. As indicated in the figure below, detailed plant strategies, in which the Corrosion Protection Strategy belongs, informs both the Asset Management Strategy (AMS) and Asset Management Plan (AMP) of the required capital programs needed to achieve the long-term objectives of the gas distribution network.

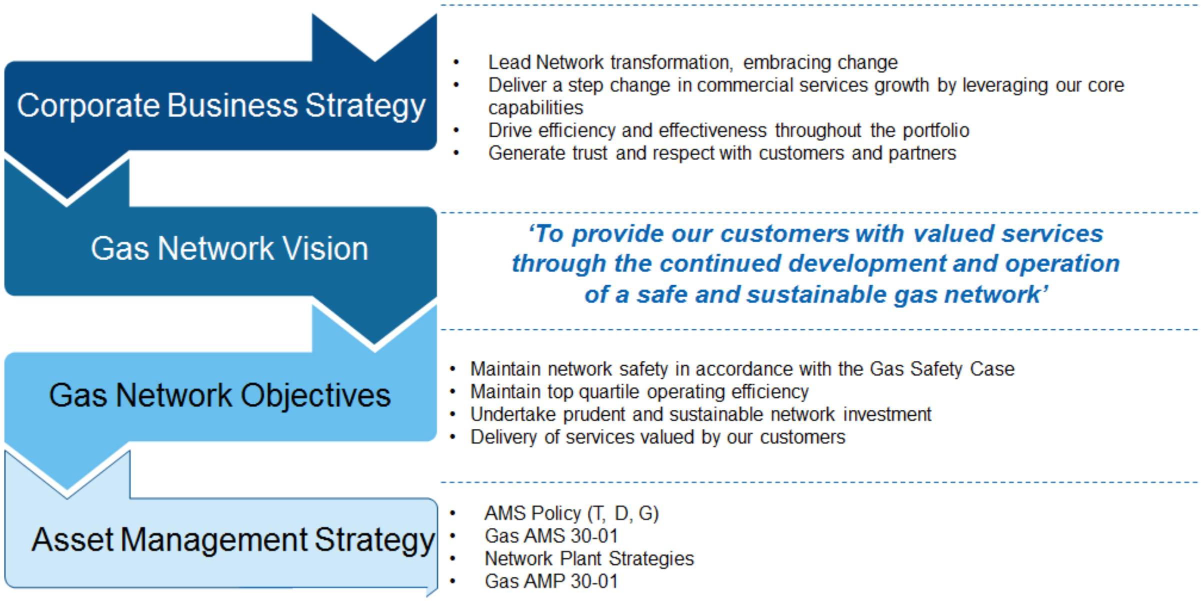
Figure 1: Asset Management System document interdependencies



2 Alignment of AusNet Services' Business Drivers and Objectives

AusNet Services' purpose statement is to "Empower communities and their energy future". This statement places the customer (as individuals and communities) at the forefront as a business driver and acknowledges the critical relationship with their energy supply and usage, and is a key theme throughout the Corporate Business Strategy. The following diagram provides the linkage between AusNet Services corporate strategy, and the gas network vision consistent with providing valued customer service and sustainable network investment. The gas network objectives which stems network vision then drives the development of the programs for each of the asset strategies

Figure 2: Alignment of Corporate, Business and Network objectives



The gas network objectives alignment with the business, regulators, and the delivery of plant strategies are detailed below:

- Maintain network safety in accordance with the Gas Safety Case
- Maintains the alignment to AusNet Services' commitment to 'Mission Zero'. The objective to maintain network safety is in recognition of AusNet Gas Services' current safety performance and design of the network.
- Maintain top quartile operating efficiency
- Aligns to the Corporate Business Plan with AusNet Services' aspiration to operate "all three core networks in the top quartile of efficiency benchmarks".
- Undertake prudent and sustainable network investment
- Alignment to AusNet Services' obligation to undertake prudent and sustainable network investment, as defined in the National Gas Rules and Gas Distribution System Code.
- Delivery of valued services to our customers
- Establishes the need to better understand our customers (their needs and behaviours) and deliver services they value.

2.1 Phasing and Financial Disclosure

All programs within the Corrosion Protection Strategy are defined in calendar years, consistent with the requirements of the GDSC, and the reporting requirements of the Australian Energy Regulator (AER).[1]

All financial figures quoted within this document, including all historic and forecasted expenditure – unless otherwise specifically stated – have the following characteristics:

- Real Expenditure / Cost (reference year = 2016);
- Direct Expenditure only (i.e. excludes overheads and corporate finance costs); and
- In units of $1,000 (i.e. '000).

2.2 References

- AS 2239 – Galvanic (sacrificial) anodes for cathodic protection
- AS 4645.1 – Gas Distribution Networks
- AS 4645.2 – Gas Distribution Networks – Steel pipe systems
- AS 2885 – Pipeline – Gas and Liquid Petroleum
- AS 2832 – Cathodic Protection of Metals
- AS 4827.1 – Coating Defect Survey for Buried Pipelines
- AS 4853 – Electrical Hazards on Metallic Pipelines.
- Victorian Government Cathodic Protection Regulations
- Corrosion Protection Services Manual
- Cathodic Protection Training and Reference Manual
- CPS 2308 – Policy – Protection from Electrical Surges and Induced Voltages on Gas Pipelines
- TS 2314 – Guide – Cathodic Protection Distribution System
- CPS 2315 – Guide – Cathodic Protection Transmission System

2.3 Glossary

Cathodic Protection

Reduction or elimination of corrosion by means of inducing a small DC current into a steel structure.

CPU

An impressed current cathodic protection unit providing corrosion protection on the distribution system. These units have registered permits required under the cathodic protection Regulations.

Coating Defect Survey

A survey conducted by traversing directly above a coated main along its length using equipment and techniques designed to identify any defects in the coating. Methods in common use include “Pearson” and Direct Current Voltage Gradient (DCVG).

Coil (Electromagnetic coil) Survey

An electromagnetic tracing technique for locating points of failed insulation or electrical contact to other metallic structures.

Direct Current Voltage Gradient (DCVG) Survey

A type of coating quality assessment survey conducted by traversing above the pipeline using equipment that applies pulsating DC electrical signals to identify coating defects.

