REGION OF PEEL

PUBLIC WORKS

DESIGN, SPECIFICATION

& PROCEDURES MANUAL

LINEAR INFRASTRUCTURE

Within Proximity of an Electrified Light Rail Transit (LRT) System

Watermain, Storm Sewer

and Sanitary Sewer Design Criteria Addendum

REVISED January 2015

PUBLIC WORKS

WATERMAIN, STORM SEWER

AND SANITARY SEWER DESIGN CRITERIA ADDENDUM

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1. INTRODUCTION

The design of municipal services in the Region of Peel is to be based upon the current "Public Works Design, Specification & Procedures Manual". All plans are to be reviewed by the Region prior to the construction of services. Such review shall not relieve the engineer from primary responsibility for the design to meet all Federal, Provincial, Regional, and local government requirements. Refer to the Environmental Assessment Process section of this manual for the steps required to fulfill the Class Environmental Assessment process.

The purpose of this addendum is to provide supplementary design standards for projects within the Region of Peel during the planning and construction of light rail transit (LRT) projects. This addendum forms a part of the "Public Works Design, Specification & Procedures Manual" for Water and Wastewater Systems and ***is to be consulted in the design and execution of all light rail-related water and sanitary sewer relocations within the Region of Peel or wherever stray currents have been identified***. The existing Public Works Design Criteria Manuals for Sanitary Sewers and Watermains shall be followed except as specified herein.

In addition, any future work for private development that requires crossing of the LRT will be governed by these standards.

1.1 Geotechnical Investigation

Prior to undertaking construction the Consultant shall undertake a geotechnical investigation at a level of detail congruent with the complexity of the project undertaken. The extent of the program will be determined by the Consultant and approved by the Region. .

The primary purpose of a geotechnical investigation would be to determine the soil's composition, bearing strength and type, and if contamination is present. The consultant shall recommend the appropriate bedding requirements based on the findings of the geotechnical investigation and state them on the drawings. The geotechnical investigation should also determine the relative corrosivity of the soil to the pipeline materials being considered for the installation. At a minimum, the soil and groundwater should be tested for the concentrations of chlorides, sulfates, sulfides, pH, oxidation-reduction potential and resistivity.

Boreholes shall be taken at a maximum spacing of 150 meters along the proposed infrastructure route and to a minimum depth of one (1) metre below the invert of the deepest utility. A minimum of 2 boreholes are required for proposed pipeline lengths in excess of 50 meters.

Where possible boreholes should be placed at all chamber and shaft locations, or as close as possible.

1.2 General Specifications

All water distribution components and lubricants are to be stated on the Region's list of approved products for watermains and must meet applicable AWWA Standards, NSF/ANSI 60 and 61 Standards, or other appropriate standards for approved materials, coatings or linings for distribution system components or chemicals that come into contact with potable water.

1.3 Effective Date

This addendum to the “Public Works Design, Specification & Procedures Manual” will become effective February 2015. All construction contracts advertised and all permits issued on or after February 2015 will be governed by this addendum.

1.4 Definitions

Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment. Corrosion of metallic structures is an “electrochemical” process that involves small amounts of direct electrical current (dc). It is an “electro” process because of the flow of electrical current. It is a “chemical” process because of the chemical reaction that occurs on the surface and corrodes the metal.

Cathodic Protection is the prevention of electrochemical corrosion of a metallic structure by causing the structure to act as the cathode rather than the anode of an electrochemical cell. This is done by applying a direct current to the metal to be protected from another metal or conductive material that acts as an anode.

Stray Current refers to extraneous direct currents in the earth. For LRT facilities it implies rail current leakage to its surroundings. Stray currents can produce corrosive reactions in LRT structures and facilities and in adjacent utilities.

Stray Current Corrosion Control at the Source applies to measures installed with the traction power system and trackwork to assure that stray earth traction currents do not exceed maximum acceptable levels. These levels are based on system characteristics and the characteristics of underground structures.

2. LIGHT RAIL TRANSIT SYSTEM

Future LRT within the Region of Peel have been assumed to consist of Light Rail Vehicles (LRV) within the existing right-of-way (ROW). The LRVs will operate on steel tracks level within the road surface or elevated platforms and will be powered by an overhead contact system (OCS). The LRT is anticipated to operate as a 750-volt ungrounded system with substations spaced approximately ever kilometer along the route. The system is anticipated to have a maximum rail to earth voltage of 50V during normal operation and 70V with one substation out of service.

For the purposes of this design standard, the LRT corridor refers to the entire ROW limits of the LRT system and an additional 30m beyond all intersections along all LRT alignments in the Region of Peel.

2.1 Zone of Influence

The estimated stray current zone of influence of the proposed LRT refers to the offset distance parallel to the centreline of track which stray current is likely to impact an electrically conductive structure. This distance is dependent on the pipeline configuration and soil resistivity as well as the, rail-to-earth resistance, traction current requirement and rail-to-earth voltage of the LRT. The Zone of Influence shall extend a minimum of 30m beyond the rail limits at intersections and to the ROW limits elsewhere.

2.2 Utility Free Zone

Prior to construction of any future LRT, relocation of conflicting infrastructure is required (e.g. manholes are located within the proposed track alignment). In order to minimize service interruptions for the proposed LRT, a Utility Free Zone (UFZ) is established by the transit agency to provide a reasonable buffer between the proposed track bed and underground utilities. The UFZ is primarily based on the clearance envelope from the track to maintain or operate the infrastructure, considering personnel or equipment that must encroach within the LRT corridor.

The UFZ provides vertical and horizontal offsets in which existing infrastructure may require relocation/lowering. The Region may extend the UFZ horizontal offset if necessary to accommodate excavation and maintenance of their assets. Asset crossings are sleeved and cathodic protection is applied to all new metallic pipe work or relined with a structural liner. All crossings should be oriented 90 degrees to the direction of the LRT tracks where practical. Manholes, valves, vaults, test stations or other pipeline appurtenances that require periodic inspection and maintenance should be located outside of the UFZ. Standard drawing 3-1-1 provides general requirements for the UFZ and crossing of the rail alignment. Where assets must remain within the LRT corridor utility free zones, Municipalities realize additional costs are necessary for the required monitoring and maintenance work.

3. GUIDELINES FOR NEW INFRASTRUCTURE

The intention of these design guidelines is to reduce the probability of damage to the infrastructure from stray current occurring between the running rails of the LRT and buried infrastructure. While every situation may be different, there are some important strategies that can be used to help achieve the service life of new infrastructure and limit the risk of service interruptions.

3.1 Material Specification

Product selection will comply with the requirements of the most recent version of the Region of Peel Approved Products List for Linear Wastewater, Watermain, and Storm Sewers, Roads and Traffic. All future infrastructure installed within the LRT corridor shall be non-metallic, unless metallic facilities are required for specific engineering purposes. The only provisions required for non-metallic piping systems are coatings and cathodic protection applied to metallic fittings contained within the piping system.

<u>Concrete Pressure Pipe</u>

Concrete pressure pipe (CPP) is considered a metallic material with regard to exposure to stray current corrosion. Where CPP is specified for use within LRT corridor, an external coal tar epoxy coating should be applied and the pipeline shall be made electrically continuous through the use of shorting straps and joint bonds. The number of bonds required must account for current attenuation along the pipeline and is calculated in accordance with AWWA Manual M9. All joints shall include a minimum of two shorting straps, spaced 90º to 180º apart, in contact with the prestressing wires and four bonding plates (2 each end) for electrical continuity bonding in accordance with AWWA M9. Joint bonding is not required for circumferentially welded pipe joints.

Ferrous Pressure Piping

All new buried cast iron, ductile iron and steel pressure piping shall be coated and cathodically protected. System design shall satisfy the following minimum criteria:

- Conformance with existing standards and specifications of the Region.
- Application of a bonded protective coating and cathodic protection to the external surface of the pipe. Polyethylene sleeves are not recommended for use in stray current areas.

Copper Piping

Copper pipe crossing the LRT tracks shall be of continuous tubing with no intermediate fittings and shall have an external protective coating and cathodic protection. The copper pipe shall be sleeved within the UFZ of the crossing. Solvent welded PVC sleeves may be utilized for water services 50 mm or less. The inside diameter of the sleeve must be a minimum of 50 mm larger than the diameter of the service pipe.

Electrical Conduits

Buried metallic conduits shall include the following provisions:

- Galvanized steel with PVC or other coating acceptable for direct burial, including couplings and fittings. The PVC coating is not required when conduits are installed in concrete.
- Electrical continuity through use of standard threaded joints or bond wires installed across non-threaded joints.

Reinforced Concrete Structures

In general, the design of cast-in-place concrete structures, standard precast components such as chambers, vaults or manholes and segmented concrete rings should be in accordance with CAN/CSA A23.1 and applicable local codes, regulations and standards.

It is recommended that reinforcing steel in underground structures (maintenance holes, valve chambers etc.) be designed to be electrically continuous. All buried structures shall be electrically isolated from the proposed pipe, per standard drawing 3-2-1, with isolation sleeves at wall and floor penetrations and pads supporting all valve stands and metallic components.

In addition to electrically isolating buried structures, external coal tar epoxy or mastic coating should be applied to underground structures within the LRT corridor.

3.2 Replacement/Relocated Facilities

Relocated or replaced utilities, installed by transit contractors as part of contractual agreement between the transit agency and the Region, shall be installed in accordance with the Region's specifications and shall include the following minimum provisions. These provisions are applicable to ferrous and reinforced concrete pressure piping. Other materials and structures will require individual review.

- Electrical continuity through the installation of insulated copper wires across all mechanical joints for which electrical continuity cannot be assured
- Installation of valves, electrical isolation fittings and test facilities on each side of the crossing. Cathodic protection shall be applied to the replaced/relocated pipeline and shall be installed in accordance with standard drawing 3-2-2.
- All pipelines crossing the LRT tracks shall be installed inside casings. The pipelines shall be installed utilizing insulating casing spacers and end seals to electrically isolate the pipeline from the casing. Test facilities shall be installed for all casings.
- For replaced/relocated pipelines that traverse parallel to the direction of the LRT tracks electrical isolation and testing facilities should be installed at approximately 150 m intervals. All branches off of the pipeline and connections to existing pipelines shall be electrically isolated from the replaced/relocated pipeline.
- Copper water services that cross the LRT tracks shall be electrically isolated from metallic water mains and from non-buried piping such as that contained in a structure through the use of an isolation corporation stop or isolation union. The isolation union should be installed where the piping enters through a wall or a floor. Pipe penetrations shall be electrically isolated from the building structural elements. The insulator should be installed on the upstream side of the meter or inside the structure and not buried. A ground rod shall be installed and attached to the piping downstream of the isolation union at the building entrance.

3.3 Gravity Flow Piping (Non-Pressurized)

All future infrastructure installed within the LRT corridor shall be non-metallic, unless metallic facilities are required for specific engineering purposes.

Corrugated steel piping shall be internally and externally coated with a sacrificial metallic coating and a protective organic coating.

The design and fabrication of cast or ductile iron piping must include the following provisions:

- An internal mortar lining with a bituminous coating on ductile iron pipe only (not required for cast iron soil pipe)
- A bonded protective coating or unbonded dielectric encasement on the external surfaces in conformance with AWWA Standard C105.
- A bituminous mastic coating on the external surfaces of pipe 150mm on each side of a concrete/soil interface

Reinforced concrete non-pressure piping shall include the following provisions:

- Water/cement ratios meeting the minimum provisions of AWWA C301

- Maximum 250ppm chloride concentration in the total concrete mix (mixing water, cement, admixture and aggregates)
- Use Type I or Type II cement
- Piping that will be installed parallel to the LRT tracks shall have an external protective coatings applied.

3.4 Test Stations

All test stations shall be located a minimum of 2.0m outside of travelled lanes and shall be in general agreement with standard drawing 3-1-1. Test stations shall be placed in locations that do not require traffic control for testing access.

Permanent test/access facilities shall be installed every 150m and at all insulated connections to allow for verification of electrical continuity, electrical effectiveness of insulators and coating, and evaluation of cathodic protection levels for all infrastructure running parallel to the LRT. Test facilities to be installed for all infrastructure that cross the LRT. The design of CPP must also consider the effects of stray current regarding the increased probability of hydrogen embrittlement of highly stressed steel components.

For pipelines that cross under and perpendicular to the track, install valves, isolation joints and test stations on each side of the crossing. Locate the joints a minimum of 2m beyond the LRT train envelope to facilitate future maintenance. The test station should contain two test wires connected to each side of the joint and two test wires connected to the casing (if a metallic casing is utilized). A minimum of two galvanic anodes (zinc for PCCP and magnesium for steel and ductile iron) and one underground reference electrode should be installed on each side of the joint. Additional galvanic anodes may be necessary to achieve adequate cathodic protection. Design calculations must be performed to determine if additional anodes are necessary.

At select locations, determined to be at high risk for stray current corrosion, the installation of coupon or corrosion rate test equipment may be appropriate.

For pipelines that are parallel to the LRT, install isolation joints and test stations at each end of the segment of pipeline that is laid parallel to and within 30m of the track. Where the length of the pipeline that is parallel to the track exceeds 150m, install isolation joints and test stations, at intervals of approximately 150m. At select locations, determined to be at high risk for stray current corrosion, the installation of current measurement, coupon or corrosion rate test equipment may be appropriate. Note: When the pipeline is installed inside a casing for the length of the parallelism, isolation joints are installed at the ends of the pipe segment within the casing.

When the pipeline is located adjacent to an LRT traction power substation an additional test station shall be installed. The test station shall include two cables (minimum No. 6 AWG) attached to the pipeline, a test lead to an underground reference electrode, a test lead to an underground coupon and provisions for adding stray current drainage bond cables (minimum No. 4 AWG) between the test station and the traction power substation.

Appendix E includes wire identification tables, for various test station arrangements.

3.5 Monitoring Requirements

Monitoring is required for all future assets within the LRT corridor to assess possible damage and prevent critical failure. By periodically monitoring the pipeline, corrosion activity can be detected and remedial action taken before significant damage occurs. Test facilities should be installed as outlined in Section 3.4 in order to conduct monitoring. The priority for stray current monitoring facilities and frequency of testing shall be determined by the Region and shall satisfy requirements of the Region's asset management group.

Potentials measured reflect electrochemical reactions occurring on metal surfaces in the pipeline and are measured against a standard reference electrode. A copper–copper sulfate electrode (CSE) is commonly used for pipeline surveys.

An effective monitoring program starts by taking an initial set of readings prior to commissioning the LRT system and then about one year after the pipeline is installed. Time intervals between subsequent surveys are usually established after evaluating the results of prior surveys. Changes in the vicinity of the pipeline, such as new construction, implementation of cathodic protection, or adjustments in existing cathodic protection systems on other structures, may necessitate surveys sooner than otherwise scheduled. Significant changes in the readings at a particular location over time or significant differences in the readings at one location compared with readings at adjacent or nearby locations may be indicative of corrosion or stray current interference. A qualified corrosion engineer, experienced in the protection of concrete pressure pipe, is important not only for conducting monitoring surveys but also for interpreting the readings.

For PCCP pipelines without an applied direct current on it (no stray current and no cathodic protection), pipeline potentials less negative than –200 mV (CSE) indicate there is 10% chance that corrosion is occurring. Pipeline potentials more negative than –350 mV (CSE) have a 90% chance of corrosion occurring. Variations in potentials along the line greater than 100 mV, or long-term trends toward more negative potentials also indicate high chances for corrosion activity.

For steel and cast-iron pipelines refer to the NACE SP0169 or CSA C22.3 No. 4 for monitoring requirements.

There are two basic survey techniques that are employed during monitoring work; these are:

- Pipe to soil potential; and
- Side drains.

Each is defined in the following sections with an additional discussion related to surface conditions.

<u>Pipe to Soil Potential</u>

A pipe to soil potential survey is performed on electrically continuous piping systems. Potentials are measured by connecting one pole of a voltmeter to the pipeline at a test station and connecting the other pole to a CSE. The CSE is moved along directly above the pipeline and voltage measurements are made approximately every 0.75 m. Potentials are recorded and an “over-the-line” potential profile is later generated in graphic form.

Side Drains

Side drain potentials refer to potentials measured laterally away from the pipeline in both directions. Physical constraints permitting, the side electrodes are placed away from the pipe a minimum distance of one half the pipe diameters plus the depth of cover. The voltmeter connection to the pipeline is the same as that described for a pipe-to-soil potential survey. Data are also collected every few feet along the pipeline. A potential profile is later generated in graphic form.
The following indicates some of the limitations in monitoring for corrosion activity on any pipeline:

- The soil surface must be adequately moist to obtain meaningful readings.
- Monitoring potentials cannot be taken through either concrete or asphalt paving. When readings are to be taken in paved areas, it is necessary to drill small holes through the pavement to permit the reference electrode to be in contact with moist soil or to place the reference cell on unpaved soil near the pipeline.
- Stray currents or impressed direct currents affect potential measurements. Currents collecting on the pipeline make measured potentials more negative. Discharging currents make potentials more positive.
- Electrical potentials of organically coated steel pipelines are more negative than potentials of concrete or mortar coated steel and will therefore appear as corrosion sites when connected to concrete pipelines.
- Knowledge of the existence and location of other underground structures (tanks, pipelines, etc.) in the vicinity and appurtenances (valves, branch outlets, etc.) on the pipeline being monitored are necessary for proper interpretation of the readings.

