Corrosion Mitigation of

Metal & Concrete Pipes and Structures

AM2739

Contents

Document History

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1. INTRODUCTION

1.1. Purpose

This document has been prepared to provide instruction and information on how South East Water (SEW) achieves the design life of its assets through prudent corrosion control measures.

While this document outlines the standards which apply to each risk control and may provide some general information and reinforcement of critical aspects of each standard, it is not intended that this document replicate technical information contained in the standards.

1.2. Scope of Specification

The following document outlines the minimum corrosion mitigation standards and requirements applied to new or replacement metallic or concrete pipelines and structures at SEW. At PRESENT, ASPECTS OF THIS STANDAR MY BE APPROPRIATE FOR REHABILITATION, ALTHOUGH THE THIS IS NOT THE SCOPE.

1.3. Overview of Corrosion Mitigation

The selection of materials and appropriate risk controls shall be undertaken in accordance with the following basic process:

1) ***Determine the criticality of the asset and select the required asset life of the asset***.
   More critical assets and long service life assets should be constructed from higher durability materials which are more resistant to the forces and the environment that they will be subjected.

2) ***Determine the environmental conditions of the asset***.
   Materials subjected to aggressive environments such as chemical storage, soils, chloride environments, biologically active environments, sewage and hydrogen sulphide gas environments will need to be carefully selected to ensure they are appropriate. It is critical that both internal and external environments are assessed and that the substrate &/or any coating are suitable for the environment to which it is exposed.

3) ***Consider the physical requirements of the asset***.
   Metals are often selected for their mechanical and fabrication properties. Impact resistance, strength and the ability to be welded and moulded are common reasons why metals are selected.
   Concrete is often selected for its compressive strength, relatively low cost, ability to form complex shapes and its' ability to withstand most natural environments. Normal Portland cement concrete is susceptible to the hydrogen sulphide found in sewerage systems.

4) ***Select the appropriate material and product***.
   In consideration of cost and the above factors, select one of the following systems:
   a) non-corrosive materials such as inorganic or polymer materials, ie: composites and plastics. These are generally preferred for buried assets and in highly corrosive situations where corrosion may be difficult to control, or
   b) an appropriate grade of stainless steel (refer to SEW Stainless Steel specification AM2760) where a high corrosion resistance is required along with good fabrication capability, or
   c) an appropriate grade of aluminium where light weight assets with moderate corrosion resistance are required, or

d) an appropriate grade of ferrous metal (steel or ductile iron) where ready fabrication into more complex shapes, high strength and high impact resistance is required without excessive cost.
e) An appropriate class of concrete for load bearing structures.

5) ***Select any necessary additional risk controls***.
Ferrous metals readily corrode and therefore require one or more of the following to ensure adequate asset life:
a) Use of an alternate corrosion resistant metal such as Stainless Steel.
b) A protective corrosion resistant coating (normally a polymer),
c) Moisture and oxygen restriction,
Steel tank underbases cannot be coated, so corrosion is restricted by ensuring that surface water drains away from tank foundations and impervious asphalt aprons are used around steel tanks to keep foundations dry.
d) Cathodic protection (application of electric potential),
All new steel ≥DN300 mains greater than 20m long require Cathodic Protection.
All welded steel tanks require internal Impressed Current Cathodic Protection.
e) Adequate sacrificial thickness (based on expected corrosion rate).
Steel tank underbases usually have thicker than usual (typically 10 or 12mm thick) plate to make an allowance for some level of corrosion.
f) Ventilation and/or chemical dosing to reduce the corrosive strength of any gas phase in contact with the metal. Air treatment measures shall generally be implemented to keep typical H_2S levels below 5 ppm if reasonably practical and below <10ppm if possible.

Portland Cement (PC) concrete and any steel reinforcement within it can corrode when subjected to high chloride &/or high hydrogen sulphide environments. They sometimes therefore require one or more of the following to ensure adequate asset life:
a) use of an alternative corrosion resistant structural material such as Fibre Reinforced Polymer (FRP)
b) use of an alternative corrosion resistant concrete such as geo-polymer concrete or calcium aluminate concrete, or
c) adequate sacrificial thickness (based on expected corrosion rate).
d) a protective corrosion resistant sheet liner (normally PE, PVC or calcium aluminate cement (CAC)), or
e) a protective corrosion resistant coating (normally a polymer), and possibly
f) cathodic protection of any steel reinforcement (refer CORR-25), or
g) Ventilation and/or chemical dosing to reduce the corrosive strength of any gas phase in contact with the concrete. Air treatment measures shall generally be implemented to keep typical H_2S levels below 5 ppm if reasonably practical and below <10ppm if possible.