[1] The AER requires notification of the outcomes of in-service compliance testing by 30 September each year. Both in-service compliance testing and meter replacement programs are defined, tracked and reported on a calendar year basis.

Distribution Area

An electrically isolated area of the distribution system which is used for assessing and maintaining the effectiveness of corrosion protection systems.

Distribution System

In the context of this document, the distribution system comprises all steel mains and services in the High and Medium Pressure system, i.e. those able to be cathodically protected.

Drainage Bond

An electrical connection from a point in the distribution system connected to tram or train substations to prevent adverse effects from stray currents. These installations may have associated equipment to control the level of flowing current.

Electrical Isolation

The effective electrical separation of structures to be protected from other structures and electrical systems. Achieved by the installation of insulating flanges, monolithic insulating joints and insulating couplings.

Electrolysis

A very severe form of corrosion caused by stray electric currents from the tram and train systems.

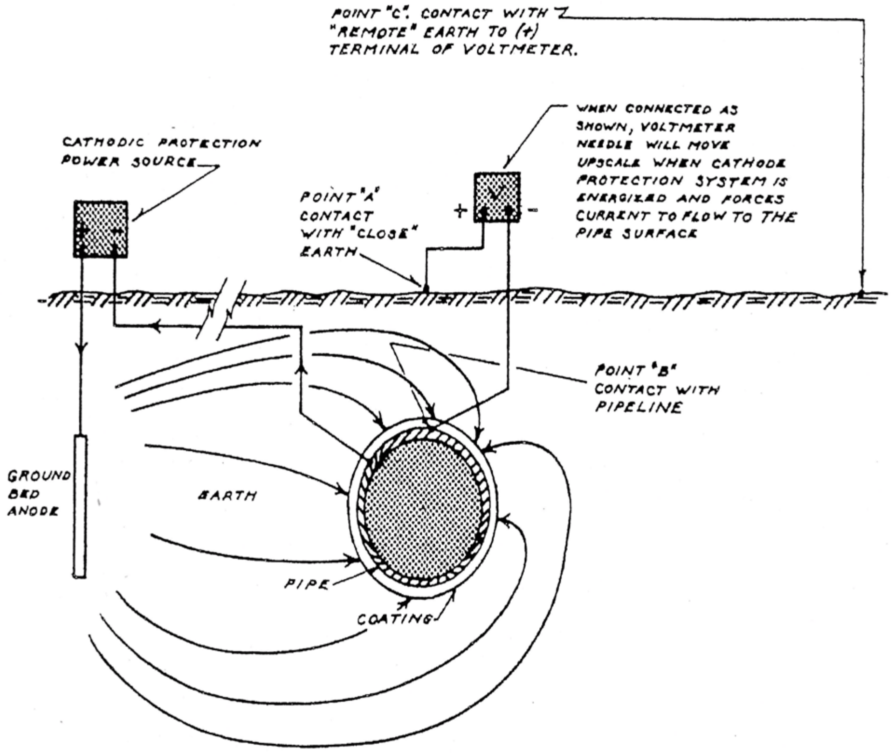
Galvanic (Sacrificial) Anode

A block of metal which provides protection by preferentially sacrificing itself instead of allowing the steel to corrode. (Magnesium is commonly used for underground service, although sometimes zinc is preferred. Refer to AS 2239 for further details).

Impressed Current Systems

A cathodic protection system in which the driving voltage for the protective current between the structure and the anode is supplied by an external direct current power source.

Figure 3: Impressed Current Cathodic Protection Schematic



Loop Resistivity Test

A loop resistivity test calculates the resistance of an anode bed, via monitoring a CP unit's potential voltage and current outputs. The higher the resistance of the anode bed, the higher its level of deterioration.

Pearson Survey

A type of coating quality assessment survey conducted by traversing above the main using equipment that applies audio frequency electrical signals (typically 1 kHz) to identify coating defects.

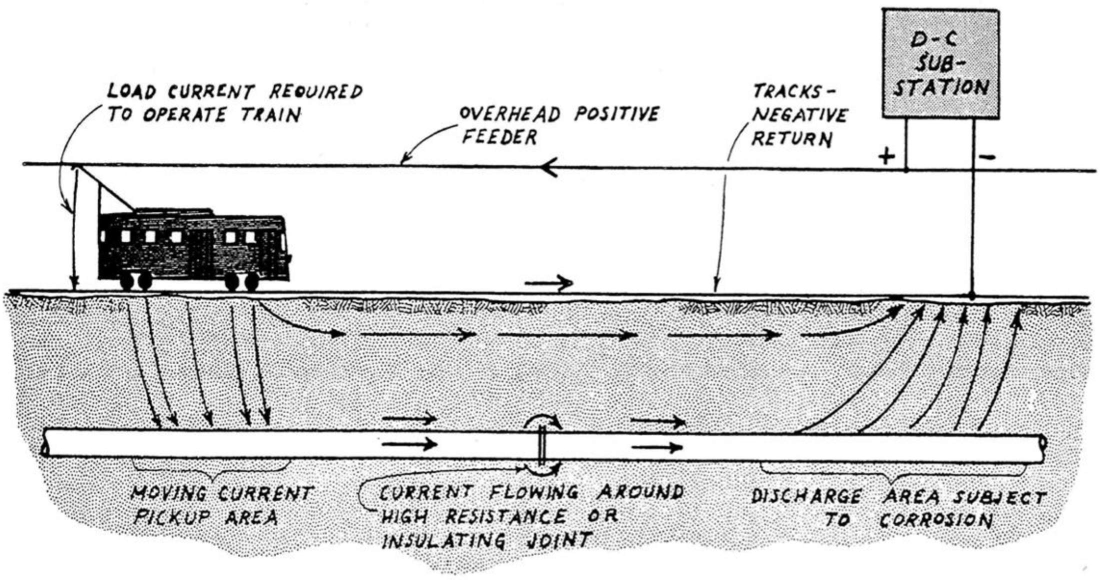
Spot Potential Reading

A measurement of pipe-to-soil potential taken at a given location at a particular point in time. Such readings can be used to assess protection status where potentials do not vary with time. However, in circumstances where potentials fluctuate due to telluric or stray current influences, recordings of potential over a period of time (usually 24 hours) are necessary.