3.6 Electrical Insulation of Piping

Devices used for electrical insulators for corrosion control shall include non-metallic inserts, insulating flanges, couplings, unions, and/or concentric support spacers. Devices shall meet the following criteria:

- A minimum resistance of 10 megohms prior to installation.
- Sufficient electrical resistance after insertion into the operating piping system such that no more than 2 percent of a test current applied across the device flows through the insulator, including flow through conductive fluids if present.
- Mechanical and temperature ratings equivalent to the structure in which they are installed.
- Internal coating (except complete non-metallic units) with a polyamide epoxy, or approved equivalent (must be in compliance with NSF 61 for

potable water pipelines) for a distance on each side of the insulator equal to two times the diameter of the pipe in which they are used. Where conductive fluids with a resistivity of less than 2,000 ohm-centimeters are present, internal coating requirements shall be based on separate evaluation.

- Devices (except non-metallic units) buried in soils must be encased in a protective coating.
- Devices (except non-metallic units) installed in chambers or otherwise exposed to partial immersion or high humidity must have a protective coating applied over all components.
- Inaccessible insulating devices, such as buried or elevated insulators, shall be equipped with accessible permanent test facilities.
- A minimum clearance of 300mm shall be provided between new and existing metallic structures. When conditions do not allow a 300mm clearance, the design shall include special provisions to prevent electrical contact with existing structure(s).
- Insulating couplings shall be NSF 61 certified for potable water pipelines.

3.7 Electrical Continuity of Piping

All new metallic pipes to be installed within the LRT corridor shall be electrically continuous with bonded joints installed per standard drawing 3-2-2.

Electrical continuity shall be provided for all non-welded metallic pipe joints and shall meet the following criteria:

- Use direct burial, insulated, stranded, copper wire with the minimum length necessary to span the joint being bonded.
- Wire size shall be based on the electrical characteristics of the structure and resulting electrical network to minimize attenuation and allow for cathodic protection.
- Use a minimum of two wires per joint for redundancy.
- Surface preparation of the structure to be coated shall be required in accordance with the coating manufacturer's recommendations.

3.8 Cathodic Protection

All new metallic pipes to be installed within the LRT corridor shall follow the requirements of OPSS 702 Cathodic Protection on New and Existing Watermain and OPSS 442 Corrosion Protection of New and Existing Watermains.

The design of cathodic protection shall be by a NACE International certified Corrosion Specialist or Cathodic Protection Specialist. Cathodic protection shall be accomplished by sacrificial anodes to minimize corrosion interaction with other underground utilities. Impressed current systems shall be used only when the use of sacrificial systems is not technically and/or economically feasible. Cathodic protection schemes that require connection to the transit system negative return system, in lieu of using a separate isolated anode ground bed, shall not be permitted.

Cathodic protection system design shall be based on industry standards (NACE International, Canadian Gas Association, Ontario Provincial Standard Specifications, etc.), recommended practices, and criteria. Theoretical design calculations shall include the following parameters:

- Estimated percentage of bare surface area
- Cathodic protection current density with consideration to pipe material and environmental conditions
- Estimated current output per anode
- Estimated total number of anodes, size and spacing
- Minimum anode life of 25 years
- Estimated anode bed resistance

Impressed current rectifier systems, if required, shall be designed using potentially controlled rectifiers with permanent reference electrode facilities. Rectifiers shall be rated at a minimum of 50% above calculated operating levels to overcome a higher-than-anticipated anode bed resistance, lower-than-anticipated coating resistance, or presence of interference mitigation bonds. Other conditions which may result in increased voltage and current requirements shall be considered.

Test facilities consisting of a minimum of two structure connections, one reference electrode connection, conduits and termination boxes shall be designed to permit initial and periodic testing of cathodic protection levels, interference currents and system components (anodes, insulating devices and continuity bonds). The Design Engineer shall specify the locations and types of test facilities for each cathodic protection system.

3.9 Coatings

External coatings shall be applied in areas of high chlorides, low pH, high sulfates and/or where the pipeline is located within a fluctuating ground water (cyclical wet/dry) area. Typically, a coal tar epoxy coating is applied if the chlorides are greater than 500mg/kg in soil (200 mg/l groundwater) unless it is also subject to cyclical wet/dry conditions. If subject to cyclical wet/dry conditions the chloride concentration threshold drops to 150mg/kg soil and 50mg/l in groundwater. For sulfates, the typical thresholds are 1000 mg/kg in soil and 150mg/l in groundwater. The pH threshold is typically 5 or less.

All coatings must be applied in accordance with manufacturer's specifications and meet applicable AWWA standards (C217).

Coatings within the LRT corridor shall satisfy the following criteria:

- Minimum volume resistivity in accordance with ASTM D-257 (typically 10^{12} to 10^{14} Ω-m).
- Minimum thickness as recommended for the specific system, but not less than 16 mm.

- A chemical or mechanical bond to the metal or concrete surface. Pressure-sensitive systems are not acceptable;
- Minimum 5 year performance record for the intended service.
- Mill application wherever possible, with field application of a compatible coating system for joints and repairs.
- Mechanical characteristics capable of withstanding reasonable abuse during handling and earth pressure after installation for the design life of the system.

Generic coating systems include but are not limited to the following:

- Extruded polyethylene/butyl based system
- Coal-tar epoxies (two component systems)
- Polyethylene-backed butyl mastic tapes (cold applied)
- Bituminous mastics (airless spray)

Coating Selection

Coatings that are applied to control corrosion must:

- Have established performance records for the intended service and be compatible with the base metal to which they are applied.
- Have minimum life expectancies, defined as the time prior to major maintenance or reapplication, of 15 to 20 years.

3.10 Preferred Alignment of Infrastructure

Wherever reasonably possible, future infrastructure should avoid placement within the LRT corridor.

At locations where the proposed metallic pipe crosses or parallels an existing metallic pipeline a wire shall be thermite welded to each pipe system and brought to a test point. The purpose of this test point is to monitor interference. The configuration of the proposed infrastructure shall generally conform with standard drawing 3-2-3, Foreign Bonded Pipe Test Station. Where pipes do not maintain a minimum 300mm offset, a pipe insulation spacer is required per standard drawing 3-2-4.

3.11 Completion Certificate Requirements

Prior to the issuance of the Substantial Completion Certificate, the Contractor shall demonstrate to the Region that the following for the newly installed metallic distribution system:

- Water distribution system is electrically continuous between isolating elements.
- Electrical discontinuity exists across all isolating elements in the distribution system.
- Test points are in good working order (i.e. that the electrical path from the anodes to the test point and from the test point to the pipe and other elements as required is complete).

- Cathodic protection, if installed, satisfies the criteria for effective cathodic protection stated in Canadian Gas Association Recommended Practice OCC-1-2005 for steel and ductile iron or NACE International Standard Practice SP0100 for concrete pressure pipe
- As-built drawing has been provided that identifies and depicts the location of all materials installed.

Additionally the Design Checklist (see appendix B) should be completed, with all submittals and requirements documented.

4. GUIDELINES FOR EXISTING INFRASTRUCTURE

All assets that have been identified for replacement and/or relocation shall follow the requirements for Future Infrastructure, outlined in Section 3.

4.1 General Assessment of Infrastructure

In general, it is recommended that all municipal water and sewer infrastructure be removed from under the proposed LRT track location and UFZ. This ensures that any future intervention on the water or sewer lines should not affect the operation of the LRT system.

For existing assets outside of the UFZ but within the LRT corridor, the Region shall determine priority and importance based on the age and status of the existing infrastructure in order to assess necessity of replacement. The follow described general high level considerations to be included when determining priority of asset replacement:

- Existing shallow water lines that cross the transit system should be relocated to a lower depth and installed inside a casing. Watermains are difficult to inspect and to perform preventative maintenance. Watermain breaks require an immediate intervention with excavation, to repair the break. Therefore, priority is placed on the relocation of the watermain to a location outside the LRT corridor.
- Existing metallic pipelines that run parallel to and below the transit system should be relocated laterally if there is available right of way. Relocation or replacement of a pipeline should also be considered if the remaining useful design life of the pipeline is less than the design life of the transit system. The relocated lines are constructed of non-metallic materials if practical. If metallic materials are utilized, the pipeline must be electrically continuous within the right of way of the transit system. Electrical insulators should be installed where the pipeline leaves the transit right of way.
- Concrete Pressure pipe (CPP) parallel to the LRT can be particularly susceptible to stray current issues. Embedded pipe is particularly vulnerable and has increased failure risks because pre-stressing wires can fail causing full pipe and system failure. For existing infrastructure, replacement and relocation is recommended; however, if this is not

feasible then test stations should be installed at strategic locations to monitor stray current activity.

- Relocation of the existing storm and sanitary sewers is based on depth of cover required by the transit system foundations. The sanitary sewers are chosen for relocation before the storm sewers because they are more likely to require intervention than storm sewers. Sanitary sewers typically operate with lower flow velocities and have a higher degree of solids in their effluent; therefore, sanitary sewers typically require more periodic cleaning and flushing than storm sewers.
- Service laterals manholes and catch basins within the LRT corridor should be replaced or rehabilitated as part of the LRT construction. All watermain services, valves, fittings and fire hydrants shall be replaced and cathodically protected.

There may be an opportunity to install a structural liner into existing sanitary and storm sewer gravity pipes. A cured-in-place pipe (CIPP) structural liner can be installed without excavation and with minimal interruption to the surroundings. The liner would be a structural liner designed for the proposed LRT loading and associated vibrations. The CIPP liner will replace the structure of the existing pipes, but will not affect the structure of the services or laterals or the catch basin leads. All CIPP liners shall be designed in accordance with ASTM F1216 or F2019 for inverted or pulled in place installations respectively.

4.2 Test Stations

All test stations shall be located a minimum of 2.0m outside of travelled lanes and shall be in general agreement with standard drawing 3-1-1.

For pipelines that are perpendicular to the track and/or within 30m of the tracks, install a 2-wire test station and underground reference electrode for the pipeline at the location nearest the tracks. At select locations (within or in excess of 10m from the tracks), determined to be at high risk for stray current corrosion, the installation of coupon or corrosion rate test equipment may be appropriate.

For pipelines that are parallel to the LRT, install a 2-wire test station and underground reference electrode for the pipeline at approximate 150m intervals for segments of pipeline that are parallel to and within 30m of the tracks. At select locations, determined to be at high risk for stray current corrosion, the installation of current measurement, coupon or corrosion rate test equipment may be appropriate.

4.3 Monitoring Requirements

Where existing infrastructure remains in service within the LRT corridor without bonding or corrosion protection, monitoring is required in order to assess anticipated damage and prevent critical failure. Monitoring requirements for existing infrastructure are similar as described in Section 3.5. The priority for stray current monitoring facilities and frequency of testing shall be determined by the Region and satisfy requirements of the Region’s asset management group.

4.4 Abandonment of Infrastructure

All existing water service lines to be abandoned shall be completely removed from the stop/valves to the existing water meter. The existing valve shall be closed at the main prior to removal of the piping. Whenever possible, it is preferable to remove all watermains and sewers from the LRT corridor; however, in some instances it may be necessary to abandon the assets. In such cases, the Region's "Public Works Design, Specification & Procedures Manual" shall be followed.

5. REFERENCE MATERIAL/ RESROURCES

1. NACE International Standard Practice SP0100, "Cathodic Protection to Control External Corrosion of Concrete Pressure Pipelines and Mortar-Coated Steel Pipelines for Water or Waste Water Service".
2. NACE International Standard Practice SP0169, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems.
3. NACE International Standard Practice SP0200, "Steel-Cased Pipeline Practices".
4. NACE International Standard Practice SP0286, "Electrical Isolation of Cathodically Protected Pipelines".
5. NACE International Test Method TM0497, "Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems".
6. NACE International Publication 35201, "Technical Report on the Application and Interpretation of Data from External Coupons Used in the Evaluation of Cathodically Protected Metallic Structures".
7. NACE International Publication 05107, Report on Corrosion Probes in Soil or Concrete".
8. Canadian Gas Association Recommended Practice OCC-1-2005, "Control of External Corrosion on Buried or Submerged Metallic Piping Systems".
9. American Concrete Pressure Pipe Association, "External Protection of Concrete Pressure Pipe".
10. AWWA, Manual M9, "Concrete Pressure Pipe".
11. AWWA Standard C105, "Polyethylene Encasement for Ductile Iron Pipe"
12. CSA C22.3 No.4 (R2004) "Control of Electrochemical Corrosion of Underground Metallic Structures", Third Edition.
13. TCRP Report No. 155 Track Design Handbook for Light Rail Transit Chapter 8, Corrosion Control
14. Construction Specification for Corrosion Protection of New and Existing Watermains (OPSS 442), November 2010.
15. AWWA C217 "Petrolatum and Petroleum Wax Tape Coatings for the Exterior of Connections and Fittings for Steel Water Pipelines"
16. ASTM G-51, "Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing"
17. ASTM D-512, "Standard Test Methods for Chloride Ion In Water"
18. ASTM D-516, "Standard Test Method for Sulfate Ion in Water"
19. ASTM C 452-75, "Standard Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate"
20. ASTM D-257, "Standard Test Methods for DC Resistance or Conductance of Insulating Materials"

21. ASTM F1216 “Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube”
22. ASTM F2019 “Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)”
23. OPSS 702 Cathodic Protection on New and Existing Watermain and
24. OPSS 442 Corrosion Protection of New and Existing Watermains.

APPENDIX A

ABBREVIATIONS

ANSI	American National Standards Institute
ASTM	American Standards for Testing and Materials
AWG	American Wire Gauge
AWWA	American Water Works Association
CI	Cast Iron
CIPP	Cured-In-Place Pipe
CSA	Canadian Standards Association
DI	Ductile Iron
LRT	Light Rail Transit
OCS	Overhead Contact System
OPSD	Ontario Provincial Standard Drawings
OPSS	Ontario Provincial Standard Specifications
PCCP	Prestressed Concrete Cylinder Pipe
PVC	Poly-Vinyl Chloride
ROW	Right-of-Way
UFZ	Utility Free Zone

APPENDIX B
CORROSION DESIGN CHECKLIST

Evaluation Completed By: ______________________ Date: ___________

1. GENERAL INFORMATION

Project Name: ______________________ Location: ________________

Contract Number: ______________________

Drawing Numbers: ____

2. EXISTING PIPE ANALYSIS (ALL SIZES)

Pipe Function: ________________ Size: ________________

Length of pipe evaluated: ___________

Minimum distance from rail lines: ___________Orientation: ____Parallel
____Perpendicular
____Acute Angle____º

Distance to nearest traction power substation:____________

Pipe Material:

______PVC ______CIP ______DIP ______PCCP _____RCP ______Steel

______Other (Specify: _______________________________)

Existing Corrosion Control:

______None

______Bonded joints or welded joints

______Coating (Specify: _______________________________)

______Cathodic protection: ______Galvanic

______Impressed Current

______Test stations

3. PRE-CONSTRUCTION CONSIDERATIONS

- Future/proposed extension of dc transit rail lines within 100m of the pipeline
- Adequacy of existing corrosion control
- Feasibility of joint bonding, if necessary
- Leak history of pipeline
- Remaining design life of pipeline
- Consequence of pipeline failure (high/low)

4. STRAY CURRENT ANALYSIS

Rail Line Parameters:

______Subway

______Elevated

______At Grade

Track Construction Type:

______Direct Fixation

______Tie and Ballast

______Embedded

Design Track-to-Earth Resistance______ohm-300m

Design Track-to-Earth Potential ______volts (normal operations)

Traction Power Grounding Configuration:

______Ungrounded

______Diode Grounded

______Directly Grounded

Pipeline/Environmental Parameters:

______Pipe <10m from rail

______10m<Pipe <20m from rail

______20m<Pipe<30m from rail

______30m<Pipe<100m from rail

______Pipe Material

______Pipe <100m from traction power substation

______Soil resistivity <1000 ohm-cm

______Order of magnitude change in soil resistivity in less than 300m

______Stray current interference documented on adjacent pipelines

______High consequence of pipeline failure

5. STRAY CURRENT MITIGATION AND MONITORING REQUIREMENTS

______Bonded joints

______Insulated joints

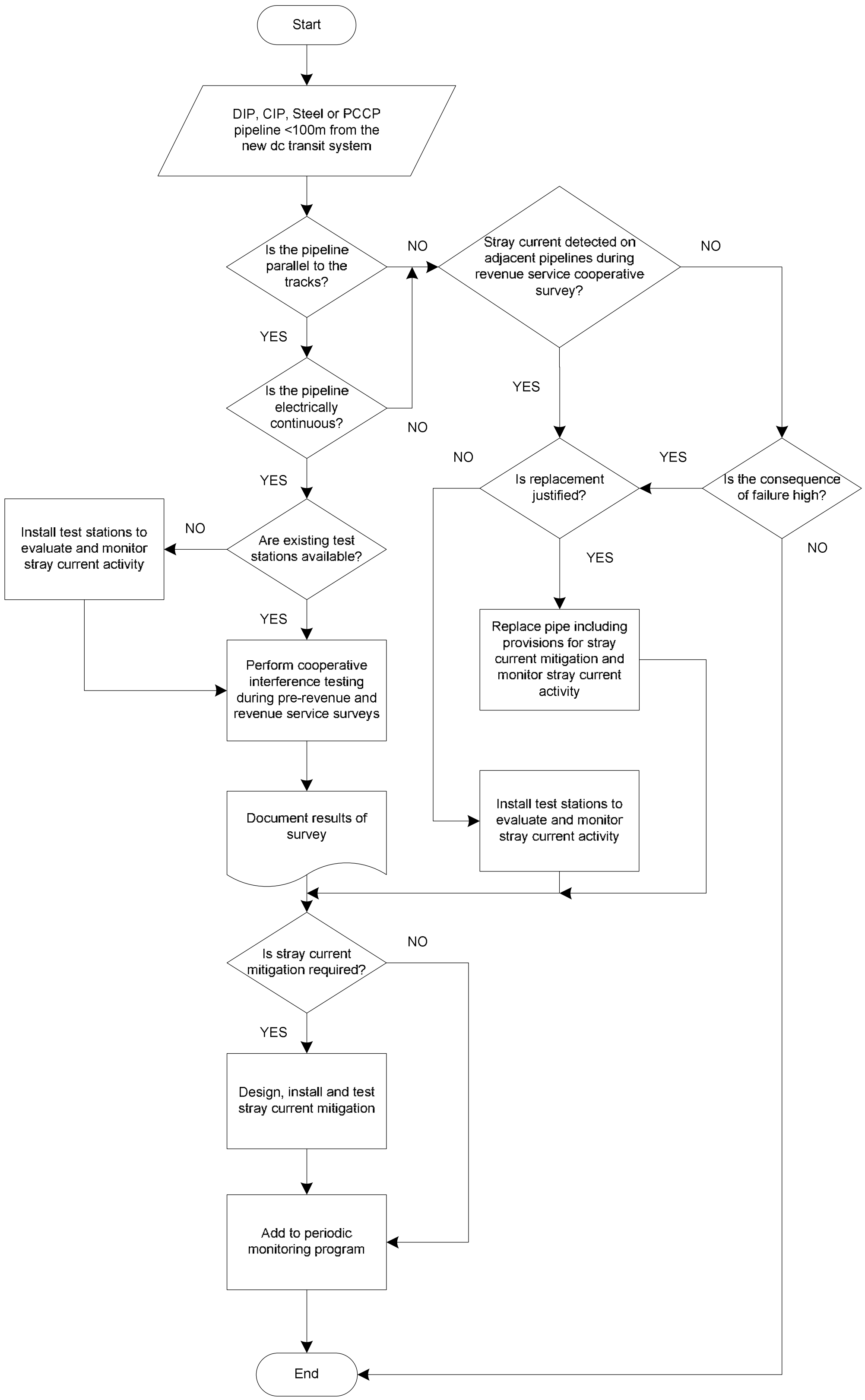
______Cathodic protection:

- ______Zinc Anodes
- ______Magnesium Anodes
- ______Impressed Current

______Test stations:

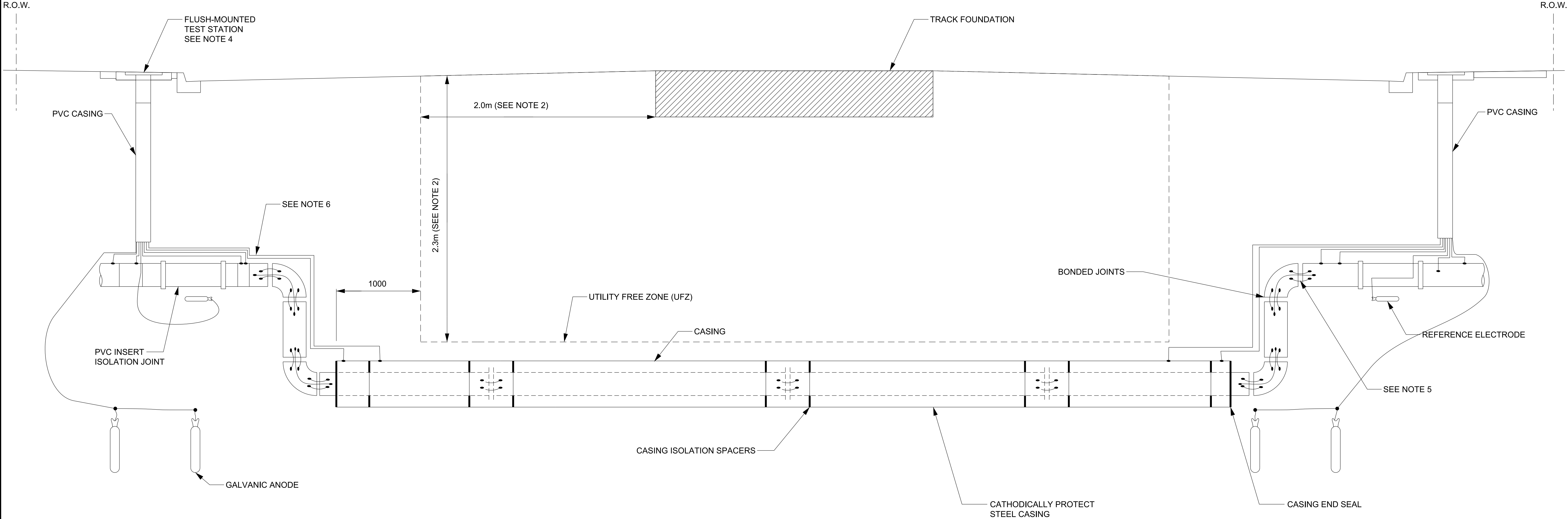
- ______Reference electrodes
- ______Coupons
- ______Corrosion rate probes
- ______Zinc grounding cells
- ______Stray current drainage

Existing Pipeline Stray Current Evaluation for New DC Rail Transit System Construction



APPENDIX C
STANDARD CORROSION DESIGN DETAIL DRAWINGS

3-1-1	Typical Pressure Pipe Lowering Detail
3-1-2	Typical Gravity Pipe Lowering Detail
3-1-3	Typical Arrangement for Pipes Cross LRT
3-1-4	Typical Arrangement for Pipes Parallel to LRT
3-2-1	General Chamber Details and Notes for within LRT Corridor
3-2-2	Metallic Pipe Bonding
3-2-3	Test Station Detail
3-2-4	Pipe Isolation Spacer
3-2-5	Insulated Pipe Coupling Detail
3-2-6	Insulating Flange Detail



PREFERRED PIPE MATERIAL FOR RAIL CROSSINGS BASED ON EXISTING PIPE BEYOND RAIL CORRIDOR

EXISTING PIPE MATERIAL	PREFERRED MATERIAL	
	< 400mm Ø	> 400mm Ø
PRESTRESSED CONCRETE CYLINDER PIPE (PCCP)	BONDED PCCP	BONDED PCCP
POLYVINYL CHLORIDE (PVC)	PVC	PVC
DUCTILE IRON (DI)	PVC	DI
CAST IRON (CI)	PVC	DI

NOTE

1. THIS STANDARD DRAWING IS INTENDED TO DEMONSTRATE GENERAL ARRANGEMENT AND COMPONENTS OF WATERMAIN AND PRESSURE PIPE SYSTEMS CROSSING THE LRT UFZ.
2. THE UTILITY FREE ZONE DIMENSIONS ARE DETERMINED BY THE TRANSIT SYSTEM DESIGNERS AND ARE SUBJECT TO CHANGE BASED ON FINAL LRT STANDARD REQUIREMENTS.
3. THE LOWERING DETAIL SHOWN IS FOR EXAMPLE PURPOSED ONLY. LOWERING AND CROSSING DESIGN DETAILS ARE DETERMINED ON A CASE BY CASE BASIS.
4. TEST STATIONS SHALL BE PLACED OUTSIDE OF THE UTILITY FREE ZONE AND TRANSIT SYSYEM ENVELOPE. THE TEST STATIONS SHOULD BE PLACED IN A LOCATION THAT DOES NOT REQUIRE TRAFFIC CONTROL FOR TESTING ACCESS AND WHERE THEY DO NOT INTERFERE WITH OR PRESENT A HAZARD TO PEDESTRIAN OR VEHICULAR TRAFFIC.
5. BOND ALL METALLIC PIPE 30m BEYOND RAIL (MIN.) OR TO ROW LIMITS.
6. INSTALL TEST STATION LEADS IN SCHEDULE 40 PVC CONDUIT.
7. WHERE PIPE CANNOT BE LOWERED, REPLACE AND ENCASE IN EXISTING LOCATION.
8. CASING SHALL BE NON-METALLIC WHERE REASONABLE.

Region of Peel
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PUBLIC WORKS
STANDARD DRAWING

REV. DATE: FEBRUARY 2015

APPROVED BY	DRAWN BY
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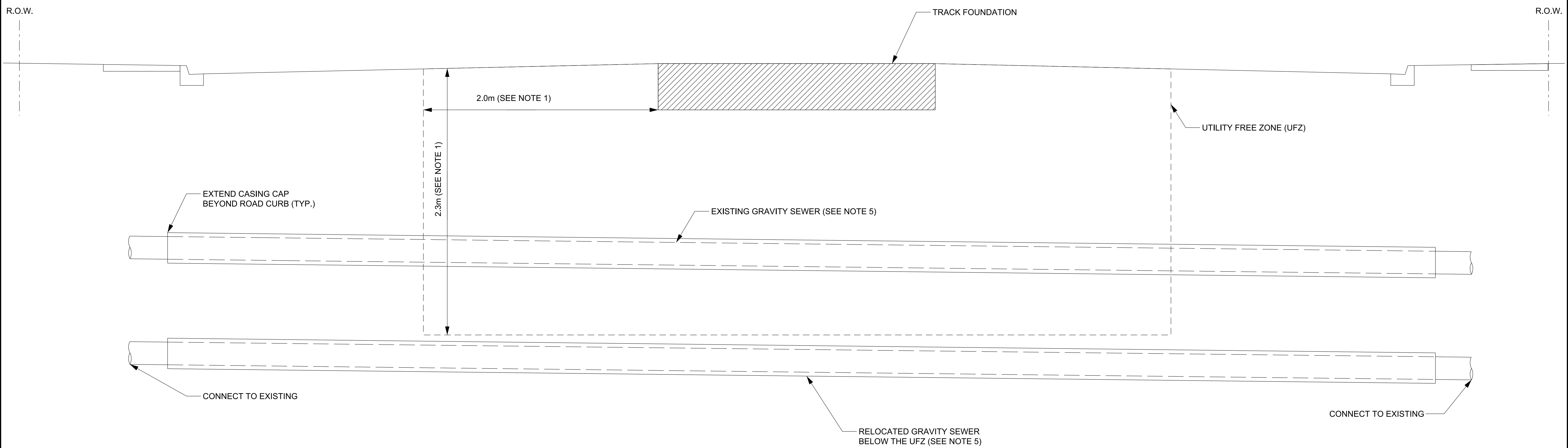
STD. DWG. NUMBER	SCALE
3-1-1	**N.T.S.**

TYPICAL PRESSURE PIPE LOWERING DETAIL



PREFERRED PIPE MATERIAL FOR RAIL CROSSINGS BASED ON EXISTING PIPE BEYOND RAIL CORRIDOR		
EXISTING PIPE MATERIAL	PREFERRED MATERIAL	
	< 400mm Ø	> 400mm Ø
PRESTRESSED CONCRETE CYLINDER PIPE (PCCP)	BONDED PCCP	BONDED PCCP
POLYVINYL CHLORIDE (PVC)	PVC	PVC
DUCTILE IRON (DI)	PVC	DI
CAST IRON (CI)	PVC	DI

NOTE

1. THE UTILITY FREE ZONE (UFZ) DIMENSIONS ARE DETERMINED BY THE TRANSIT SYSTEM DESIGNERS AND ARE SUBJECT TO CHANGE BASED ON FINAL LRT STANDARD REQUIREMENTS.
2. THE LOWERING DETAIL SHOWN IS FOR EXAMPLE PURPOSED ONLY. LOWERING AND CROSSING DESIGN DETAILS ARE DETERMINED ON A CASE BY CASE BASIS.
3. TEST STATIONS SHALL BE PLACED OUTSIDE OF THE UTILITY FREE ZONE AND TRANSIT SYSYEM ENVELOPE. THE TEST STATIONS SHOULD BE PLACED IN A LOCATION THAT DOES NOT REQUIRE TRAFFIC CONTROL FOR TESTING ACCESS AND WHERE THEY DO NOT INTERFERE WITH OR PRESENT A HAZARD TO PEDESTRIAN OR VEHICULAR TRAFFIC.
4. BOND ALL METTALIC PIPE 30m BEYOND RAIL (MIN.) OR TO ROW LIMITS.
5. WHERE PIPE CANNOT BE LOWERED OUTSIDE OF THE UFZ, REHABILITATE WITH STRUCTURAL LINER (CURED IN PLACE PIPE, OR GLASS REINFORCED PLASTIC), OR REPLACE AND ENCASE IN EXISTING LOCATION.

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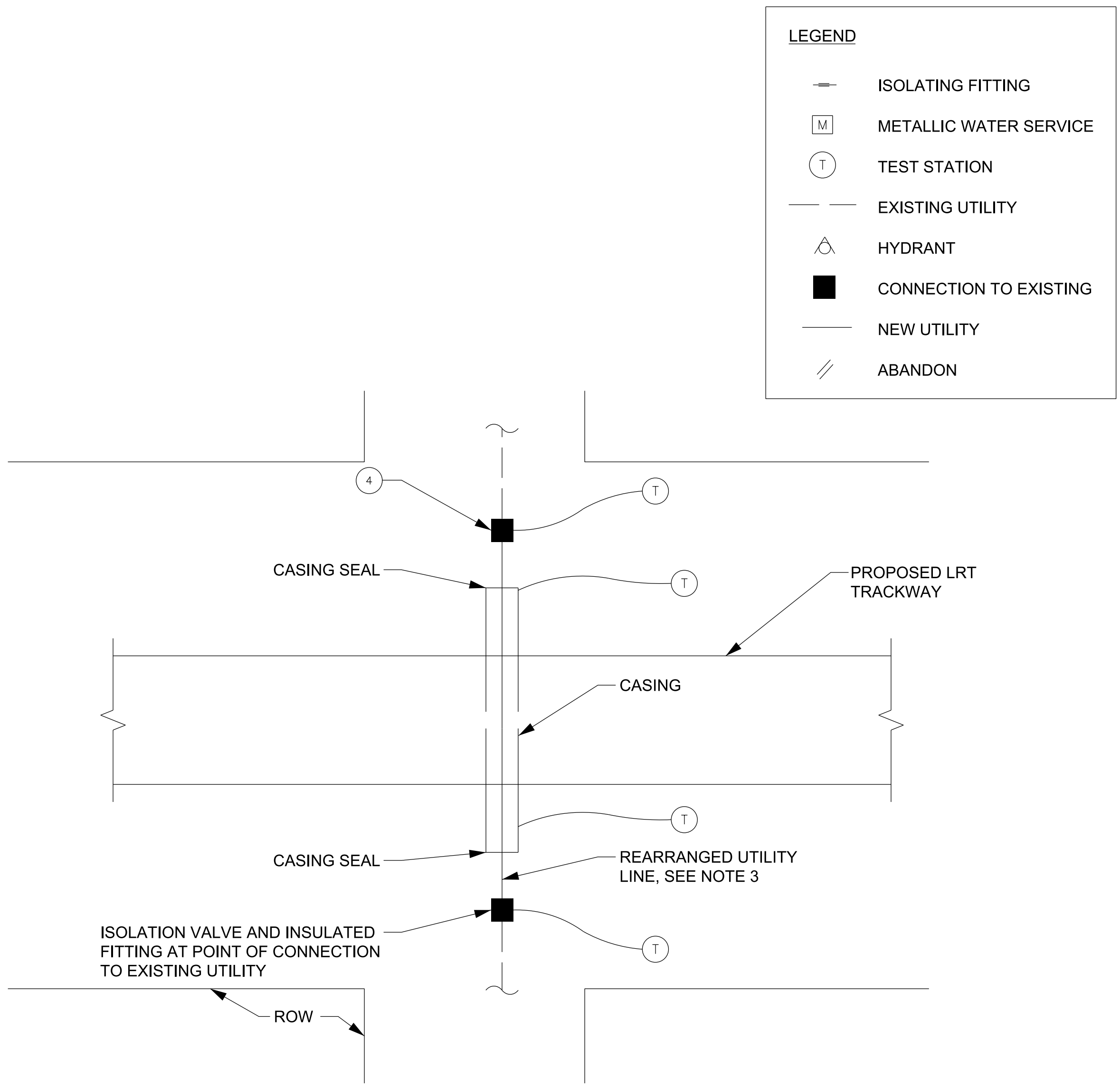
		APPROVED BY	DRAWN BY
		WT	**AECOM**
TYPICAL GRAVITY PIPE LOWERING DETAIL		STD. DWG. NUMBER	SCALE
		3-1-2	**N.T.S.**



NOTE

1. RETROFIT OF JOINT BONDING NOT REQUIRED ON EXISTING WATER MAIN PARALLELING PROPOSED LRT.
2. USE NON-METALLIC MATERIALS FOR CASING AND UTILITY RE-ARRANGEMENT IF PRACTICAL.
3. BOND ALL MECHANICAL JOINTS OF NEW METALLIC UTILITY REARRANGEMENT.
4. INSTALL INSULATING JOINTS TO ELECTRICALLY ISOLATE REARRANGEMENT FROM EXISTING PIPE.
5. INSTALL CASING INSULATORS TO ISOLATE UTILITY FROM METALLIC CASINGS.
6. SEE DRAWING NUMBER 3-1-1 FOR PIPING MATERIAL SELECTION.
7. BONDING AND REPLACEMENT SHALL EXTEND 30m AT EACH INTERSECTION BEYOND LIMIT OF RAIL.