Dissimilar metals and alloys will corrode when in electrical contact with each other as each has a different electrode potential. When in contact with an electrolyte, one metal acts as the anode and the other as the cathode to form a corrosion cell. To prevent this corrosion, each metal must be electrically isolated from the other using an insulating bush, insulating washers or an insulating membrane. Refer to MRWA figure 306A-B for an example of this kind of insulation.

The remainder of this document assumes that a ferrous metal or PC concrete has been selected for the asset based on cost and the required physical and fabrication properties of the material.

2. COATING AND BARRIER SYSTEMS

The primary protection measure to control metal corrosion and a common measure to control PC concrete corrosion is the application of a protective coating or barrier to isolate the surface from the surrounding environment. Bare ferrous metals are not acceptable unless otherwise approved (eg: Ductile Iron covers). A number of options are available as described in Table 1:

Table 1: Coating and barrier systems

<table>
<tr><th>Coating System</th><th>Material Examples</th><th>Typical Use</th><th>Applicable Standard - Ref</th></tr>
<tr><td>Galvanised coating of ferrous metals</td><td>Zinc rich sacrificial coating</td><td>Low risk items in less corrosive environments (eg: building furniture)</td><td>AS/NZS 4680, and AS2309</td></tr>
<tr><td>Tape system application over metals</td><td>Petrolatum, Butyl rubber</td><td>Coating system repairs and small areas</td><td>WSA 03-2011-3.1 MRWA edition of the Water Supply Code of Australia.
MRWA-W-306A & 400</td></tr>
<tr><td>Polymer coating of metals or PC concrete</td><td>Epoxy, Polyurea or Fusion Bonded Epoxy (FBE)</td><td>Pipes and water or sewage containing structures</td><td rowspan="3">WSA201- Manual for the Selection and Application of Protective Coatings.
Sydney Water Supplement to WSA201.
MRWA Products web portal.
Concrete: Table 307-E from MRWA-S-307, MRWA-S-309 & MRWA-S-401.
Metal coating testing: WSA 03-2011-3.1 MRWA edition & CORR-23A.</td></tr>
<tr><td>Sheet lining of PC concrete</td><td>PVC or PE</td><td>New sewage or sludge containing PC structures</td></tr>
<tr><td>Mortar lining of PC concrete</td><td>Calcium aluminate cement (CAC) mortar</td><td>Rehabilitation of degraded sewage containing PC structures</td></tr>
</table>

In the case of all pipeline products, the coating system is assessed and included in the WSAA Product Appraisal, the SEW product assessment, and the eventual approval of the product as indicated in the MRWA Product web portal (refer http://www.mrwa.com.au/Pages/Products.aspx). The product manufacturer's instructions indicate how their product should be repaired once damaged.

Critical to the success of these coating systems is that their integrity be maintained through the entire life of the asset. Inspections and holiday (coating gap) testing during the delivery and installation of the ferrous products is an important aspect of corrosion risk control. The coating must also remain undamaged during the backfilling process and future maintenance or alterations undertaken on the asset. Refer WSA 03-2011-3.1 MRWA edition of the Water Supply Code of Australia, CORR-23A and WSA201 for details on coating integrity inspections and testing.

3. CATHODIC PROTECTION SYSTEMS

Refer to WSAA Materials Fact Sheet No. 01- Cathodic Protection (CP) for a summary of the principles, management arrangements and design and construction requirements of Cathodic Protection.

Cathodic protection is a method that uses direct electric current to control corrosion (or rusting) of buried or surface level metallic structures. This is achieved by applying an appropriate direct current flowing in opposition to the original corrosion current, thus preventing the natural tendency of the metal to react with its environment.