Stray Current Electrolysis

A form of corrosion, often severe, caused by "stray" electrical current entering the ground from the tram and train systems, which then affects buried metallic structures.

Figure 4: Stray Current Corrosion Induced by DC Transit Systems



Stray Current Electrolysis Testing

This testing is performed to identify any stray currents and interference connections that may be entering the ground from the tram and train system. This testing is carried out in a five (5) year cycle in conjunction with the Victorian Electrolysis committee or as determined via the implementation of a test model.

Test Point

A conveniently located termination point for electrical cables connected to a buried pipeline or main. This allows measurement of pipeline potential, and is the principal method of assessing the effectiveness of corrosion protection. Test points are also required for coating quality surveys and electromagnetic coil surveys to investigate losses in protection.

Thyristor Drainage Unit (TDU)

Equipment installed in tram or train substations to provide sufficient negative voltage for drainage bonds to be effective. Normally controlled in proportion to substation load.

Variable Conductance Drainage Bond (VCDB)

Electronic equipment to control the current in a drainage bond. In this case it is controlled by the protected structures potential. In some cases may also have a DC supply to provide sufficient protective current.

VEC

The Victorian Electrolysis Committee who co-ordinates testing required to monitor and maintain effective protection from stray currents caused mainly by the operation of the train and tram systems. They also administer the Cathodic Protection permits and regulations.

3 Asset Overview

3.1 Introduction

Corrosion of a metal is an electrochemical reaction between it and the surrounding environment which results in the reduction of metal mass. Thus, corrosion is a combination of chemical effects with an associated flow of electrical energy (corrosion current).

The primary method of preventing corrosion on steel structures is via the use of protective coatings that prevent exposure of the metallic surface. However, no coating is perfect and over the life of the asset, through damage and wear, the coating will inevitably deteriorate, exposing points of the metallic surface to corrosive action.

Cathodic protection is an electrochemical technique for preventing corrosion of exposed metal surfaces. The process involves the application of DC electrical current to a metal surface from an external source flowing in opposition to the original corrosion current. In this way, the metals natural tendency to react with its environment is effectively ‘cancelled out’. The external source can be either a commercial power source (impressed current systems) or through connection to galvanic metals (sacrificial anode systems).

Cathodic protection is used extensively throughout the AusNet Services gas transmission and distribution network as a means of arresting corrosion and extending asset life. Effective application of cathodic protection can provide complete protection to any exposed areas for the life of the structure.

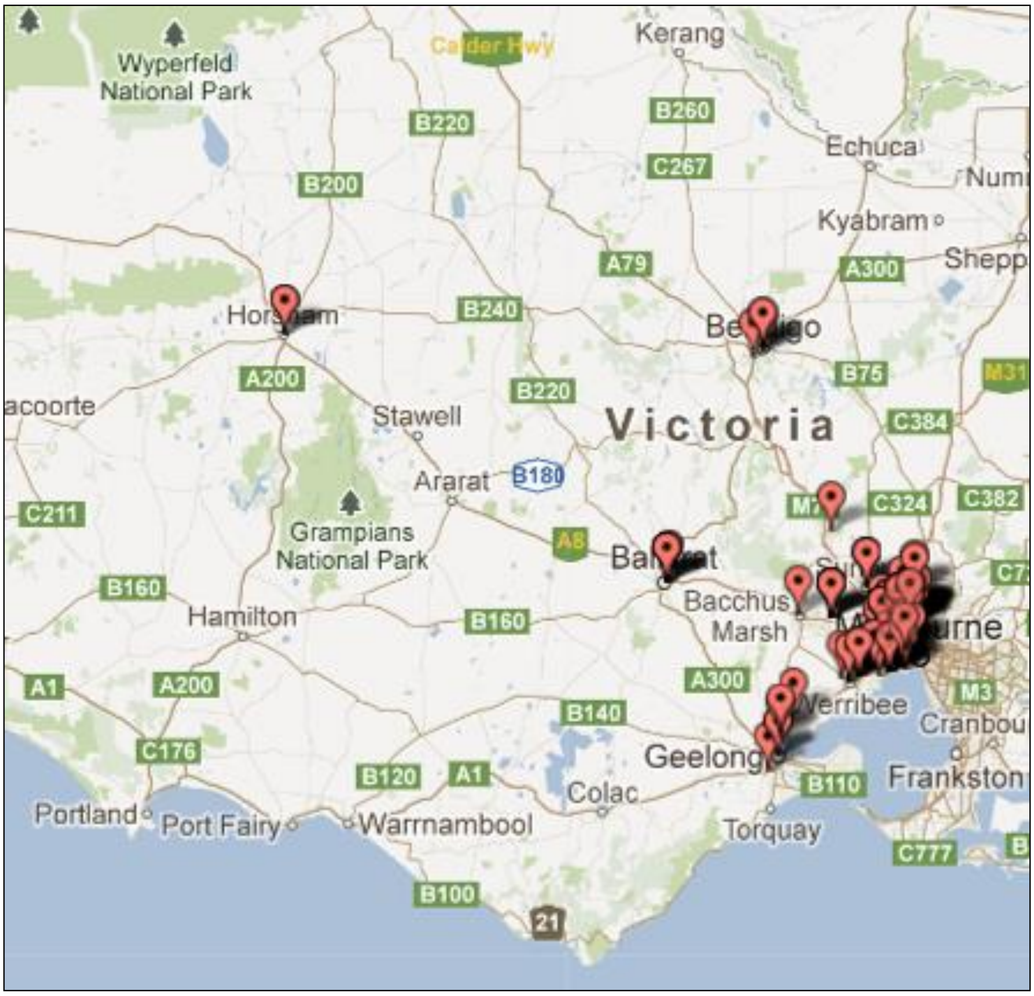
Only buried and coated, electrically conductive, ferrous metal mains are cathodically protected. Uncoated mains are unable to be effectively protected due to current dissipation to the surrounding soil.