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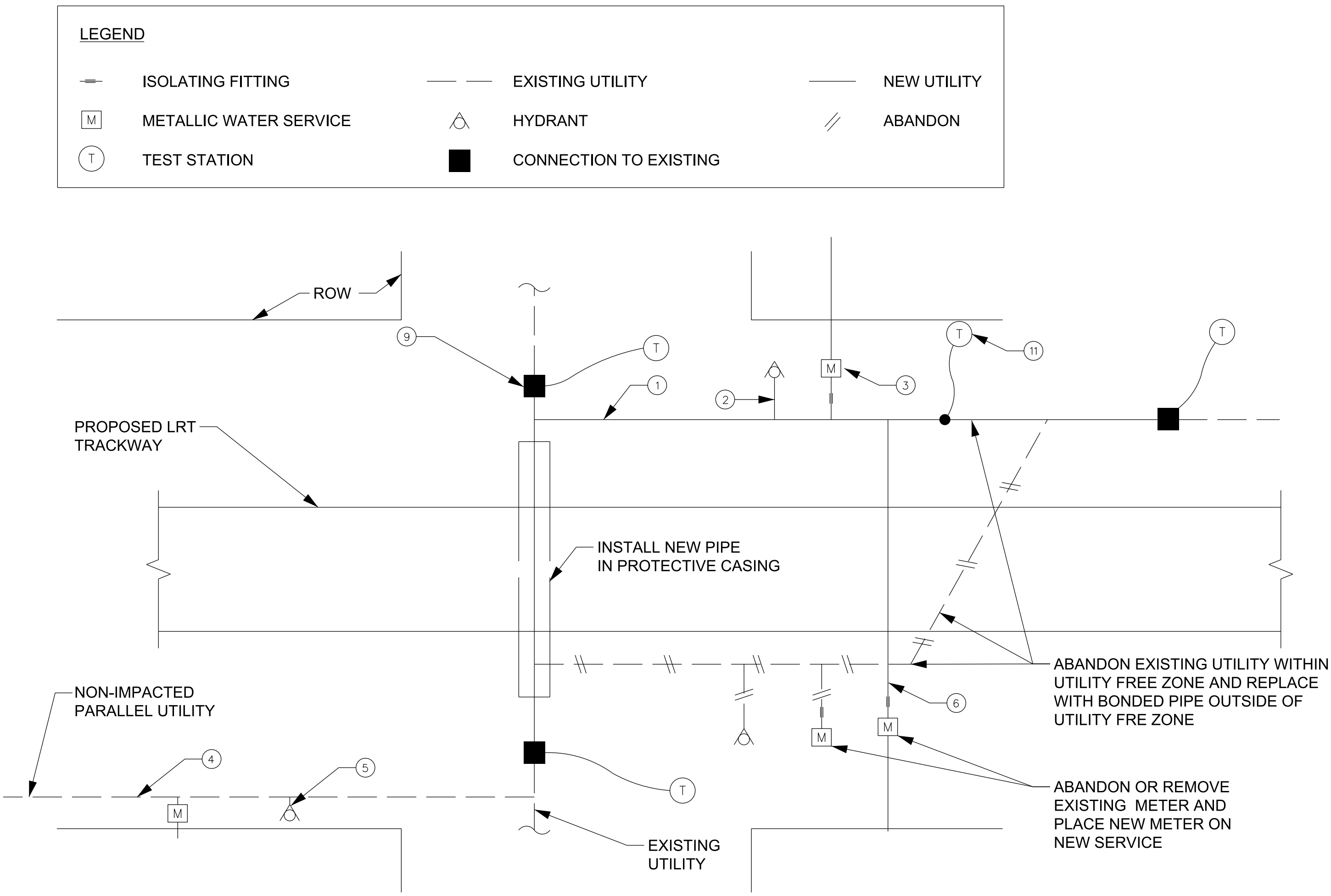
PUBLIC WORKS
STANDARD DRAWING

REV. DATE: FEBRUARY 2015

APPROVED BY	DRAWN BY
WT	AECOM
STD. DWG. NUMBER	SCALE
3-1-3	N.T.S.

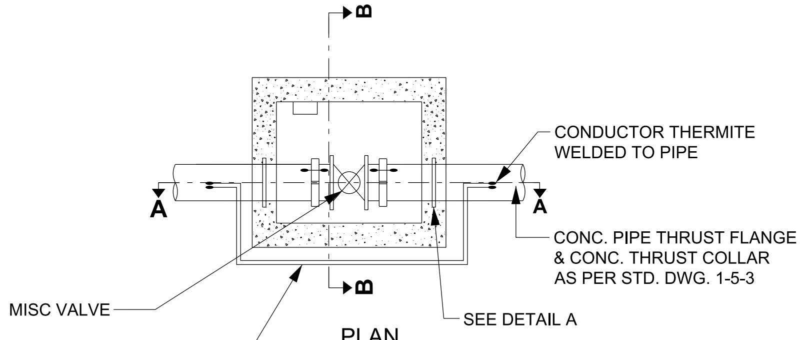
TYPICAL ARRANGEMENT FOR
PIPES CROSSING LRT



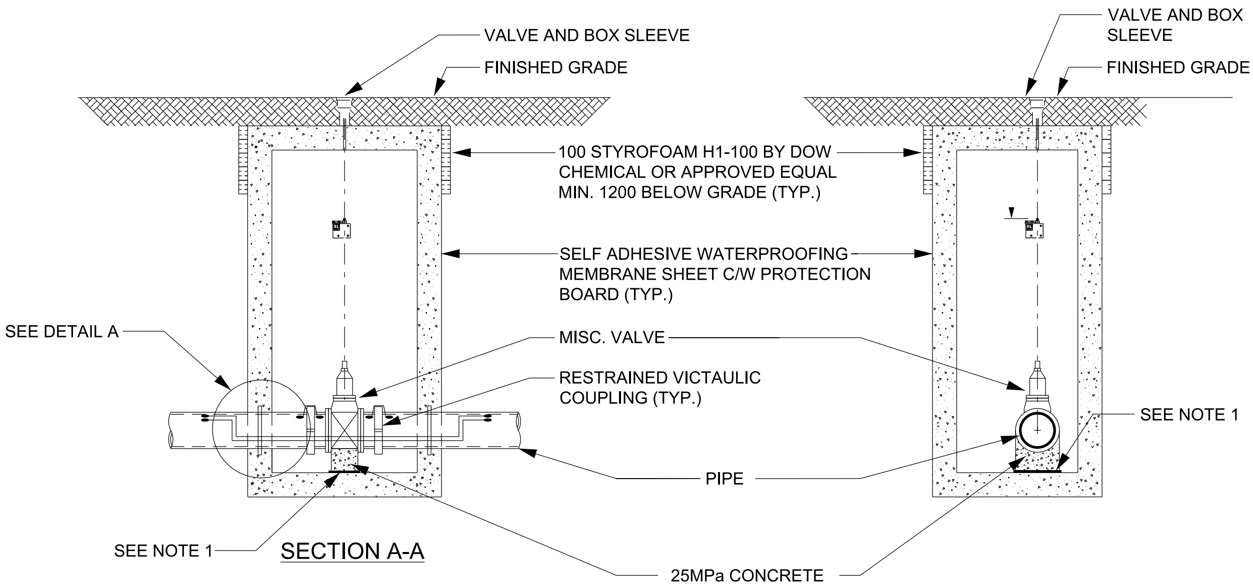
NOTE

1. BOND ALL JOINTS OF NEW PARALLEL METALLIC UTILITY FACILITIES.
2. JOINTS ON NEW FIRE HYDRANT LATERALS CONNECTED TO WATER MAIN WITH BONDED JOINTS SHALL BE BONDED.
3. METALLIC WATER SERVICES ON BONDED JOINT MAIN SHALL BE BONDED AND HAVE INSULATED COUPLING/UNION AT CONNECTION TO EXISTING SERVICE.
4. RETROFIT OF JOINT BONDING NOT REQUIRED ON EXISTING WATER MAIN PARALLELING PROPOSED LRT OUTSIDE OF UTILITY FREE ZONE.
5. BOTH NEW AND EXISTING SERVICES AND HYDRANT LATERALS CONNECTED TO UNBONDED WATER MAIN DO NOT REQUIRE BONDING.
6. FOR METALLIC PIPE, INSULATING FITTINGS ARE REQUIRED AT THE MAIN AND AT THE SERVICE CONNECTION.
7. USE NON-METALLIC MATERIALS FOR CASING AND UTILITY RE-ARRANGEMENT IF PRACTICAL.
8. BOND ALL MECHANICAL JOINTS OF METALLIC UTILITY REARRANGEMENT.
9. INSTALL INSULATING JOINTS TO ELECTRICALLY ISOLATE NEW PIPE FROM EXISTING PIPE.
10. WHERE POSSIBLE, NEW NON-METALLIC (PE/PVC) SERVICES SHALL BE USED IN PLACE OF METALLIC/COPPER.
11. INSTALL TEST STATIONS APPROX. 150m SPACING ON PIPE PARALLEL TO LRT.
12. SEE DRAWING NUMBER 3-1-1 FOR PIPING MATERIAL SELECTION.
13. BONDING AND REPLACEMENT SHALL EXTEND 30m AT EACH INTERSECTION BEYOND LIMIT OF RAIL.

Region of Peel *Working for you* — PUBLIC WORKS STANDARD DRAWING	REV. DATE: FEBRUARY 2015	
	APPROVED BY **WT**	DRAWN BY **AECOM**
TYPICAL ARRANGEMENT FOR PIPES PARALLEL TO LRT	STD. DWG. NUMBER **3-1-4**	SCALE **N.T.S.**

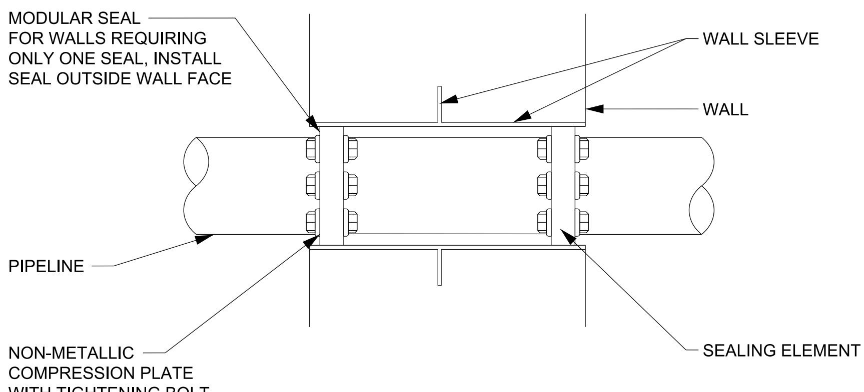


PLAN
(CHAMBER A)



SECTION A-A

SECTION B-B



DETAIL A

NOTE

1. METAL VALVE STANDS SHALL BE PLACED ON 3mm FIBREGLASS PADS, OR RUBBER PADS.
2. IF RESTRAINING RODS ARE REQUIRED IN WALL OR FLOOR SLEEVES, COAT THE RODS WITH COAL TAR EPOXY AND FILL VOID WITH NON-METALLIC EPOXY GROUT.
3. DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE NOTED.
4. VALVE CHAMBER TO BE CONSTRUCTED IN ACCORDANCE WITH REGION STANDARD.

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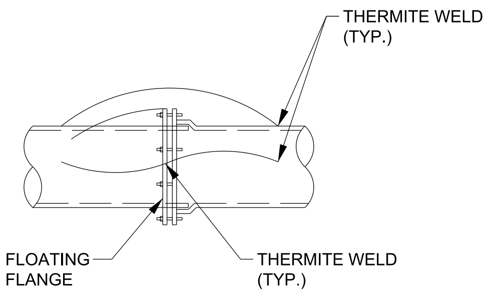
PUBLIC WORKS
STANDARD DRAWING

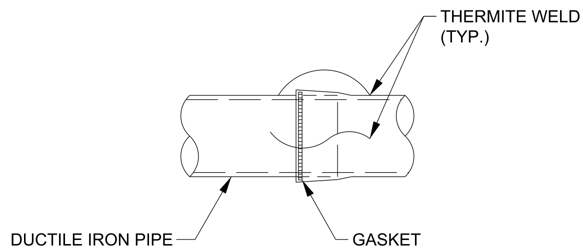
REV. DATE: FEBRUARY 2015

APPROVED BY	DRAWN BY
WT	**AECOM**
STD. DWG. NUMBER	SCALE
3-2-1	**N.T.S.**

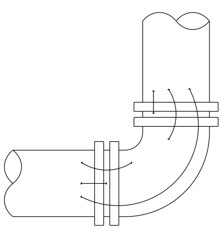
GENERAL CHAMBER NOTES
FOR WITHIN LRT CORRIDOR



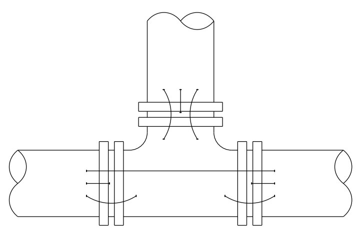
MECHANICAL JOINT



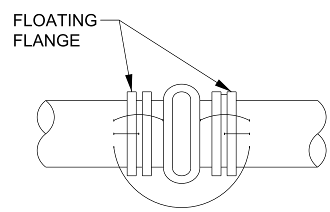
PUSH ON JOINT



BEND



TEE

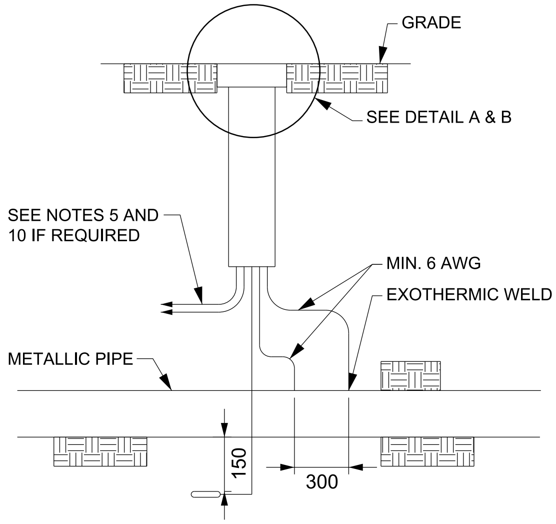


VALVE

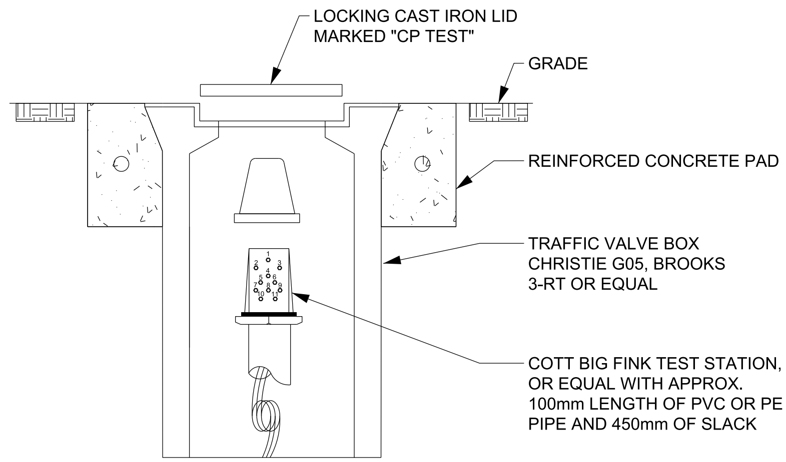
NOTE

1. BONDING ARRANGEMENTS SHALL APPLY WHERE BONDING IS SPECIFIED FOR DUCTILE OR CAST IRON PIPE.

Region of Peel — Working for you	PUBLIC WORKS STANDARD DRAWING	REV. DATE: FEBRUARY 2015	
		APPROVED BY	DRAWN BY
		WT	**AECOM**
METALLIC PIPE BONDING		STD. DWG. NUMBER	SCALE
		3-2-2	**N.T.S.**