Cathodic protection is used in the water industry to control and prevent corrosion of assets which are exposed to soil and water environments and which include buried steel pipelines, steel tanks and reservoirs, steel piles, steel weirs and gates, pumping stations and reinforced concrete structures. Cathodic protection is generally applied as a secondary corrosion protection measure as a back up to the primary protective coating. It has proven to be a cost effective, non - intrusive technique for extending the life of assets and reducing the risk of failures.

There are two types of Cathodic Protection:

1) ***Impressed Current Cathodic Protection (ICCP).***
Impressed current systems use an external direct current power source to achieve the driving voltage for the protective current between the structure and the anode. These systems are typically used for poorly coated structures where high protective currents are required and on long well coated pipelines. The output current and consequently the level of protection of these systems can be controlled. Power is typically supplied by the local electric supply company (240 volt AC) to a cathodic protection unit where it is transformed to a lower voltage (typically a maximum of 50 volts) and rectified to produce direct current. Alternative power sources such as solar, wind power and batteries may be used when appropriate.

2) ***Galvanic Cathodic Protection (GCP).***
Galvanic anode systems use metallic anodes that are consumed to provide the source of direct current for protection of the structure. The driving voltage for the protective current comes from the natural potential difference that exists between the structure and a second metal (the galvanic anode). These systems are typically used where small currents are required to achieve protection, such as larger structures with protective coatings in very good condition and small structures. Anodes may be bolted to the structure or placed a short distance away and connected via an electric cable.

Electrolysis mitigation is required where pipelines are adversely affected by the operation of stray DC ground currents which drive and accelerate the corrosion rate. Typical stray current sources are electrified rail transport system i.e. trains and trams and 3rd party cathodic protection systems. Typically, stray traction current drainage systems are installed between the pipeline and the rail system to mitigate against otherwise current discharge from the pipeline and subsequent corrosion.

Cathodic Protection is typically applicable to steel reservoirs and electrically continuous pipelines which comprise of welded joint or electrical bonds around elastomeric seal joints.

3.1 Cathodic Protection References and Standards

Table 2: Cathodic Protection References and Standards

Reference / Standard	Authorising Body	Content description
Electricity Safety Act 1998	Parliament of Victoria	Contains provisions to constitute the VEC (Victorian Electrolysis Committee) and for the ESV to regulate
Electricity Safety (Cathodic Protection) Regulations 2009		Sets out the requirements for the registration and operation of cathodic protection systems
Code of Practice for Electrolysis Mitigation and Cathodic Protection	Energy Safe Victoria (ESV)	Provides specific requirements for the installation, registration, operation and testing of both Cathodic Protection and Electrolysis Mitigation systems in Victoria

AS 2832.1 - Cathodic protection of metals Part 1: Pipes and cables	Standards Australia	This Standard specifies requirements for the CP of buried or submerged metallic pipes and cables
AS 2832.3 - Cathodic protection of metals Part 3: Fixed immersed structures	Standards Australia	Specifies the requirements for the CP of immersed structures such as offshore platforms, jetties, tanks and piles etc
AS 2239 - Galvanic (sacrificial) anodes for cathodic protection	Standards Australia	Specifies requirements for galvanic (sacrificial) anodes for GCP. Specifies the composition of suitable alloys for magnesium, zinc and aluminium anodes and gives details of shapes, design, backfill compositions.
AS 4853 - Electrical hazards on metallic pipelines	Standards Australia	This Standard describes the mechanisms which create hazardous electrical conditions on pipelines and provides guidance on how to calculate and mitigate these hazards
CORR-09 - Electrolysis Test Point Requirements - Installation, Maintenance and Abandonment	Melbourne Water (in consultation with MRWA)	Specifies construction associated with WAT-1411, test point performance requirements; (ES) electrolysis asset numbers, installation, location, maintenance, repair and abandonment of test points.
CORR-14 - Design and Specification of Cathodic Protection for Mild Steel Pipelines	Melbourne Water (in consultation with MRWA)	Provides general CP requirements for new, replacement and existing mild steel pipelines. Outlines the preparations and investigations (desk top and field) required prior to designing the cathodic protection system. Describes the Authority's requirements for the functional and detail design and the specification for galvanic and impressed current cathodic protection
CORR-15 - Installation of ICCP Systems and Commissioning Cathodic Protection Systems for Mild Steel Pipelines	Melbourne Water (in consultation with MRWA)	Describes requirements for the installation, commissioning, reporting and Operations and Maintenance (O&M) manual preparation for ICCP and GCP systems for mild steel pipelines
CORR-17 - Specification for impressed current Cathodic protection systems (ICCP) for the internal protection of **steel storage reservoirs**	Melbourne Water (in consultation with MRWA)	Describes requirements for the design, supply, installation, commissioning, reporting and Operations and Maintenance (O&M) manual preparation for ICCP internal protection of steel reservoirs