3.2 Age Profile / Utilisation / Asset Profile

3.2.1 Cathodic Protection Units

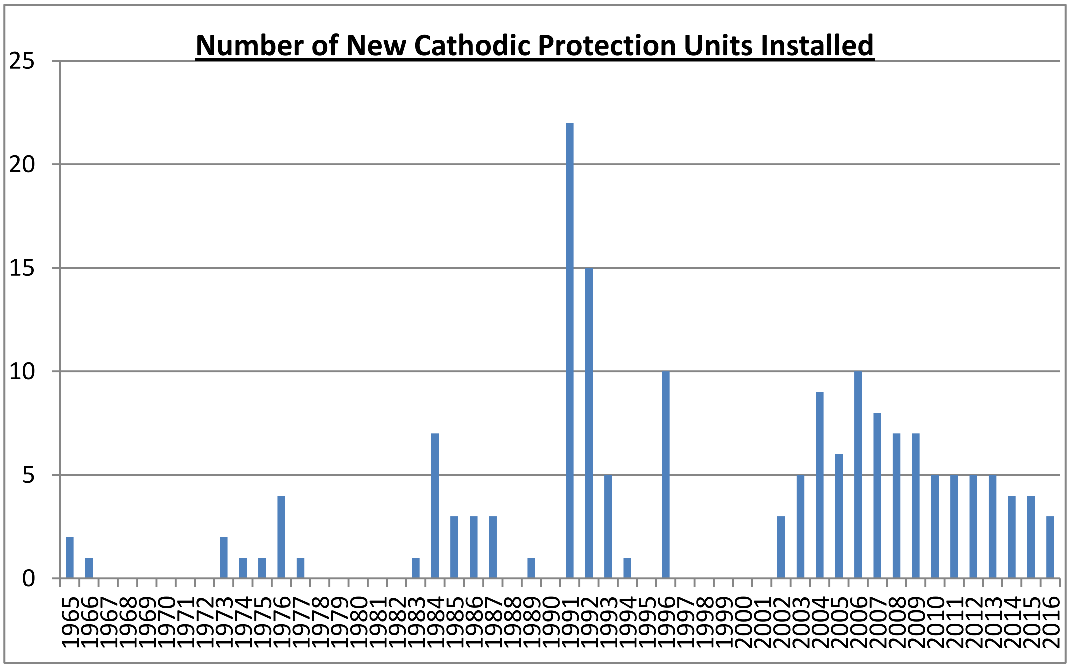
The AusNet Services gas transmission and distribution system features 183 active cathodic protection units of various current outputs that protect 2,683km of steel pipeline and mains. All 183 km of transmission network is fully cathodically protected. 398 km of steel main is dispersed within the distribution system that cannot be effectively cathodically protected due to its electrical isolation, bad coated pipeline and high soil resistivity.

Figure 5: Locations of AusNet Services' Cathodic Protection Units



The above map highlights the distribution of AusNet Services' impressed current CPU systems. They are primarily concentrated around the western Melbourne area, with additional units in some regional centres (Ballarat, Bendigo, Geelong and Horsham). In a number of regional towns, such as Lara, Ballan, Colac, Cobden, Daylesford, Stawell, Ararat, Castlemaine, Warrnambool, Maryborough, Portland, Hamilton Koroit and Wallan the cathodic protection of the steel network is provided by electrical bonding at the City Gate sites. In this way AusNet Services' network piggy backs off the protection systems of APA GasNet's transmission pipeline network. AusNet Services monitors the performance and effectiveness of these systems via test points installed in each network.

Figure 6: Number of Cathodic Protection Units Installed Each Year



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3.2.2 Sacrificial Anodes

At present the network contains approximately 851 magnesium sacrificial anode sites. 784 of these provide low levels of cathodic protection to the steel distribution network. The remainder support the systems protecting the transmission network. Sacrificial anodes decay at varied rates that depend on the environment they are situated in and the rate of corrosion on the associated main or pipeline. These installations are monitored via associated test points, and replaced when they are no longer effective indicated by their low output.

3.2.3 Test Points

Test points are installed as per the recommendations of AS 2832.1 – Cathodic Protection of Metals – Pipes and Cables.

Table 2: Maximum Test Point Spacing – AS 2832

	Typical Maximum Spacing (AS 2832.1)	
Area Classification	**Uncoated or Poorly Coated Structures**	**Well Coated Structures**
Broad-rural	1,000m	5,000m
Semi-rural	500m	2,000m
Suburban and high-rise	500m	500m
Low density dwelling	500m	1,000m

[2] Historical installation records prior to 2000 are not reliable.

AS 2832 also recommends Test Points be installed at the following locations:

- At rail crossings, road crossings and at waterways.
- At steel casings, on the casing and on the structure.
- Adjacent to insulating joints and at structure terminations.
- At highly corrosive soil locations.
- At likely sources and discharge points of stray currents.
- Adjacent to air/electrolyte interfaces.
- At close proximity to foreign structures and at crossings with foreign structures.

At present, AusNet Services currently has 2,947 test points installed throughout the distribution network and 452 covering the 183km of transmission pipeline in operation.

3.2.4 Surge Protection Assets – Batteries, Thyristors, Drainage Units

Various surge protection devices are installed throughout the network to protect both personnel and equipment. This includes insulated flanges and monolithic joints positioned to electrically isolate sections of pipework. These devices are in turn fitted with NiCad batteries, thyristors, isolating spark gaps or Govan boxes to provide an electrical path for any large surge spikes to dissipate to earth.

Stray current drainage systems are also installed throughout the network to remove unwanted stray current caused by traction systems in the steel pipe networks. The gas network features:

- 63 on the distribution system (10 tram network related, 52 train network related, 1 other);
- 22 on the transmission system (2 tram network related, 18 train network related, 2 other).

To prevent unwanted potential increases in the metallic systems, 41 earthing sites have been installed throughout the network, 31 of which are on the transmission pipeline network.

3.3 Historical Asset Performance

The performance and function of the cathodic protection systems is monitored by means of test point potential level surveys. The results of which are detailed in monthly reports along with other cathodic protection issues, coil survey results, coating fault survey results, VEC testing details and any other relevant matters. The protection criterion specified in Section 2.2.2.2 of AS 2832.1 states that the potential of a fully protected structure should be more negative than -850mV Vs. a saturated copper/copper-sulphate reference electrode.