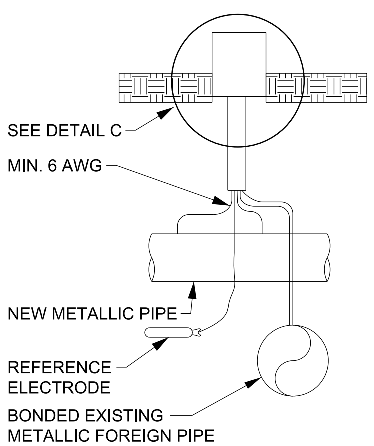


PIPE ACCESS TEST STATION

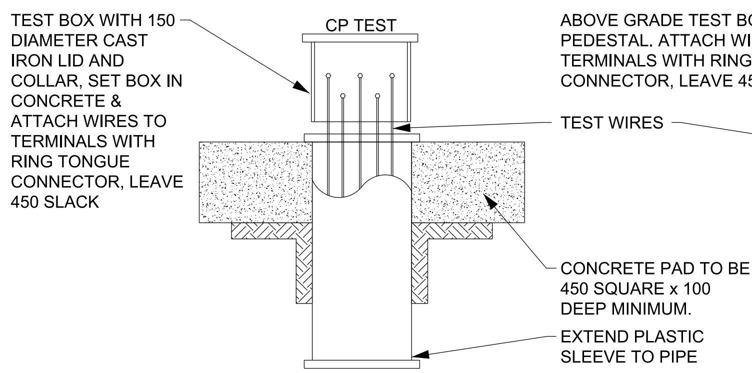


FLUSH-MOUNTED TEST STATION SUBJECT TO TRAFFIC LOADS

DETAIL B

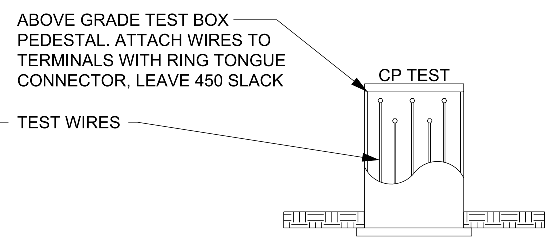


FOREIGN BONDED PIPE TEST STATION



SIDEWALK AT GRADE TEST BOX

DETAIL A



ABOVE GRADE TEST BOX

DETAIL C

NOTE

1. TEST STATIONS SHALL BE IN AGREEMENT WITH OPSS 442.
2. TEST STATION LEADS SHALL BE INSTALLED IN SCHEDULE 40 PVC CONDUIT.
3. DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED.
4. AN ADDITIONAL TEST STATION SHALL BE INSTALLED AS CLOSE AS POSSIBLE TO EACH SUBSTATION.
5. ALONG THE LRT CORRIDOR, TEST STATIONS SHALL BE SPACED APPROXIMATELY 150m APART.
6. PROVIDE HARDWOOD BLOCKING OR OTHER SUPPORT TO PREVENT SETTLEMENT AND/OR DAMAGE TO WIRE INSULATOR.
7. LEAVE A MINIMUM OF APPROXIMATELY 450mm OF SLACK IN THE TEST LEADS, NEATLY COILED IN THE BOTTOM OF THE VALVE BOX TO ALLOW REMOVAL OF THE TEST STATION. CONDUIT SHALL BE SECURELY FASTENED TO THE PIPE OR POST WITH BANDING STRAPS OR CONDUIT CLIPS, MAXIMUM FASTENER SPACING SHALL BE 400.
8. TEST STATION TO BE LOCATED OUTSIDE OF THE TRAVELLED ROAD WHERE THEY ARE REASONABLY ACCESSIBLE FOR TESTING WITHOUT THE NEED FOR TRAFFIC CONTROL.
9. PIPE ACCESS TEST STATIONS UTILIZED TO CONNECT ANODES TO THE PIPELINE SHALL CONTAIN 2 - #8 AWG ANODE HEADER CABLES CONNECTED TO THE PIPELINE AT THE TEST STATION TERMINAL BOARD. PIPE ACCESS TEST STATIONS INSTALLED ADJACENT TO LIGHT RAIL TRANSIT TRACTION POWER SUBSTATIONS SHALL CONTAIN SPARE TERMINALS FOR FUTURE CONNECTION OF 2 STRAY CURRENT DRAINAGE CABLES. THE MINIMUM SIZE OF STRAY CURRENT DRAINAGE CABLES SHALL BE #2 AWG.
10. ALL MATERIAL AND TEST STATION BOXES ARE SUBJECT TO REGION OF PEEL APPROVAL.

Region of Peel *Working for you*	PUBLIC WORKS STANDARD DRAWING	REV. DATE: FEBRUARY 2015	
		APPROVED BY	DRAWN BY
		WT	**AECOM**
TEST STATION		STD. DWG. NUMBER	SCALE
		3-2-3	**N.T.S.**

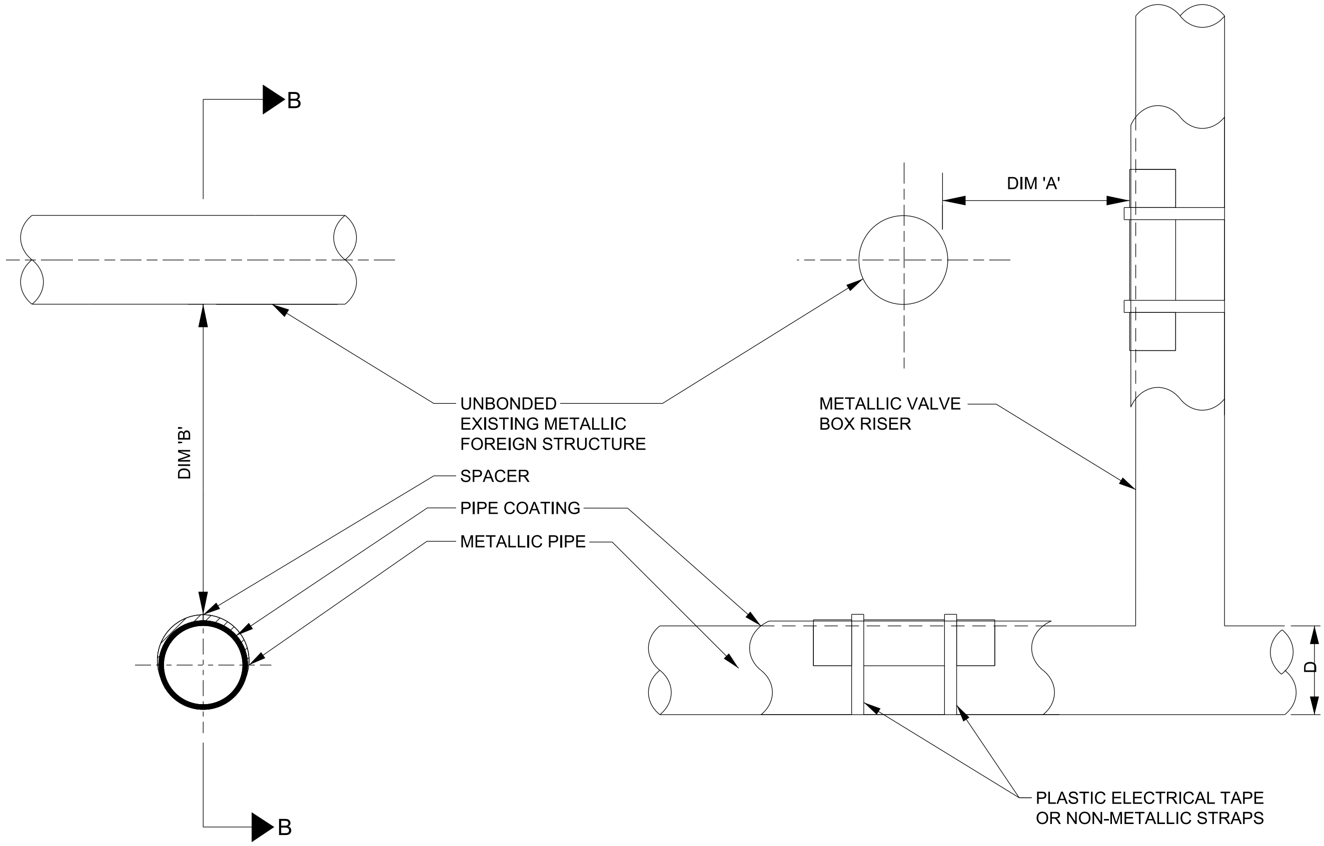


TABLE 1

SPACER THICKNESS & LENGTH TABLE		
PIPE DIAMETER (NOMINAL)	MINIMUM THICKNESS	SPACER LENGTH
25 - 38mm	2mm	150mm
50mm	2mm	300mm
75 - 100mm	2.3mm	300mm
150mm	3mm	300mm
200mm	3.8mm	300mm
250mm	4.3mm	300mm
300mm	4.8mm	400mm
350mm	5.8mm	400mm
400mm	6.4mm	400mm
500mm +	8mm	400mm

NOTE

1. APPLICATIONAL SPACER ON METALLIC PIPE REQUIRED WHEN DIM 'A' AND/OR DIM 'B' IS LESS THAN 300mm OR AS SPECIFIED BY DESIGNER.
2. REFER TO TABLE 1 FOR RECOMENDED SPACER DIMENSIONS.
3. SPACER SHALL MEET THE REQUIREMENTS OF REGION OF PEEL WATERMAIN, STORM SEWER AND SANITARY SEWER DESIGN CRITERIA ADDENDUM, SECTION 3.6.
4. FOR BONDED FOREIGN PIPE ARRANGEMENTS, SEE DRAWING NUMBER 3-2-3 FOR TEST STATION AND CROSS BONDING DETAIL.

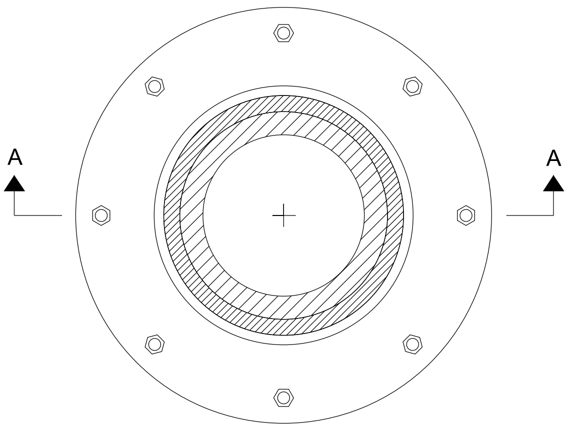
Region of Peel
Working for you

PUBLIC WORKS
STANDARD DRAWING

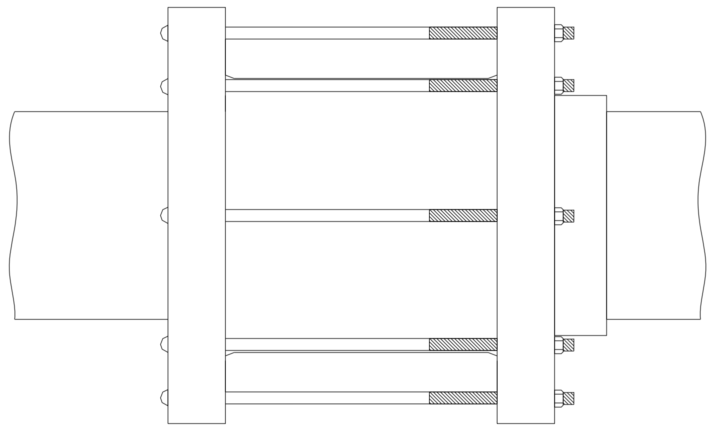
REV. DATE: FEBRUARY 2015

APPROVED BY	DRAWN BY
WT	**AECOM**
STD. DWG. NUMBER	SCALE
3-2-4	**N.T.S.**

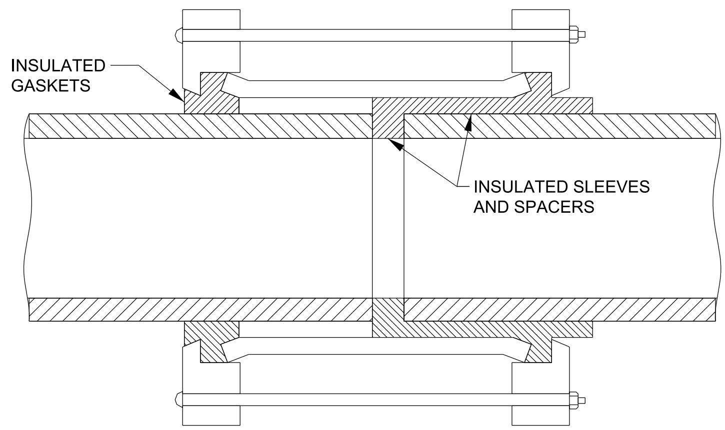
PIPE INSULATION SPACER



INSULATING COUPLING PLAN



INSULATING COUPLING PROFILE

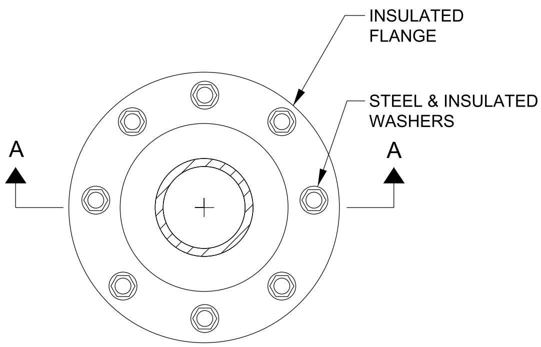


SECTION A-A

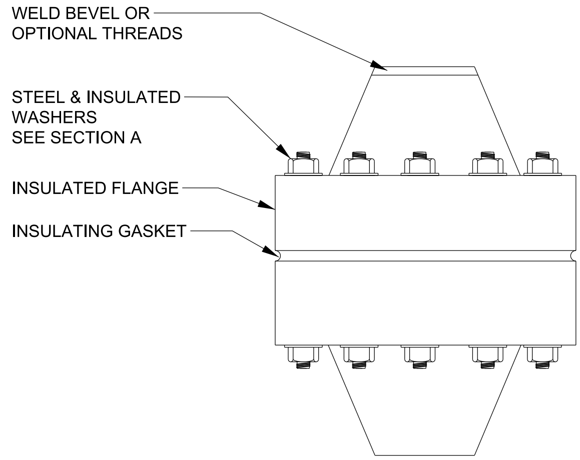
NOTE

1. FOR PIPES RUNNING PARALLEL TO LRT AND WITHIN THE ZONE OF INFLUENCE (30m), ELECTRICAL ISOLATION JOINTS SHALL BE PLACED NO GREATER THAN 150m APART.
2. DURING CONSTRUCTION, BOND TESTING SHALL BE PERFORMED AT SHORTER INTERVALS IF NECESSARY.
3. INSULATED COUPLINGS TO BE SELECTED FROM THE APPROVED PRODUCT LIST.

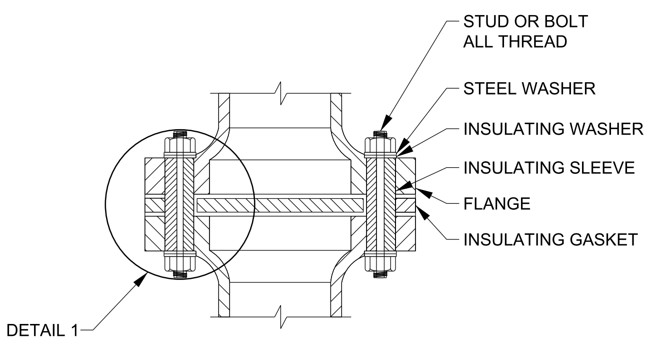
Region of Peel Working for you — PUBLIC WORKS STANDARD DRAWING	REV. DATE: FEBRUARY 2015	
	APPROVED BY **WT**	DRAWN BY **AECOM**
INSULATED PIPE COUPLING	STD. DWG. NUMBER **3-2-5**	SCALE **N.T.S.**



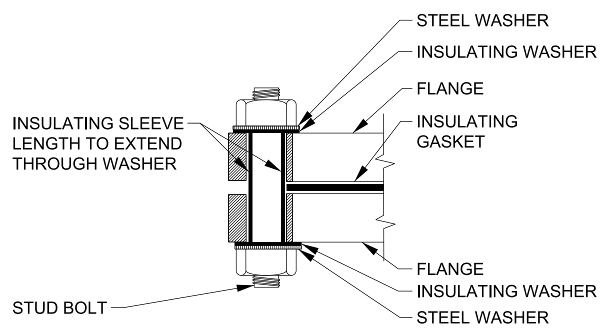
INSULATING FLANGE PLAN



INSULATING FLANGE PROFILE



SECTION A-A



DETAIL 1

NOTE

1. PROVIDE FITTINGS & INSULATING COMPONENTS SUITABLE FOR PRESSURES, TEMPERATURES & MATERIALS WITHIN & ADJACENT TO THE PIPE. ALL FITTINGS POTABLE WATER SHALL BE NSF 61 CERTIFIED.
2. INSULATED FITTINGS SHALL BE SIZED SO AS NOT TO RESTRICT FLOW CHARACTERISTICS.
3. INSULATED FLANGE TO BE SELECTED FROM THE APPROVED PRODUCT LIST.

Region of Peel *Working for you*	PUBLIC WORKS STANDARD DRAWING	REV. DATE: FEBRUARY 2015	
		APPROVED BY **WT**	DRAWN BY **AECOM**
INSULATING FLANGE		STD. DWG. NUMBER **3-2-6**	SCALE **N.T.S.**

APPENDIX D

SAMPLE FIELD TEST METHODOLOGY

1) Test Procedure Structure-to-Electrolyte Potential
2) Pipeline Test Station Location
3) Isolation Fitting Leakage Test
4) Galvanic Anode Current Test Procedure
5) Structure Resistance Calibration and Current Measurement Procedure

D1. Structure-to-Electrolyte Potential Measurement Procedure

1. General

This procedure provides guidelines for field testing necessary to measure a structure-to-electrolyte potential required by various related testing procedures.

1.1. Purpose

The purpose of this procedure is to provide guidance for consistent and accurate measurement of structure-to-electrolyte potentials.

1.2. Definitions

1. Remote Earth – A location on the earth far enough from the affected structure that the soil potential gradients associated with the currents entering the earth from the affected structure are insignificant. Note: The remote earth must be electrically continuous with the electrolyte in contact with the structure.
2. Structure-to-Electrolyte Potential – The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.
3. Electrolyte – A chemical substance, such as soil, water or concrete, containing ions that migrate in an electric field.
4. Electrode – A conductor used to establish contact with an electrolyte and through which current is transferred to or from the electrolyte.
5. Reference Electrode – An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials. Also known as a half-cell.
6. Bond – A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.
7. Anode – The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the electrolyte at the anode.
8. Cathode – The electrode of an electrochemical cell at which reduction occurs. Electrons flow toward the cathode in the external circuit.
9. Cathodic Protection – A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.
10. Current Density – The current to or from a unit area of an electrode surface.
11. Stray Current – Current flowing through a path other than the intended path.
12. Open Circuit Potential – The potential between two electrically isolated metallic structures.
13. Instant-Off Potential – The half-cell potential of a structure taken immediately after the applied current is interrupted or stopped.
14. IR Drop – The voltage across a resistance when current is applied in accordance with Ohm's Law.
15. Electrical Isolation – The condition of being electrically separated from other metallic structures or the environment.
16. Long-Line Current – Current through the electrolyte between an anodic area and a cathodic area that returns along the structure.
17. Polarization – The change from the open-circuit electrode potential as a result of current across the electrode/electrolyte interface.