Reference / Standard	Authorising Body	Content description
CORR-21 - Cathodic Protection General Requirements for New and Replacement Mild Steel Pipelines	Melbourne Water (in consultation with MRWA)	Specifies requirements for choosing between ICCP and GCP and requirements of: • Specifications, standards and references • Placement and selection of tests points • Other authorities metallic pipelines; • Insulating joints; • Hazardous voltage mitigation; • Bonding requirements; • Rail stray traction mitigation; • Monitoring and reporting obligations during the defects liability period; • Commissioning of CP systems; • Other CP issues relevant to pipeline construction
WAT-1410-M - CP Electrolysis Test Connections Steel Mains DN100-DN300 (refer MRWA web site)	MRWA / MW	Electrolysis test point connection that only has a current lead and a potential lead which are the same size with no earth stake. A WAT-1410 test point is a non-preferred test point and shall not be used unless requested by the Authority.
WAT-1411-M - CP Electrolysis Test Connections Steel Mains DN375-DN1200 (refer MRWA web site)		Electrolysis test point connection, with an orange circular cable which has 3 current leads, an earth stake and a potential lead. May include zero or more galvanic anodes.

Note that the CORR standards can be obtained on request of an MRWA or Melbourne Water officer involved in the management of Cathodic Protection. Alternatively, copies of these documents may be requested through the Standards & Products specialist at standardsissues@sew.com.au.

A number of other CORR specifications exist which provide information on maintenance and less frequent activities:

- CORR-01. Impressed Current Cathodic Protection Monitoring and Maintenance – Pipelines and Service Reservoir Underbases.
- CORR-02. Mild Steel Pipeline Potential Surveys.
- CORR-04. Impressed Current Cathodic Protection Monitoring and Maintenance Service Reservoir / Tank Interiors.
- CORR-06 Corrosion Test Point Maintenance for Mild Steel Pipelines.
- CORR-07. Victorian Electrolysis Committee Area Testing.
- CORR-08. Safety Earth Bed Survey.
- CORR-10. Condition Inspection Report Template for Mild Steel Pipelines.
- CORR-16 Monitoring & Measurement of Potentials on the Underbase of Selected Service Reservoirs
- CORR-19 Graffiti Repainting and Graffiti Repair of ICCP Cubicles and Electrical Meter Boxes.
- CORR-22 Guidelines for Field Assessment of Low Frequency Induction (LFI) Hazards LFI “Rule of Thumb”
- CORR-23A. Coating Defect Surveys - New &/or Replacement Mild Steel Pipelines
- CORR-23B. Coating Defect Surveys - Existing Mild Steel Pipelines.

- CORR-24. Insulated Flanges Testing the Electrical Integrity for New, Replacement and Operational Mild Steel Pipelines.
- CORR-25. Cathodic Protection of Reinforced Concrete Structures
- CORR-90. Corrosion Protection Services on Melbourne Water Mild Steel Pipelines and Water Tanks (Where included as part of the corrosion protection services contract).

3.2 Level of Competence

Cathodic Protection is a specialised area and it requires specific expertise to design, install, manage and maintain the system. Details of cathodic protection specialists are obtainable from the Australasian Corrosion Association (ACA) web site. Competency requirements are summarised in table 3.