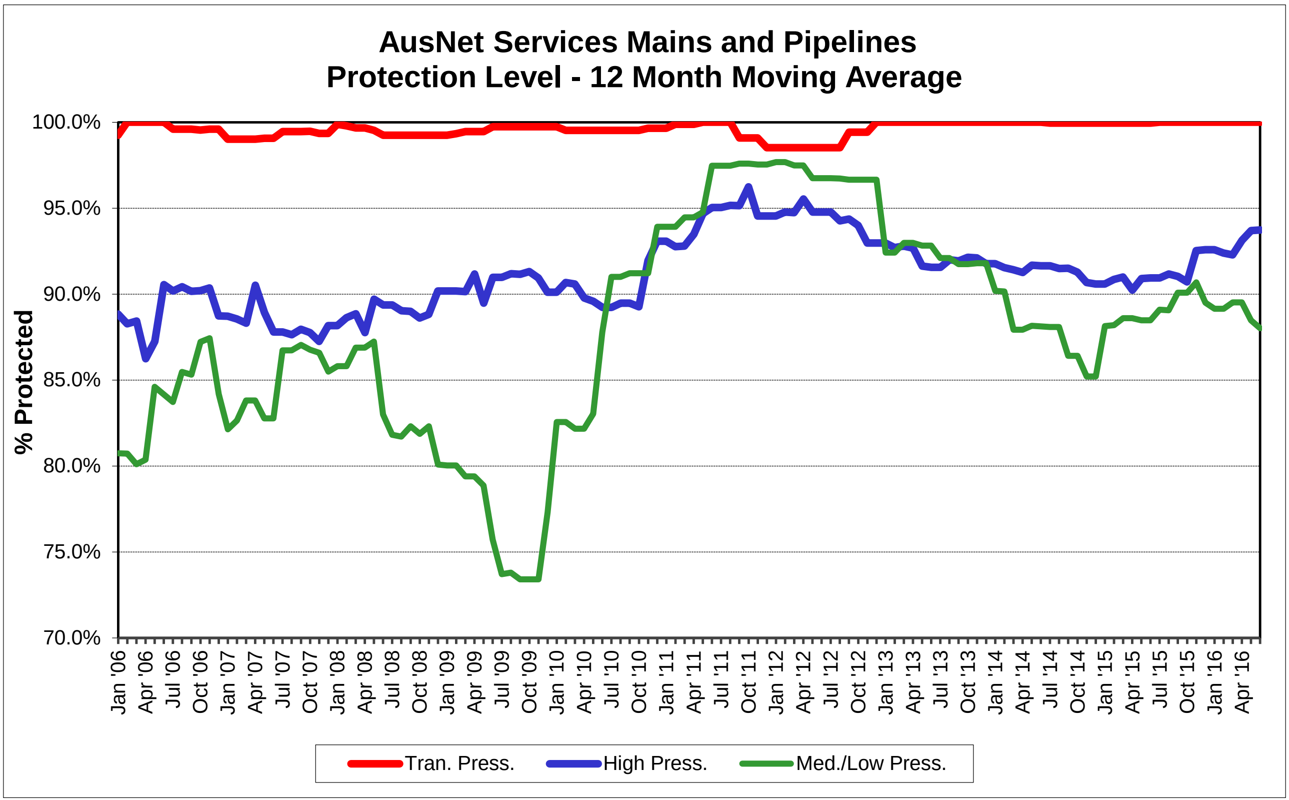
The Gas Maintenance Plan, AMP 30-02, sets minimum target levels for the percentage of protected steel mains to be within this range. These are as follows:

Table 3: Target CP Protection Levels

	Target Protection Level
Licensed (Transmission) Pipelines	98%
High Pressure Areas	90%
Medium Pressure Areas	85%
Low Pressure Areas	80%

Potential surveys conducted on the networks monitor the cathodic protection voltages to ascertain if these target levels are being reached. The following graph shows the historical average performance of these systems.

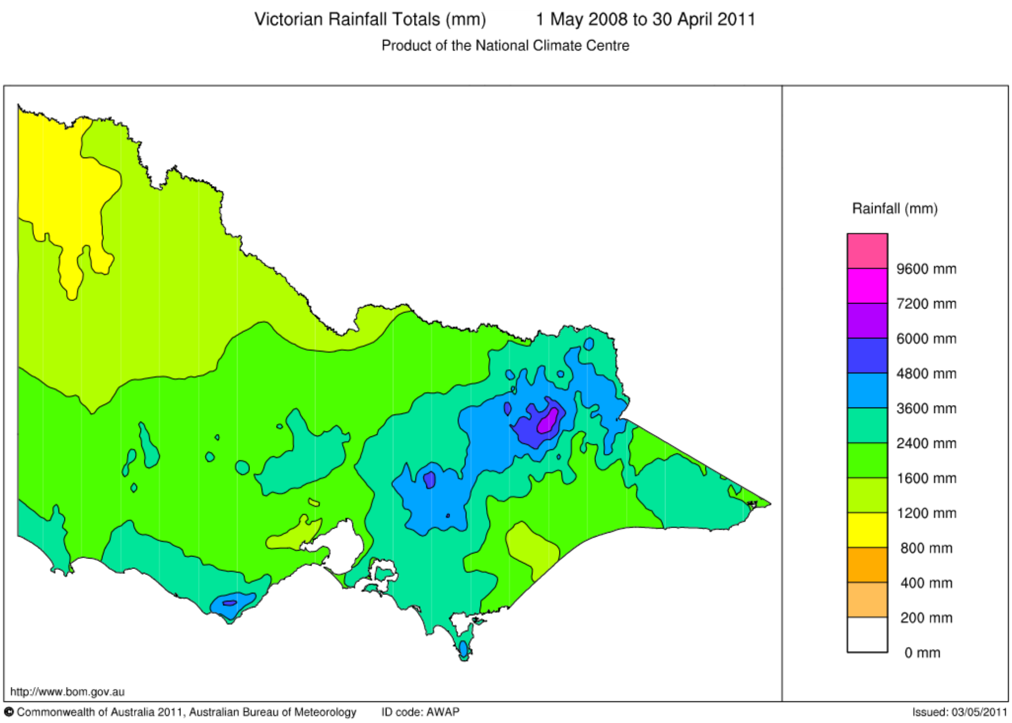
Figure 7: Historical Cathodic Protection Performance