18. Potential Gradient – A change in the potential with respect to distance, expressed in millivolts per unit distance.
19. Resistance to Electrolyte – The resistance of a structure to the surrounding electrolyte.
20. Test Lead – A wire or cable attached to a structure for connection of a test instrument to make measurements.
21. Voltage – An electromotive force or a difference in electrode potentials expressed in volts.

1.3. Equipment

The user must be knowledgeable of the capabilities and limitations of the equipment, follow the manufacturer's instruction manual, and be skilled in the use of the instruments in order to avoid errors in measurements. The following presents typical equipment requirements to measure structure-to-electrolyte potentials.

1. Voltmeter, D.C.: Multi-scale, minimum 10 megohm input impedance (or equivalent input resistance), capable of reading positive and negative values without removing the test leads and covering at least the following full-scale ranges:

   0 to 5 mV; 0 to 500 mV; 0 to 5 V; 0 to 50 V; 0 to 500 V.
   Meters shall be accurate within 1% of full scale.
   Meters with selectable input impedance (input resistance for analog meters) are preferable.

2. Test Wires: Single conductor cable, stranded copper, with a minimum 600 volt insulation in perfect condition. Provide sufficient length(s) as required to establish test circuits with appropriate terminal lugs and clamp or clip terminations.

3. Reference Electrode: Saturated copper-copper sulfate reference half-cell with a ceramic or wooden porous plug, diameter of approximately $1\frac{3}{8}$ or 3 inches. A thin wetted sponge may be utilized to improve the electrical contact between the reference electrode and the electrolyte when necessary.

4. Miscellaneous hand tools necessary for disconnecting and reconnecting test leads.

1.4. Safety Considerations

Appropriate safety precautions, in accordance with Region of Peel requirements, shall be observed when making electrical measurements. The following, in addition to the Region of Peel requirements, should be considered:

1. Be knowledgeable and qualified in electrical safety precautions before installing, adjusting, repairing, removing, or testing energized equipment, including cathodic protection equipment.

2. Use properly insulated test leads, clips and terminals to avoid contact with unanticipated high voltage. Attach test clips one at a time using a single-hand technique for each connection.

3. Use caution when long test leads are extended near overhead high-voltage alternating current power lines, which can induce hazardous voltages onto the test leads. High-voltage direct current power conductors do not induce voltages under normal operations, but transient conditions can cause hazardous voltages.

4. Use caution when making tests at electrical isolation devices. Before proceeding with tests, use appropriate voltage detection instruments or voltmeters with insulated test leads to determine whether hazardous voltages exist.

5. Avoid testing when thunderstorms are in the area. Remote lightning strikes can create hazardous voltage surges that travel along the structure under test.

6. Use caution when running test leads across streets, sidewalks, and other locations subject to vehicular or pedestrian traffic. When conditions warrant, use appropriate barricades, flagging, or other warning methods.

7. Prior to entering excavations or confined spaces, inspect to determine that they are safe in accordance with all Region of Peel confined space entry procedures.

8. Observe applicable electrical codes and safety regulations during all testing.

1.5. Procedure

"This procedure does not encompass all possible field conditions to obtain accurate structure-to-electrolyte potential measurements. No general set of test procedures will be applicable to all situations."

Prepare a test data template for recording of the field data. Identify the locations for structure-to-electrolyte potential measurements. A sample test data template is included in the Supporting Documents.

Conduct a Pre-Testing "tailgate" meeting with the testing personnel, if necessary, to review the locations for test data collection.

Visually examine the location to be tested to ensure that there is no appreciable degree of debris, water, dirt, vegetation, ballast, or other material that may affect the accuracy of the measurement. Record on the data sheet the weather conditions for the previous 48 hours.

1. Connect a test wire from the negative terminal of the voltmeter to the structure.
2. Connect a test wire from the positive terminal of the voltmeter to the reference electrode.

    NOTE: A positive voltage reading will be displayed on the voltmeter when the structure is negative with respect to the reference electrode using the test circuit polarity described in steps 1 and 2 above.

3. Place the reference electrode on the electrolyte surface as close as reasonably practical to the structure in order to measure a "local" potential. Utilize a permanently installed underground reference electrode to measure a "local" potential where available. Place the reference electrode on the electrolyte surface electrically remote from the structure in order to measure a "remote" potential.
    a. Ensure a low resistance contact between the reference electrode and the electrolyte. Do not place the reference electrode on soil that has been contaminated with oil, grease, or other similar substance. The contact resistance can be lowered in most cases by removing a thin layer of topsoil or by wetting the electrolyte surface with water. A thin wetted sponge may also be useful for reducing contact resistance on concrete electrolytes. Note: Frozen soil creates a very high contact resistance for a reference electrode. The electrode should be placed on fresh soil beneath the frozen layer.

4. Turn on the voltmeter to the highest scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the voltage measured should be in the upper two-thirds of the voltage scale.
5. Observe the reading on the voltmeter. If the reading is “jittery” or unstable, and dynamic stray current effects are not anticipated, check all test lead connections and the reference electrode placement to ensure no high resistance connections exist in the measurement circuit.
6. For structures where dynamic stray current effects are anticipated, the voltage level will fluctuate with time. At these locations, the voltmeter should be set to record the minimum, maximum, and average voltage values over a period of at least 5 minutes.
7. Record the potentials on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the type of reference electrode utilized, the location of the reference electrode, the location of the structure connection, the time that the readings were taken and the polarities of the voltages observed. A sketch of the measurement circuit should be added to the Test Data Sheet when appropriate to clarify the measurement circuit.

1.6. Possible Sources of Measurement Error

In order to make sound judgments based on structure-to-electrolyte potential data, it is very important that the Technician understands possible sources of error inherent in the measurements and utilizes his/her knowledge and experience to avoid or reduce these errors.

Measurement Circuit. A typical structure-to-electrolyte potential measurement circuit is shown in Figure 1 below. Figure 2 depicts an equivalent electrical circuit for the measurement. When the circuit is complete, a small current will flow due to the voltage difference between the structure and the reference electrode. Voltage drops occur across each of the resistive elements in the measurement circuit due to this current flow in accordance with Ohm’s Law. These measurement circuit voltage drops are separate from the more commonly discussed IR drops, which are due to current flowing through the electrolyte external from the measurement circuit. Both the measurement circuit voltage drops and the external IR drop are incorporated into the potential measurement and are sources of error. Different methods must be employed to minimize the error introduced by each type of voltage drop.

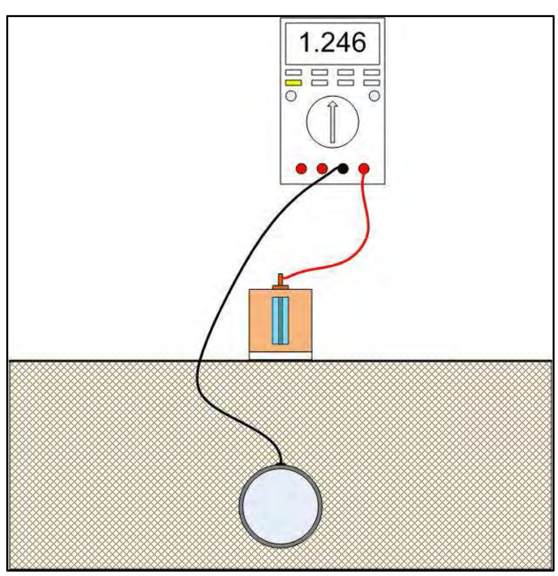


Figure 1. Structure-to-Electrolyte Potential Measurement.

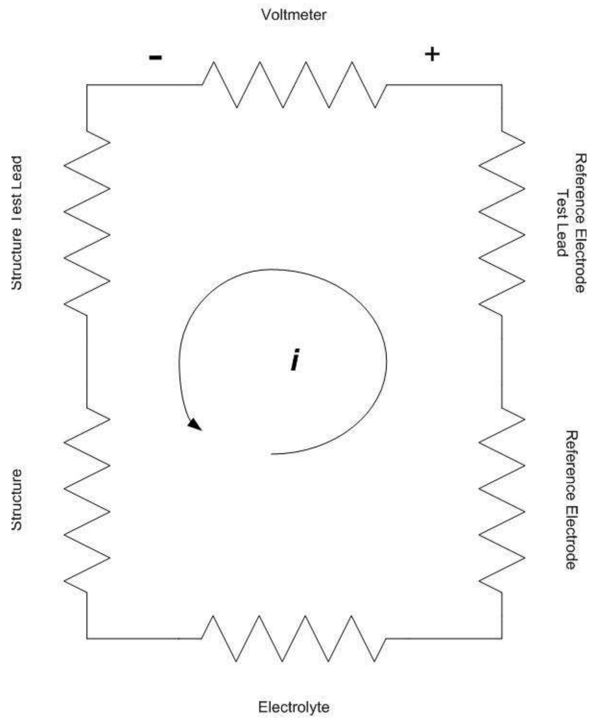


Figure 2. Equivalent Electrical Measurement Circuit.

The resistance of the test lead wires and the structure are sufficiently small that the voltage drop created by them in the measurement is insignificant in most cases. Most copper-copper sulfate reference electrodes have an internal resistance on the order of 1kΩ. The voltmeter, as described above, has a minimum internal resistance of 10MΩ. The electrolyte resistance and contact resistance between the reference electrode and the electrolyte is highly variable and is the most common source of significant errors in structure-to-electrolyte potential measurements. The contact resistance between the reference electrode and electrolyte can be minimized by increasing the diameter (contact area) of the reference electrode and wetting the electrolyte at the test location. To minimize the possible error introduced by these resistances, a meter whose internal resistance/input impedance is several orders higher than the electrolyte resistance (and contact resistance) is required so that the voltage drop across the meter resistance, for practical purposes, represents the entire voltage drop and limits the current flow in the measurement circuit.

External IR Drop. External IR drop is an error introduced if current is flowing in the electrolyte between the reference electrode and the structure being tested. The error introduced can be substantial, depending upon the magnitude of the current flow and the resistance of the electrolyte. Sources of current flow in the electrolyte may include cathodic protection systems, stray DC current, welding operations, manufacturing facilities utilizing DC induction equipment, etc. In some cases it may be possible to minimize the external IR drop error by temporarily interrupting the current flow or by measuring the structure-to-electrolyte potential when the sources of current flow are inactive. If it is impractical or impossible to eliminate the current flow through the electrolyte during the measurement, the use of embedded or buried coupons may be appropriate. Coupons are small pieces of bare metal similar to the structure being tested which are placed in the electrolyte near the structure and electrically bonded to the structure through test leads in a test station. It is assumed that the behavior of the coupon will be similar to the structure. The structure-to-electrolyte potential measurement is made by temporarily disconnecting the coupon from the structure.

Special conditions of external IR drop can be experienced in some cases when measuring structure-to-electrolyte potentials through concrete and where there are significant changes in electrolyte resistance (layers) between the structure and the reference electrode. The use of embedded/buried coupons and/or reference electrodes can help to minimize errors in these cases. For some very high resistance electrolytes, the use of a potentiometer may be required to obtain more accurate measurements.

Reference Electrodes. Other possible sources of error in a structure-to-electrolyte potential measurement can be the improper use or maintenance of the reference electrode or a lack of understanding of the conditions that can affect the stability of the electrode. A copper-copper sulfate reference electrode can be affected by temperature, light, contamination of the copper sulfate solution and contamination of the porous plug (junction) that contacts the electrolyte. Proper maintenance and usage of an electrode can minimize these effects or allow for correction of the effect.

1. Temperature – Copper-copper sulfate reference electrodes are temperature sensitive. They have a temperature coefficient of approximately ½ mV/ºF. The temperature of the reference electrode should be approximately equal to the temperature of the structure being tested and then the potential measurement corrected to a standard temperature value. For example, if a potential of 925 mV is measured on a day when the temperature is 90ºF, the value corrected to a standard 77ºF temperature would be $V = V_0 + C_t\Delta T$ = 925 + (0.5 x -13) = 918.5 mV.
2. Light – Copper-copper sulfate reference electrodes are photosensitive. Many reference electrodes have a clear window so that the condition of the copper sulfate solution and copper rod can be inspected. If this clear window is exposed to bright sunlight a voltage shift can occur. Calculation of the amount of voltage shift that will occur is very complicated but, shifts of up to 50 mV or more have been reported. To avoid this affect, a piece of electrical tape can be placed over the reference electrode window.
3. Contamination – To be a standard reference a copper-copper sulfate reference electrode should consist of a clean pure copper rod immersed in a saturated solution of pure copper sulfate. The water utilized to create the copper sulfate solution should be distilled, and preferably deionized, water. To ensure a saturated solution, enough crystals are added so that a few remain undissolved. The water used to create the solution contains some dissolved oxygen that can gradually react with the copper rod to form copper oxide on the rod surface that is evident by a discoloring of the copper rod. The presence of the copper oxide creates a “mixed” potential that will shift the potential measured from the potential that would be measured with a “clean” reference electrode. To avoid this problem, a reference electrode should be cleaned and rebuilt on a regular basis. A copper-copper sulfate reference electrode can also be contaminated by chemicals entering the reference electrode through the porous ceramic tip and by clogging of the tip pores. To avoid these problems, a reference electrode should not be placed directly on contaminated electrolyte if possible and the reference electrode should not be allowed to dry out. If it is suspected that the tip has become chemically contaminated it should be replaced. A dried out tip should be soaked in distilled water for several days or boiled in distilled water for an hour or two.

1.7. Supporting Documents

1. Exhibit A, Blank Field Data Sheet.

Exhibit A

REGION OF PEEL

Field Data Sheet

Personnel: ______________________

Location/Circuit No.: ______________________

Location Description: ______________________

Sheet: ________ of ________

Date: ________

Project No.: ________

Test Equip.: ________

SKETCHES, CALCULATIONS, ETC.

TEST													
SCALE													
TIME													

D2. Metallic and PCCP Pipeline Test Station Location General Guidelines for Stray Current Monitoring

1. New Pipeline Track Crossings

   Install isolation joints and test stations on each side of the crossing. Locate the joints a minimum of 2m beyond the edge of the track slab to facilitate future maintenance. The test station should contain two test wires connected to each side of the joint and two test wires connected to the casing (if a metallic casing is utilized). A minimum of two galvanic anodes (zinc for PCCP and magnesium for steel and ductile iron) and one underground reference electrode should be installed on each side of the joint. At select locations, determined to be at high risk for stray current corrosion, the installation of coupon or corrosion rate test equipment may be appropriate.

2. New Pipelines Parallel to the Track

   Install isolation joints and test stations at each end of the segment of pipeline that is laid parallel to and within 30m of the track. Where the length of the pipeline that is parallel to the track exceeds 150m, install isolation joints and test stations at intervals of approximately 150m. At select locations, determined to be at high risk for stray current corrosion, the installation of current measurement, coupon or corrosion rate test equipment may be appropriate. Note: When the pipeline is installed inside a casing for the length of the parallelism, isolation joints are installed at the ends of the pipe segment within the casing.

3. Existing Pipelines
   1. Pipelines Perpendicular to the Track

      For pipelines that are perpendicular to and within 10m of the track, install a 2-wire test station and underground reference electrode for the pipeline at the location nearest the tracks. At select locations (within or in excess of 10m from the tracks), determined to be at high risk for stray current corrosion, the installation of coupon or corrosion rate test equipment may be appropriate.

   2. Pipelines Parallel to the Track

      Install a 2-wire test station and underground reference electrode for the pipeline at approximate 150m intervals for segments of pipeline that are parallel to and within 30m of the tracks. At select locations, determined to be at high risk for stray current corrosion, the installation of current measurement, coupon or corrosion rate test equipment may be appropriate.

Pipeline Stray Current Testing and Evaluation General Guidelines

4. Electrically Continuous Pipelines
    1. Pipelines without cathodic protection
        i. Electrical continuity of bonded joint pipelines. Electrical continuity of a pipeline is measured by impressing a current across a known length of pipeline and measuring the metallic millivolt drop across the length caused by the current flow. The test stations at insulating joint locations are typically utilized for access to the pipeline to perform the test. Ohms law is then utilized to calculate a measured pipeline resistance. For Prestressed Concrete Cylinder pipelines, consideration of a fringing effect is necessary for accurate calculation of the theoretical resistance of the pipeline. The fringing factor adds an equivalent length of the pipeline cylinder to account for the bond cable connections. Measured resistance should be <= 120% of theoretical resistance of continuous pipe (welded joints).
        ii. Electrical isolation joint effectiveness. Several methods can be utilized to evaluate the effectiveness of and electrical isolation joint. The effectiveness of an in-service isolation joint is difficult to quantify to a specific acceptance criterion, particularly for uncoated pipelines without cathodic protection. The resistance of an in-service isolation joint is the difference in the resistance to earth of the pipeline on each side of the joint and can also be influenced when a conductive fluid is transported by the pipeline. The resistance can be measured utilizing a 4-terminal ac ohmmeter (such as a soil resistivity meter) connected to the pipeline on either side of the joint utilizing the test wires inside the test station. Another test involves applying a dc current to one side of the isolation joint and measuring the structure-to-electrolyte potential shift on the opposite side of the isolation joint. The structure-to-electrolyte potential on the opposite side should change very little due to the current applied. A third method that may be utilized, if sufficient testing facilities are available is to measure the current leakage across the isolation joint. The current leakage measurement is a variation of the electrical continuity test described in 1.a.i above.

iii. Structure-to-electrolyte potential. The structure-to-electrolyte potential can be utilized to aid in identifying the magnitude of stray current influence on the pipeline by measuring the amount of polarization (current pick up) or depolarization (current discharge) from the free corrosion potential. Anodic potential shifts of more than approximately 20mV (excluding IR drop) indicate additional investigation is warranted. Cathodic potential shifts of a magnitude that can damage coating or create hydrogen embrittlement of prestressing wires, if present, should also be evaluated. Cathodic potential shifts that create a cathodic structure-to-electrolyte potential in excess of 1100 mV (excluding IR drop) indicate that additional investigation is warranted. Additionally, significant cathodic potential shifts at the test location suggest that damaging anodic potential shifts may be occurring at other locations on the pipeline circuit. At test facilities equipped with two underground reference electrodes, the potential difference between the reference electrodes can be utilized to estimate and monitor the stray current leakage from the tracks.