Table 3: CP Competency Standards

Task	Level of Expertise
Design and Specification	Corrosion Technologist with a minimum 10 years' experience in cathodic protection systems design and Specification, or Corrosion Technician under the direct supervision of a Corrosion Technologist
Testing and monitoring	Corrosion Technician with experience in pipeline potential survey and cathodic protection system monitoring, under the indirect supervision of a Corrosion Technologist
Analysis and Reporting	Corrosion Technologist with experience in pipeline potential survey and cathodic protection system monitoring or Corrosion Technician under the direct supervision and with report reviews and approvals by a Corrosion Technologist or Corrosion Engineer.
Role	**Qualification**
Corrosion Technologists	Certified and listed technologist on the Australasian Corrosion Association web site: https://membership.corrosion.com.au/training/aca-corrosion-technologists/
Corrosion Technicians	Certified and listed technician on the Australasian Corrosion Association web site: https://membership.corrosion.com.au/training/aca-corrosion-technicians/
Corrosion Engineer	Holds a Bachelor of Engineering in a field relevant to cathodic protection or exhibits an equivalent level of competence and has "Corrosion Technologist" Certifications provided by the ACA or exhibits an equivalent level of competence

3.3 Selection of Cathodic Protection Type

Consideration shall be given between GCP and ICCP when determining which type of cathodic protection system is to be used.

When proposing a CP system the following shall be considered, but not limited to:

- Length of pipeline.
- Connection to existing steel mains.
- Other Authorities metallic pipeline assets that cross or are adjacent.
- Connection or isolation from of other authority assets.
- Proximity to stray traction current sources including existing cathodic protection systems.

- Future development.
- Soil conditions that exhibit;
  - Porosity (aeration)
  - Low electrical resistivity
  - Dissolved salts
  - High moisture content
  - Low pH
  - Within old landfill
- Major road, rail crossings and waterways.
- Junctions of dissimilar metals.
- Requirement to isolate from electrical protective earthing systems. Electrical isolation from network assets such as pump stations.
- Electrical isolation from new and old pipelines.
- Electrical isolation from metallic fire and consumer services.

As a first option (new pipelines >3 km) an ICCP system shall be investigated. The output of an ICCP system can be altered to compensate for either purpose or inadvertent changes within the pipeline scheme over time.

3.4 Cathodic Protection Design

A detail design shall include the following as required:
- Identification of the Authority's and other authorities' pipelines and other metallic assets.
- Identification of all existing CP systems.
- Identification of the likely sources of hazardous voltages including Earth Potential Rise and Low Frequency Induction.
- Identification of the required locations, types and quantities of test points.
- A summary of the adequacy of existing test points indicating the number and type of additional test points required.
- Proposed CP system(s) and locations.
- Availability of power supplies.
- CP current density requirement for new and existing pipelines.
- Bonding requirements to other CP systems.
- Identification of all buried, electrically continuous metallic structures that may require test points for interference testing or cross-bonding.
- Identification of locations requiring insulated flanges/joints or bonds, i.e. offtakes, bypasses, cross connections, valves, network asset such as pump stations, junction to old metallic pipelines, fire and consumer services etc.
- Estimation of galvanic anode design life.
- All other conceptual aspects of the project, pipeline and environmental details that may affect the design and specification.

3.5 Cathodic Protection Test Points

Test Points shall be installed on pipelines to allow electrical measurements to determine whether or not the pipeline is cathodically protected.

Test point configurations shall be installed to provide the following as required:
- Electrical pipe connection to surface level to enable pipe-to-soil potential recording.
- Permit galvanic anode output measurement.

- Bonding point across inline valves, fittings and non-metallic pipe lengths to maintain pipeline electrical continuity between pipe sections.
- Bonding to foreign structures.
- Line current recording location across inline insulating flanges/joints or bonds.
- Electrical isolation, limitation or bonding parts of the pipeline to facilitate the control of cathodic protection and the effects of stray traction current.
- Pipeline to safety earth bed / mat connection to assist with personnel electrical safety where pipelines are subject to induced hazardous currents or ground potentials.

The location of Test Points shall be chosen subject to the following:

- At each end of the pipeline.
- Major road crossings and waterways.
- Rail crossings.
- Steel sleeves or casings.
- Off-takes.
- In-line insulated joints including isolating valves or fittings.
- At the cross-connection to network assets such as pump stations Pump Stations.
- At junction to existing old pipelines.
- Potential source and discharge of stray currents.
- Proximity to buried foreign structures and crossings.
- Ownership demarcation points.
- Requirement to isolate from electrical protective earth.

Test points shall be installed on pipelines greater than 20 metres in length and shall have a separation that shall not exceed:

- 500 metres in urban environments or where future urban growth is foreseeable;
- 1000 metres in a rural or low-density residential environment where no significant urban growth is foreseeable.