The effectiveness of a cathodic protection system is dependent on a number of variables. Some issues that affect cathodic protection system performance, and hence measured pipeline potentials are:

- **Soil Moisture Content:** The moisture content of the soil affects its electrical resistance, and hence the ability of the cathodic protection system to replace lost electrons. As such, periods of drought will see a decline in system performance. This is evident in Figure 7 for the October 2009 to July 2010 period for the localised medium pressure network, which saw a period of drought followed by heavy rain. The geographical area that AusNet Services serves also sees lower average rainfalls than the east of the state.

Figure 8: Victoria 3 Year Historical Rainfall



- **Soil Composition:** The soil resistivity, and hence system performance, will also vary based upon the soil composition in which both the anode bed and protected asset lie.

- **Anode Bed Condition:** A cathodic protection systems performance will start to decline over time as its associated anode bed is depleted over time. The systems performance and life can be renewed by simply replacing the anode bed of the unit.

4 Alignment with network objectives

Each project / program of the corrosion protection strategy for the gas transmission and distribution network is aligned with AusNet Services' key business drivers aiming to:

- Maintain network Safety in accordance with the Gas Safety Case;
- Maintain top quartile operating efficiency;
- Undertake prudent and sustainable network investment;
- Delivery of services valued by our customers.

Specifically this is accomplished through the following means.

4.1 Network Resilience and Reliability

The installation of cathodic protection equipment is directly targeted at maintaining network resilience. Through the deployment of cathodic protection systems throughout the gas transmission and distribution network, AusNet Services actively defends against the corrosion of its buried steel assets. This resilience of the network results in decreased corrosion and induced leakage.

4.2 Compliance

Due to the importance of cathodic protection, the ability of stray currents to impinge on nearby assets, and the dangers of electrical surges and other electrical interference, a number of standards and codes mandate and guide the use of cathodic protection units and associated systems. These include, but are not limited to, the following:

- AS 2885 – Pipelines – Gas and Liquid Petroleum
- AS 4645.2 – Gas distribution networks – Steel pipe systems
- AS 2832 – Guide to the Cathodic Protection of Metals
- AS 4853 – Electrical hazards on metallic pipelines
- AS 2239 – Galvanic (Sacrificial) Anodes for Cathodic Protection
- Victorian Government Cathodic Protection Regulations – 1988
- Railways of Australia Code
- NACE RP-01-69 (1991) Recommended Practice for Control of External Corrosion on Underground or Submerged Metallic Piping Systems

The use of cathodic protection is a feature of AusNet Services' Gas Safety Case, a primary tool for ensuring the safe operation of the network.

As an employer AusNet Services is required by law to provide a safe working environment for its employees and is required to comply with relevant codes and standards, such as AS/NZS 4853 – Electrical hazards on metallic pipelines, which specifies acceptable electrical limits on pipelines.

4.3 Safety

Cathodic protection mitigates the risk of gas escapes on steel pipes and hence maintains the safety of the network and the surrounding public.

By ensuring that the transmission and distribution networks are adequately protected from electrical surges and other electrical interferences, AusNet Services ensures a safe working environment for its employees, and the safety of the public.

4.4 Sustainability

Corrosion of steel pipes causes a reduction in the wall thickness of the pipe. Corrosion eventually leads to a loss of containment resulting in leakage of natural gas containing Methane, a greenhouse gas, to the atmosphere. Corrosion of the mains also accelerates the aging process of the pipe and shortens its expected life. As a result, the pipe must be renewed prematurely. By maintaining adequate levels of corrosion protection, leakage of natural gas can be minimised, the asset life of the main maximised and replacement works deferred.

5 Detailed CAPEX requirements

5.1 Summary

The corrosion protection works program aims to maximise the life of buried steel pipes. The works program to 2021/22 has been determined by analysing the performance of the corrosion protection systems and designing works to meet the protection levels in accordance with the Gas Safety Case. The program consists of installing additional corrosion protection units (CPUs), upgrading of existing systems, installing surge protection and replacement of anode beds. Program Drivers

This section outlines the business drivers and strategic alignment common to all corrosion protection capital programs detailed in the following sections. Any unique drivers are listed under the relevant programs.

Cathodic Protection

The primary driver behind the use of cathodic protection systems, and all works programs associated with it, is to maintain the integrity of the network. It's deployment and use throughout both the distribution and transmission networks ensures that the probability and hence the overall risk of corrosion of its steel assets is mitigated. With effective cathodic protection, steel assets are 'shielded' from corrosion, and hence the threat of corrosion induced leaks and failures are reduced, ensuring the integrity of the network.

Cathodic protection systems, by their nature, also prolong the useful life of the assets they are designed to protect from corrosion. The useful life of steel pipeline assets is maximised by installing and maintaining adequate cathodic protection systems.

Stray Current Drainage

Stray currents from train and tram systems can cause extensive damage to buried steel structures. Accordingly the effects of stray currents are monitored by co-ordinated testing of structures near train and tram substations. These testing and mitigation works are mandated by the Victorian Electrolysis Committee.

Standards

Due to the importance of cathodic protection, the ability of stray currents to impinge on nearby assets, and the dangers of electrical surges and other electrical interference, a number of standards and codes govern the use of cathodic protection systems.

By adhering to these standards (shown in section 2.2) and all other relevant standards related to cathodic protection and associated systems, the integrity of the networks is maintained.

The integrity of the transmission and distribution system is maintained by minimising corrosion through the application of corrosion protection systems. This ensures the capacity of the networks and hence the levels of supply available to customers.

Cathodic Protection Levels

The use of cathodic protection as a means of limiting corrosion induced leakage throughout the network is a key measure listed in the Gas Safety. Therefore appropriate cathodic protection potentials, at or above the set target levels, must be maintained.