    1. As part of the pre and post-revenue surveys coordinated with the transit agency, pipe-to-track correlation recordings should be performed. The correlation recordings provide information that can be utilized as a baseline for the influence of the transit system on the pipeline. Subsequent correlation testing can identify changes in the correlation between the pipeline and tracks that can aid in identifying degradation in the electrical isolation of the tracks from earth or a change in the electrical circuit of the pipeline.

iv. Current flow magnitude and direction for pipelines equipped with current measurement test facilities. The current magnitude and direction can aid in identifying changes in stray current patterns and magnitude and can be used for locating current pick up and discharge areas on the pipeline. Current flow can be measured utilizing permanently installed hall-effect transducers, if necessary in critical areas, or by utilizing test stations. To utilize the test stations, the electrical continuity test described in 1.a.i above is utilized to determine the resistance of a span of pipeline under test. The calculated resistance then can be utilized to calculate the amount of current flow on the pipeline due to stray current utilizing Ohms law.

v. Coupon current density and direction for pipelines equipped with coupon test facilities. Current discharge from the coupon indicates a corrosive condition exists. The corrosion rate can be estimated from the current density and time relationship. Testing procedures and data analysis for coupons is dependent upon the type and configuration of the coupon installation. In some cases, special instrumentation can be utilized to automate the testing.

vi. Corrosion rate for pipelines equipped with corrosion rate probes. The corrosion rate can be monitored to estimate the remaining design life of the pipeline. When corrosion rate probes are installed for a pipeline, it is generally recommended to install two probes. The first probe will provide a relatively fast response to changes in the corrosion rate but, the design life of the probe will be much shorter than the design life of the pipeline. The second probe should be designed with a life expectancy similar to the design life of the pipeline to provide long-term monitoring capabilities. Special testing equipment is utilized to measure and calculate the corrosion rate information. The corrosion rate should be monitored and compared to the pipeline design to ensure stray current effects (or corrosive soil) do not significantly reduce the intended service of the pipeline.

2. Pipelines with cathodic protection

   i. All testing procedures and analysis associated with electrically continuous pipelines without cathodic protection described in 1.a above apply. Modifications and additions to testing and analysis for pipelines with cathodic protection are provided below.

   ii. Structure-to-electrolyte potential. Anodic potential shifts that reduce the level of cathodic protection below the criteria for adequacy for a significant portion of a 24-hour test period indicate additional investigation is warranted. Cathodic shifts that increase the level of cathodic protection above 1100 millivolts for a significant portion of a 24-hour test period indicate that additional investigation is warranted. The criteria for evaluating the adequacy of cathodic protection are presented in the Canadian Gas Association Recommended Practice OCC-1-2005, "Control of External Corrosion on Buried or Submerged Metallic Piping Systems".

   iii. Coupon current density and direction for pipelines equipped with coupon test facilities. Current discharge from the coupon indicates a corrosive condition exists. The corrosion rate can be estimated from the current density and time relationship. The coupon current density and coupon-to-reference electrode potential can also be utilized to evaluate the adequacy of cathodic protection on the pipeline.

iv. Corrosion rate for pipelines equipped with corrosion rate probes. The corrosion rate can be monitored to evaluate the adequacy of cathodic protection on the pipeline and to estimate the remaining design life of the pipeline.

v. Cathodic protection system anode current output. The current output of anodes installed at test stations can be measured with a dc ammeter. The level of current output of the anodes can be monitored over time and compared to the design values for estimation of the remaining useful life of the anodes. The current should flow in the electrical circuit from the pipeline (+) on the ammeter to the anode (-) on the ammeter, indicating that cathodic protection current is flowing from the anode to the pipeline through the soil. If the current is flowing in the opposite direction it indicates that stray current is being picked up by the anode and distributed to the pipeline. This strongly suggests that a stray current discharge area is present on the pipeline circuit and additional investigation is required. In some instances, diodes can be inserted in the anode/pipeline circuit to prevent stray current pick up by the anodes.

5. Electrically Discontinuous (Existing) Pipelines

vi. Structure-to-electrolyte potential. The structure-to-electrolyte potential can be utilized to aid in identifying the magnitude of stray current influence on the pipeline by measuring the amount of polarization (current pick up) or depolarization (current discharge) from the free corrosion potential. Anodic potential shifts of more than approximately 20mV (excluding IR drop) indicate additional investigation is warranted. Cathodic potential shifts of a magnitude that can damage coating or create hydrogen embrittlement of prestressing wires, if present, should also be evaluated. Cathodic potential shifts that create a cathodic structure-to-electrolyte potential in excess of 1100 mV (excluding IR drop) indicate that additional investigation is warranted. Additionally, significant cathodic potential shifts at the test location suggest that damaging anodic potential shifts may be occurring at other locations on the pipeline circuit. At test facilities equipped with two underground reference electrodes, the potential difference between the reference electrodes can be utilized to estimate and monitor the stray current leakage from the tracks.

1. As part of the pre and post-revenue surveys coordinated with the transit agency, pipe-to-track correlation recordings should be performed. The correlation recordings provide information that can be utilized as a baseline for the influence of the transit system on the pipeline. Subsequent correlation testing can identify changes in the correlation between the pipeline and tracks that can aid in identifying degradation in the electrical isolation of the tracks from earth or a change in the electrical circuit of the pipeline.

vii. Coupon current density and direction for pipelines equipped with coupon test facilities. Current discharge from the coupon indicates a corrosive condition exists. The corrosion rate can be estimated from the current density and time relationship. Testing procedures and data analysis for coupons is dependent upon the type and configuration of the coupon installation. In some cases, special instrumentation can be utilized to automate the testing.

D3. Isolation Fitting Resistance Measurement Procedure

1. General

This procedure provides guidelines for field testing necessary to determine the effectiveness of an electrical isolation fitting. The isolation fittings addressed by this procedure includes isolation flanges, pipeline isolation joints, mechanical isolation fittings and isolating unions.

1.1. Purpose

The purpose of this procedure is to provide guidance for consistent evaluation of the effectiveness of an electrical isolation fitting. Evaluation methods are provided for both above grade and underground electrical isolation fittings.

1.2. Definitions

1. Remote Earth – A location on the earth far enough from the affected structure that the soil potential gradients associated with the currents entering the earth from the affected structure are insignificant. Note: The remote earth must be electrically continuous with the electrolyte in contact with the structure.
2. Structure-to-Electrolyte Potential – The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.
3. Electrolyte – A chemical substance, such as soil, water or concrete, containing ions that migrate in an electric field.
4. Electrode – A conductor used to establish contact with an electrolyte and through which current is transferred to or from the electrolyte.
5. Reference Electrode – An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials. Also known as a half-cell.
6. Bond – A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.
7. Anode – The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the electrolyte at the anode.
8. Cathode – The electrode of an electrochemical cell at which reduction occurs. Electrons flow toward the cathode in the external circuit.
9. Cathodic Protection – A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.
10. Current Density – The current to or from a unit area of an electrode surface.
11. Stray Current – Current flowing through a path other than the intended path.
12. Long-Line Current – Current flowing between an anodic and cathodic area on a structure that are separated by a considerable distance.
13. Open Circuit Potential – The potential between two electrically isolated metallic structures.
14. Instant-Off Potential – The half-cell potential of a structure taken immediately after the applied current is interrupted or stopped.
15. IR Drop – The voltage across a resistance when current is applied in accordance with Ohm's Law.
16. Attenuation – Electrical losses in a conductor caused by current flow in the conductor.

17. Conductivity – A measure of the ability of a material to conduct an electric charge.
18. Discontinuity – A condition in which the electrical path through a structure is interrupted.
19. Driving Potential – A difference in potential that produces current flow through a resistance.
20. Electrical Isolation – The condition of being electrically separated from other metallic structures or the environment.
21. Polarization – The change from the open-circuit electrode potential as a result of current across the electrode/electrolyte interface.
22. Potential Gradient – A change in the potential with respect to distance, expressed in millivolts per unit distance.
23. Resistance to Electrolyte – The resistance of a structure to the surrounding electrolyte.
24. Test Lead – A wire or cable attached to a structure for connection of a test instrument to make measurements.
25. Voltage – An electromotive force or a difference in electrode potentials expressed in volts.

1.3. Equipment

The user must be knowledgeable of the capabilities and limitations of the equipment, follow the manufacturer's instruction manual, and be skilled in the use of the instruments in order to avoid errors in measurements. The following presents typical equipment requirements to measure structure-to-electrolyte potentials.

1. Voltmeter, D.C.: Multi-scale, minimum 10 megohm input impedance (or equivalent input resistance), capable of reading positive and negative values without removing the test leads and covering at least the following full-scale ranges:

   0 to 5 mV; 0 to 500 mV; 0 to 5 V; 0 to 50 V; 0 to 500 V.
   Meters shall be accurate within 1% of full scale.
   Meters with selectable input impedance (input resistance for analog meters) are preferable.

2. Ammeter, D.C.: Multi-scale, covering the following full-scale ranges:

   0 to 5 A; 0 to 10 A; 0 to 100 A.

3. Millammeter, D.C.: Multi-scale, covering the following full-scale ranges:

   0 to 5 mA; 0 to 500 mA.

4. Shunts: An alternative to the ammeter and millammeter is a voltmeter with external shunts. Meter and shunt combinations should be accurate to within one percent of full scale.

5. D.C. Current Source With Controls: Six or twelve volt automotive type wet cell battery or equivalent. For circuits having high internal resistance, two or more batteries may be required. For circuits having very low internal resistance adequate controls are necessary to limit the test current and avoid damage to the testing instruments.

6. Test Wires: Single conductor cable, stranded copper, with a minimum 600 volt insulation in perfect condition. Provide sufficient length(s) as required to establish test circuits with appropriate terminal lugs and clamp or clip terminations.

7. Magnetic compass.

8. Radio frequency skin-effect meter (Gas Electronics Model 601 or Tinker & Rasor RF IT).

9. Copper-copper sulfate reference electrode.

10. Miscellaneous hand tools necessary for disconnecting and reconnecting test leads.

1.4. Safety Considerations

Appropriate safety precautions, in accordance with Region of Peel requirements, shall be observed when making electrical measurements. The following, in addition to the Region of Peel requirements, should be considered:

a. Be knowledgeable and qualified in electrical safety precautions before installing, adjusting, repairing, removing, or testing energized equipment, including cathodic protection equipment.

b. Use properly insulated test leads, clips and terminals to avoid contact with unanticipated high voltage. Attach test clips one at a time using a single-hand technique for each connection.

c. Use caution when long test leads are extended near overhead high-voltage alternating current power lines, which can induce hazardous voltages onto the test leads. High-voltage direct current power conductors do not induce voltages under normal operations, but transient conditions can cause hazardous voltages.

d. Use caution when making tests at electrical isolation devices. Before proceeding with tests, use appropriate voltage detection instruments or voltmeters with insulated test leads to determine whether hazardous voltages exist.

e. Avoid testing when thunderstorms are in the area. Remote lightning strikes can create hazardous voltage surges that travel along the structure under test.

f. Use caution when running test leads across streets, sidewalks, and other locations subject to vehicular or pedestrian traffic. When conditions warrant, use appropriate barricades, flagging, or other warning methods.

g. Prior to entering excavations or confined spaces, inspect to determine that they are safe in accordance with all Region of Peel confined space entry procedures.

h. Observe applicable electrical codes and safety regulations during all testing.

1.5. Procedure

"This procedure does not encompass all possible field conditions to obtain accurate evaluation of electrical isolation effectiveness. No general set of test procedures will be applicable to all situations."

Prepare a test data template for recording of the field data. Identify the locations for testing. A sample test data template is included in the Supporting Documents.

Conduct a Pre-Testing "tailgate" meeting with the testing personnel, if necessary, to review the locations for test data collection.

Visually examine the location to be tested to ensure that there is sufficient access to the isolation fitting for testing. Visually examine the location to be tested to ensure that there is no appreciable degree of debris, water, dirt, vegetation, ballast, or other material that may affect the accuracy of the measurements. Record on the data sheet the weather conditions for the previous 48 hours.

Isolation Fitting Test Methods. There are several test methods that may be utilized to evaluate the effectiveness of an isolation fitting. The method selected depends primarily upon access to the fitting. A summary of each test method and basic test set-up sketches are provided below:

1. Radio Frequency Skin-Effect Test. This test is only used for aboveground or fully excavated isolation fittings. The test is conducted with a specially designed meter that applies a radio frequency signal between two probes. Radio frequency signals do not travel through a structure in a uniform fashion like DC but, rather, they travel completely on the surface of the structure which leads to a relatively high AC resistance. This phenomenon is known as a "skin-effect". The Gas Electronics Model 601 meter is a radio frequency skin-effect meter. The needle deflection on the 601 meter is a reflection of the effective AC resistance of the material between the meter probes. The power output of the meter is very low so that it can be used to test isolation fittings that may have parallel paths around the isolation fitting being tested. The low power output of the meter also makes it more vulnerable to damage from high voltages across an isolator. The meter should not be used if the DC voltage across the isolator exceeds 50 volts. The meter can usually withstand substantial AC voltages across the isolator. However, high transient AC voltages might damage diodes within the meter circuit.

   For an effective isolator, the AC resistance is very large and the meter needle will be fully to the right side of the scale. Any needle deflection towards the left side of the scale indicates probable "leakage" through the isolation fitting or could indicate inadequate contact between the meter probes and the fitting. If probable leakage is indicated across a bolted fitting, the meter can be utilized to test individual bolts to determine the effectiveness of isolation of each bolt.

   The Model 601 meter should be operated in accordance with the manufacturers operating instructions. Prior to utilizing the 601 meter, the DC voltage across the isolation fitting should be measured with a voltmeter to ensure less than 50V is present across the fitting. The testing procedures are summarized below:

   a. Remove the protective guards from the meter probes.

   b. Perform a battery test to ensure the meter is ready for testing.

   c. Select the fixed probe or the fixed/flexible probe testing method.

   d. Turn on the meter and "zero" the meter.

   e. Make contact with each probe across the isolation fitting.

      i. It is imperative that positive low contact resistance connections are made between the probes and the fitting. If either probe is not making good contact and erroneous reading will result.

   f. Observe the needle on the meter scale. Note any deflection towards the left side of the scale. If any deflection towards the left is noted, check the quality of the probe contacts to the fitting and repeat the test to confirm the deflection is not due to inadequate probe contact.

g. Test each bolt of a bolted isolation fitting if the initial testing indicates leakage across the isolator. Note any bolts that indicate current leakage and schedule to replace the faulty isolation materials.

h. Record all test data and observations on a Field Data Sheet. Include sketches as necessary.

i. Turn the instrument off and replace the protective guards on the meter probes.

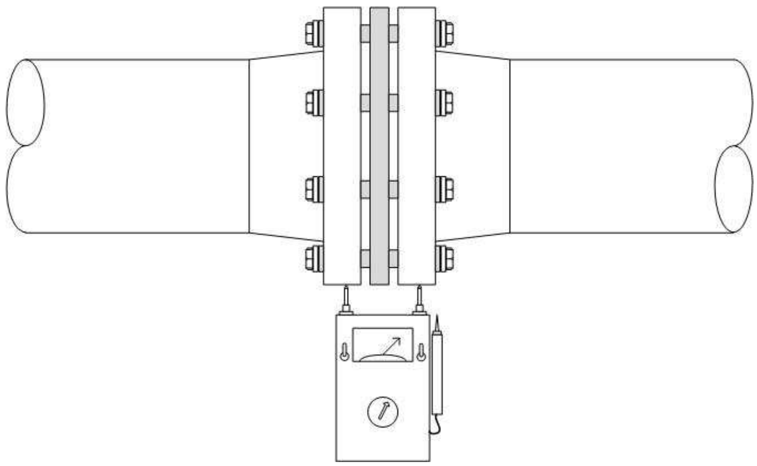


Figure 1. Radio Frequency Skin-Effect Test.

2. Isolator Resistance Test. This test is only used for aboveground or fully excavated isolation fittings. The test measures the DC resistance across the isolation fitting by impressing a test current across the fitting and measuring the voltage across the fitting as a result of the test current.