5.2 New CPU Installation

5.2.1 Introduction

New Cathodic Protection Units installed by AusNet Services are generally 2 Amp or larger systems. Due to their power requirements, these units require a metered 240V electrical connection. As such, the units are typically mounted directly to an electricity pole or in proximity to their base. The systems also require placement of an anode bed, sized in accordance with the units output. These anode beds are typically laid in a nearby nature strip or other suitable area. The system is then wired via a Test Box, to the steel main it protects. The units must also be registered and licensed with the Victorian Electrolysis Commission which restricts the maximum output of the unit.

Figure 9: Typical CP Unit Installation

New CPUs are installed where more than 200 mA of potential to the main or pipeline is required. Where less than 200 mA is required, sacrificial anodes are preferred as they are a less expensive alternative. (Refer section 5.5.)

5.2.2 Works Program

A program involving the installation of new cathodic protection units has been undertaken over the last 9 years (see the table below**Error! Reference source not found.**). This program has begun to stabilise cathodic protection levels on the steel pipeline network at the desired levels of protection and coverage. The works have also been aimed at eliminating AusNet Services' reliance on third party cathodic protection units; those owned and operated by APA GasNet. Moving away from this reliance ensures that AusNet Services has oversight and control of the cathodic protection of our assets. The proposed volume of new units is expected to remain at current levels in order to fully protect and cover the network.

An average new CPU installation cost of C-I-C is assumed based on the 2016 program costs and also including remote data logger in each new Cathodic Protection cabinet:

Table 4: New CPU Program

New CPU Installation Program	2017	2018	2019	2020	2021	2022	Period Total
Units	3	4	4	4	4	4	20
TOTAL Expenditure ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.3 Anode Bed Replacement

5.3.1 Introduction

If during potential surveys the protection level (mains potential) of an area is found to be below the optimal level, then the output of the CP units in the area is increased. However, if this does not improve the surveyed potential levels, this may indicate a problem with the anode bed of the CP unit.

As the anode bed of a CP unit will be consumed as part of its function, it must be renewed when the level of deterioration becomes excessive. The rate of this deterioration is directly proportional to the load placed on the unit (by the selected output level and level of corrosion on the main being protected). To verify the state of an anode bed, a loop resistivity test is performed.

Once an anode bed is replaced, the output of the CP unit will again be at its maximum and the life of the unit renewed.

Figure 10: A Small Anode Bed Installation (Single Anode)

5.3.2 Works Program

The volume of anode bed replacements needed to maintain output levels increase as the total number of cathodic protection units utilised within the network increases. The number of replacements required in any given year is also dependant on each site's load and environmental conditions.

An average small anode bed replacement cost of C-I-C per site is assumed based on costs from the 2016 program.

Table 5: Small Anode Bed Replacement Program

Small Anode Bed Replacement Program	2017	2018	2019	2020	2021	2022	Period Total
Units	6	2	2	3	3	3	13
TOTAL Expenditure ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.4 Large Anode Bed Replacement

5.4.1 Introduction

The size of a cathodic protection unit's anode bed is directly related to the maximum output of the unit. The larger the unit, the larger the anode bed required to provide adequate corrosion protection of the steel assets. Large anode beds consist of multiple metal anodes, usually 5 to 6, laid either vertically or horizontally in a bed of conducting earth backfill. These anodes are wired together, increasing the available output of the cathodic protection unit, and hence the level of corrosion protection. These larger units also deplete over time, requiring replacement when their failure is identified.

Figure 11: Large Anode Bed Installation (Multiple Anodes)

5.4.2 Works Program

The number of replacements required in any given year is dependent on each sites load and environmental conditions. It is expected that one replacement per year is sufficient in maintaining protection levels.

An average anode bed replacement cost of C-I-C per site is assumed based on the cost of the 2016 program.

Table 6: Large Anode Bed Replacement Program

Large Anode Bed Replacement Program	2017	2018	2019	2020	2021	2022	Period Total
Units	1	1	1	1	1	1	5
TOTAL Expenditure ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.5 New sacrificial anode

5.5.1 Introduction

The alternative to powered impressed current systems for active corrosion protection is the use of sacrificial anodes. These systems are capable of providing approximately 200 mA of potential to the main or pipeline to which they are connected. These systems function by electrically connecting a sacrificial anode, usually a bar of magnesium or zinc, to the main via a test point. This sacrificial anode is preferentially corroded instead of the main to which is attached as it supplies electrons to replace those in the main lost to corrosive action. The system usually consists of four 10kg anodes.

For sites requiring less than an additional 200mA of potential to achieve adequate cathodic protection levels, the installation of new sacrificial anodes is preferred. Due to their substantially lower upfront capital cost, lack of monthly monitoring requirements, and lower current output levels, they are considered more economic and technically feasible than full impressed current systems.

Sacrificial anode are necessary when there is CP interference issues from nearby buried steel infrastructure, and there is no potential to install a CP unit.

5.5.2 Works Program

Based on current unit rates and previous works performed the programs expenditure is estimated as follows:

Table 7: New Sacrificial Anode Program

New Sacrificial Anode Program	2017	2018	2019	2020	2021	2022	Period Total
Units	3	3	3	2	2	2	12
TOTAL Expenditure ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.6 Replace expiring sacrificial anode

5.6.1 Introduction

During routine potential surveys, the current output of the sacrificial anodes is measured via their associated test point. If the current measured is approaching 0 then the anode is generally depleted and requires replacement.

5.6.2 Works Program

Based on current unit rates and previous works performed the programs expenditure is estimated that 4 units per years is consistent with maintaining protection levels. The program is as follows:

Table 8: Replace Expiring Sacrificial Anode Program

Replace Expiring Sacrificial Anode Program	2017	2018	2019	2020	2021	2022	Period Total
Units	4	4	4	4	4	4	30
TOTAL Expenditure ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.7 CP Unit Remote Monitoring

Installation of remotely read data loggers in CP Units to remotely monitor current output at prioritised locations.

Based on number of the current CP units with no remote data loggers and previous works performed the programs expenditure is estimated as follows:

CP UNIT Remote Monitoring	Units in 2018 to 2022)	19	19	19	19	19	95
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.8 City Gate Remote Potential survey

Installation of remotely read data logger test points in City Gate locations to remotely measure the potential of the pipelines.

Based on current number of City Gates with no remote data loggers for potential survey and previous works performed the programs expenditure is estimated as follows:

City Gate remote Potential survey	Units in 2018 to 2022)	5	5	5	5	5	25
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.9 Critical Test point on Licence Networks for remote potential survey

Installation of remotely read data logger test points at critical asset locations to remotely measure the potential of the pipelines.

Based on current number of the critical test points with stray current drainage bonds on Licence networks for potential survey and previous works performed the programs expenditure is estimated as follows:

Critical Test point on Lic Networks remote potential survey	Units in 2018 to 2022)	10	10	10	10	10	50
	Exp ('000)	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

5.10 Miscellaneous CPS

5.10.1 Introduction

A number of minor items are required as necessary adjuncts to the main cathodic protection system. These items allow the monitoring of the systems performance, mitigate the effects of stray currents, protect from electrical surges and drain induced currents. The miscellaneous CPS program also covers all other CPS related capital works not expressly covered by the other programs planned.

5.10.2 Scope

This program includes the following and any other unforeseen CPS capital works:

- **Replacement of equipment damaged / destroyed by electrical surges**
  - This includes replacement of surge arrestors (battery packs, thyristors), monolithic joints, insulated flanges, and in extreme cases the replacement of pit lids after explosive events.

- **Test point installations**
  - As the network expands, and polyethylene mains renewals isolate sections of old steel mains, the installation of additional test points becomes required.

- **Current drainage point installations**
  - AusNet Services' network is predominately located within a high stray current area, with a number of major train and tram lines running throughout the area. The outcome of VEC surveys may reveal the need to install current drainage systems to combat these stray currents.

- **Electrical bonding / isolation works**
  - Through the course of alterations to the network, via augmentations and mains replacements, it may become necessary to either electrically bond, or isolate, particular networks to ensure adequate cathodic protection system performance.

- **Utility isolation works / service replacement**
  - Through the use of potential and coiling surveys, drains on the cathodic protection system may be identified. Potential drains are often located at points where the gas main has 'touched' other metallic assets in the area, and become electrically bonded to them. To remove these drains from the system, and ensure the full potential of the cathodic protection system is utilised, alteration works may be required to separate them.

- **Earthing Works**
  - Earthing works involve the earthing of structures to eliminate unwanted potential rises induced by nearby electrical infrastructure, either by installation of earthing rods or electrical bonding via cable.

- **Data Loggers**

The installation of CP data loggers on critical assets. This project aims to increase the integrity of the Cathodic protection system's effectiveness on the existing network and in particular that of licenced gas pipelines, via the introduction of remote data loggers.

5.10.3 Works Program

Based on previous works performed the programs expenditure is estimated as follows:

Table 9: Miscellaneous CPS Program

Miscellaneous CPS Program	2017	2018	2019	2020	2021	2022	Period Total
TOTAL Expenditure ('000)	$84	$84	$80	$84	$84	$84	$422

6 OPEX Overview

All maintenance practices are carried out in accordance with the following references.

- AS 4645.2 – Gas distribution networks – Steel pipe systems
- AS 2885 Pipeline – Gas and Liquid Petroleum
- AS 2832 Cathodic Protection of Metals
- AS 2239 Galvanic (sacrificial) Anodes for Cathodic Protection
- Victorian Government Cathodic Protection Regulations – 1998
- Corrosion Protection Services Manual
- Technical Standard CPS 2315 (Cathodic Protection – Transmission Systems)

Maintenance activities are carried out as described in the following sections.

6.1 Potential Survey (Transmission)

At intervals not exceeding six (6) months a potential survey of the pipeline, including tests for stray current electrolysis must be performed. This survey ensures an acceptable level of protection is being maintained on the pipeline. The steel pipeline is considered protected when the potential on all parts of its surface is equal to or more negative than -850mV relative to a saturated copper/copper sulphate reference electrode. A summary of the results of these surveys is submitted annually to the Chief Electrical Inspector. AusNet Services' target protection level for its transmission mains is 98%.

6.2 Potential Survey (Distribution)

At intervals not exceeding six (6) months on high risk networks and intervals not exceeding twelve (12) months on lower risk networks a potential survey of the protected steel pipe is performed. This survey provides an acceptable level of protection is being maintained on the steel pipe. The target protection levels are:

- High pressure pipe 90%;
- Medium pressure pipe 85%;
- Low pressure pipe 85%.

6.3 CPU (Corrosion Protection Unit) Maintenance

All cathodic protection units are monitored at monthly intervals. Identified faults are repaired to ensure that the particular protected asset is being protected satisfactory.

6.4 Coating Defect Survey

Transmission pipeline coating assessment surveys are carried out at 5 year intervals.

Following the non-destructive coating survey, AusNet Services carries out dig ups to visually validate identified coating faults. The number of dig ups is considered based on the overall risk profile of the pipeline such as age of the asset and type of coating, result of previous dig ups, potential loss of gas supply, public safety, environmental damage, etc.

6.5 Coiling Survey

Location of unintentional earthed contacts to buried mains is required to facilitate their subsequent removal and to allow the cathodic protection system to function efficiency.

6.6 Stray Current Electrolysis Testing

This testing is undertaken in conjunction with the Victorian Electrolysis Committee (VEC) and is performed to identify any stray currents and interference connections that may be entering the ground from the tram and train system. This testing is carried out in a five (5) year cycle. The testing is governed by the VEC and is not subject to variation by AusNet Services.

6.7 Protection from Electrical Surges and Induced Voltage

All surge protection devices are inspected for effective operation at twelve (12) month intervals. Polarisation cells are checked for electrolyte level every twelve (12) months.

Where protection devices fail the protection requirements, the device is reassessed and the installation redesigned as necessary.

Polarisation cells have their electrical characteristics measured every five (5) years.

Such measurements normally require laboratory testing. Only cells, which have the required electrical characteristics, are returned to service.