   Set up the isolation fitting resistance test in accordance with the sketch and instructions below:

   a. Connect a test wire from the positive terminal of the voltmeter to the structure on one side of the isolation fitting.
   b. Connect a test wire from the negative terminal of the voltmeter to the structure on the other side of the isolation fitting.
   c. Connect a test wire from the negative terminal of the DC Current Source to the structure on the same side of the isolation fitting as the voltmeter negative terminal connection.
   d. Connect a test wire from the positive terminal of the DC Current Source to the positive terminal of the ammeter. Note: Some DC Current Sources have a built-in ammeter and the positive terminal of the source can be connected directly to the structure on the same side of the fitting as the voltmeter positive connection, avoiding Step e.
   e. Connect the negative terminal of the ammeter to the structure on the same side as the voltmeter positive connection.

f. Turn on the voltmeter to the highest scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the voltage measured should be in the upper two-thirds of the voltage scale.
g. Observe the reading on the voltmeter. If the reading is "jittery" or unstable, and dynamic stray current effects are not anticipated, check all test lead connections to ensure no high resistance connections exist in the measurement circuit.
h. For structures where dynamic stray current effects are anticipated, the voltage level will fluctuate with time. At these locations, the voltmeter should be set to record the minimum, maximum, and average voltage values over a period of at least 5 minutes.
i. Record the potentials on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the location of the structure connections, the time that the readings were taken and the polarities of the voltages observed. A sketch of the measurement circuit should be added to the Test Data Sheet when appropriate to clarify the measurement circuit.
j. Adjust the DC Current Source to the lowest current output utilizing the control circuits.
k. Turn on the DC Current Source. Adjust the current output utilizing the control circuits until the current flow produces an easily measureable voltage value on the voltmeter. Measure and record the current flow in the test circuit utilizing the built in ammeter or a portable ammeter. Measure and record the voltage across the isolation fitting and polarity utilizing the voltmeter. Temporarily disconnect the current flow in the circuit utilizing the control circuits or by turning off the DC Current Source then measure and record the "instant off" voltage and polarity across the fitting. Repeat the measurement and recording of at least 3 sets of the "current on" and "instant off" test current and voltage values.

Calculate the isolation fitting resistance by dividing the change in voltage across the fitting by the change in test current for each set of values (Ohm's Law). Compare the calculated resistance values. The resistance values should not vary by more than approximately 5%. If a variance of greater than 5% exists, additional testing may be necessary to obtain a reliable resistance value. The overall resistance of the fitting should be estimated as the average of the calculated resistance values.

Each bolt can be tested if the overall fitting resistance indicates the fitting is ineffective. To evaluate each bolt, perform the test as described above with the exception that, instead of measuring the voltage across the isolation fitting, the voltage across each bolt is measured with the test current "on" and "instant off". A shorted bolt will be indicated by a millivolt shift across the bolt caused by the test current. An effective bolt will typically have a zero millivolt shift as a result of the test current.

This test method should be used with caution if alternate parallel paths around the isolation fitting are possible. In this case, the test results may indicate an ineffective isolation fitting when, in fact, the electrical path is an alternate parallel path to the fitting.

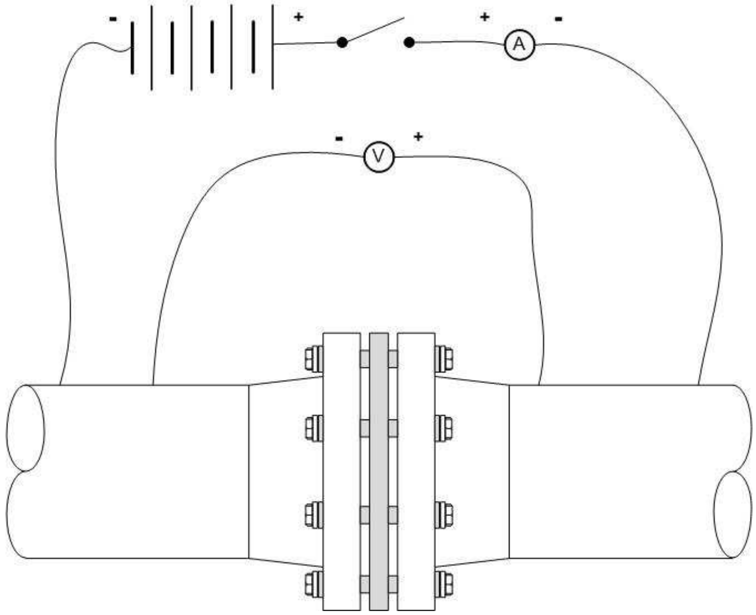


Figure 2. Isolator Resistance Test.

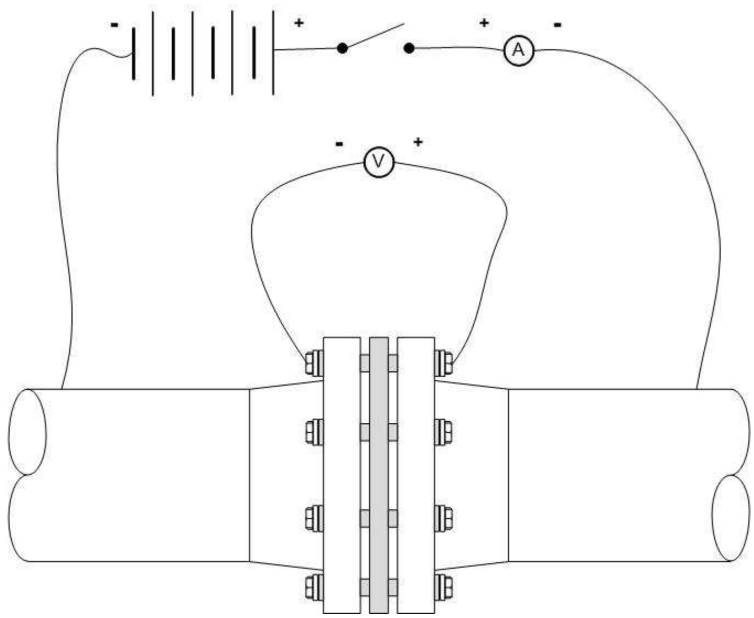


Figure 3. Isolator Resistance Bolt Test.

3. Magnetic Compass Test. This test is only used for aboveground or fully excavated isolation fittings. The test measures the change in the electromagnetic field across an isolation fitting caused by current flow through the fitting. This test can be performed by impressing a test current across the isolation joint or by applying a test current between the structure and a grounded structure one side of the joint. Current flow through the fitting is indicated by the compass needle aligning with the direction of the current flow.

   Set up the isolator magnetic compass test in a similar manner as the isolator resistance test or current can be applied to between one side of the isolator and a grounded structure. A sketch of a typical set up is shown below.

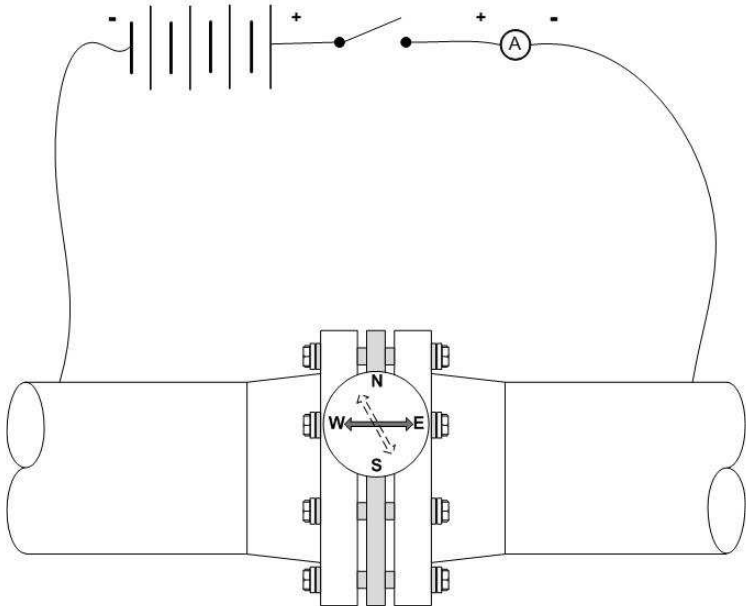


Figure 4. Magnetic Compass Test.

Each bolt can be tested if the overall fitting resistance indicates the fitting is ineffective. To evaluate each bolt, perform the test as described above with the compass placed over each bolt. A shorted bolt will be indicated by the needle aligning with the bolt when the current is applied across the fitting. An effective bolt typically will not align with the bolt or will align but not as definitely as for a shorted bolt.

4. Percent Leakage Test. This test can be utilized for both above grade and underground isolation fittings. However, it should be noted that for underground isolation fittings the percentage leakage calculated will include both leakage through the isolation fitting and leakage around the isolation fitting through the soil. The percent leakage will also include leakage around the fitting through the liquid within a pipe.

   The test is a special application of a structure resistance calibration/continuity test and is set up in a similar manner. Set up the percent leakage test in accordance with the sketch and instructions below:

   a. Connect a test wire from the positive terminal of the voltmeter to the structure at test point 2.
   b. Connect a test wire from the negative terminal of the voltmeter to the structure at test point 3.
   c. Connect a test wire from the negative terminal of the DC Current Source to the structure at test point 4.
   d. Connect a test wire from the positive terminal of the DC Current Source to the positive terminal of the ammeter. Note: Some DC Current Sources have a built-in ammeter and the positive terminal of the source can be connected directly to the structure at test point one, avoiding Step e.
   e. Connect the negative terminal of the ammeter to the structure at test point 1.
   f. Turn on the voltmeter to the highest scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the voltage measured should be in the upper two-thirds of the voltage scale.
   g. Observe the reading on the voltmeter. If the reading is “jittery” or unstable, and dynamic stray current effects are not anticipated, check all test lead connections to ensure no high resistance connections exist in the measurement circuit.

h. For structures where dynamic stray current effects are anticipated, the voltage level will fluctuate with time. At these locations, the voltmeter should be set to record the minimum, maximum, and average voltage values over a period of at least 5 minutes.
i. Record the potentials on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the location of the structure connections, the time that the readings were taken, the polarities of the voltages observed, and the approximate structure temperature at the time of the test. A sketch of the measurement circuit should be added to the Test Data Sheet when appropriate to clarify the measurement circuit.
j. Adjust the DC Current Source to the lowest current output utilizing the control circuits.
k. Turn on the DC Current Source. Adjust the current output utilizing the control circuits until the current flow produces an easily measureable voltage value on the voltmeter. Measure and record the current flow in the test circuit utilizing the built in ammeter or a portable ammeter. Measure and record the voltage drop and polarity in the structure utilizing the voltmeter. Temporarily disconnect the current flow in the circuit utilizing the control circuits or by turning off the DC Current Source then measure and record the “instant off” voltage drop and polarity in the structure. Repeat the measurement and recording of at least 3 sets of the “current on” and “instant off” test current and voltage drop values.
l. Calculate the structure calibration factor (K_f) by dividing the test current (A) by the change in voltage drop caused by the test current (mV). Compare the calculated values. The values should not vary by more than approximately 5%. If a variance of greater than 5% exists, additional testing may be necessary to obtain a reliable calibration factor value. The structure calibration factor of the test section between test points 2 and 3 should be estimated as the average of the calculated values.
m. Repeat Steps k and l with the connection at test point 1 moved to the opposite side of the isolation fitting.
n. The estimated percent leakage of the isolation fitting is calculated as follows:

$$\% \text{ Leakage} = (K_{f1} / K_{f2}) \times 100$$

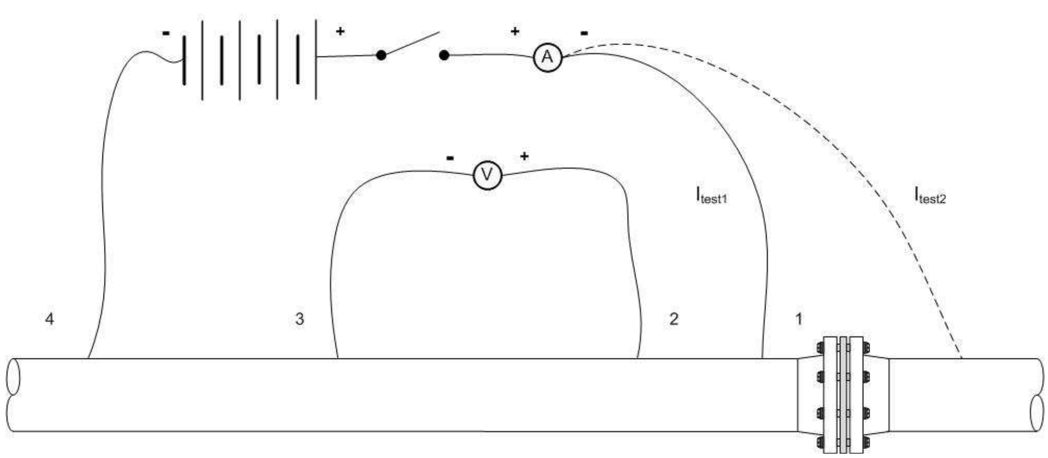


Figure 5. Percent Leakage Test.

5. Structure-to-Electrolyte Couplings. This test is primarily applicable to underground isolation fittings but, can be utilized for abovegrade fittings in limited conditions. The test measures the approximate resistance to earth of the structures on each side of the isolation fitting. This test method should be used with caution if alternate parallel paths around the isolation fitting are possible. In this case, the test results may indicate an ineffective isolation fitting when, in fact, the electrical path is an alternate parallel path to the fitting.

   The test is performed by applying a DC test current to one side of an isolation fitting and measuring the structure-to-electrolyte potential response to the test current on each side of the isolation fitting. The test current can be applied utilizing an existing cathodic protection system or by temporarily applying a test current between the structure and a grounded structure as shown in the test set up below.

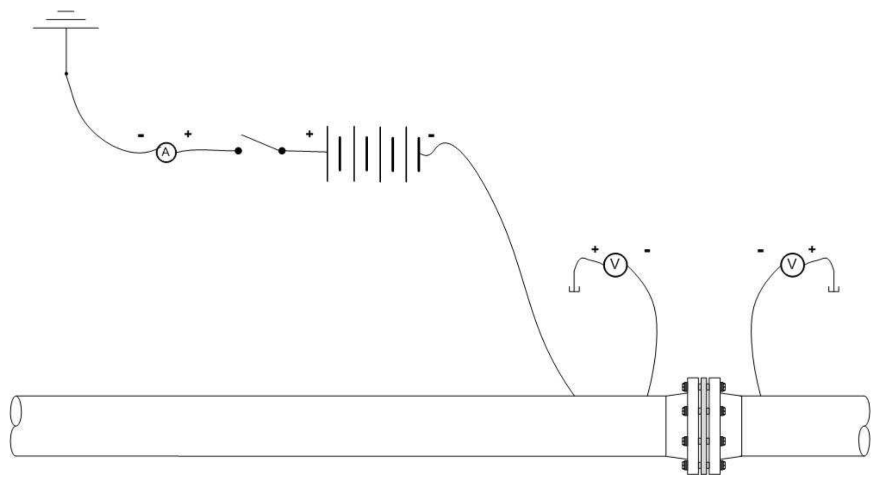


Figure 6. Structure-to-Electrolyte Coupling Test.

   With the test current temporarily interrupted, measure both the "on" and "instant off" structure-to-electrolyte potentials on each side of the isolation fitting. A minimum of three sets of readings should be recorded. The structure-to-electrolyte coupling is calculated as the change in structure-to-electrolyte potential divided by the test current (V/A). If the isolation joint is effective, the coupling on the side of the joint to which the test current is applied will be significantly larger than the coupling on the opposite side of the fitting. The coupling on the opposite side of the fitting should be very small or even opposite in polarity as compared to the coupling on the side of the joint to which the test current is applied. An ineffective isolation fitting is indicated by essentially equal structure-to-electrolyte couplings on each side of the fitting. Caution must be used in evaluating the results of this test. The couplings are dependent upon the resistance-to-earth of the structure and therefore, are significantly affected by the quality of the coating applied to the structure and the electrolyte resistivity. Caution in interpretation of the test results must be used if there are significant differences in coating quality or electrolyte resistivity on opposite sides of the isolation fitting.

Internal Resistance Test. This test is primarily applicable to underground isolation fittings but, can be utilized for above grade fittings in limited conditions. The test measures the approximate resistance to earth of the structures on each side of the isolation fitting by utilizing one side of the isolation fitting as a temporary anode with respect to the other side. The internal resistance is the sum of the resistance to earth on each side of the fitting. This test method should be used with caution if alternate parallel paths around the isolation fitting are possible. In this case, the test results may indicate an ineffective isolation fitting when, in fact, the electrical path is an alternate parallel path to the fitting.

Set up the internal resistance test in accordance with the sketch and instructions below:

a. Connect a test wire from the positive terminal of the voltmeter to a reference electrode placed directly above the structure on one side of the isolation fitting.
b. Connect a test wire from the negative terminal of the voltmeter to the structure on the other side of the isolation fitting.
c. With a second voltmeter, connect a test wire from the positive terminal of the voltmeter to a reference electrode placed directly above the structure on the opposite side of the isolation fitting as in Step a.
d. With the second voltmeter, connect a test wire from the negative terminal of the voltmeter to the structure on the opposite side of the isolation fitting as in Step b.
e. Connect a test wire from the negative terminal of the DC Current Source to the structure on the same side of the isolation fitting as the voltmeter negative terminal connection.
f. Connect a test wire from the positive terminal of the DC Current Source to the positive terminal of the ammeter. Note: Some DC Current Sources have a built-in ammeter and the positive terminal of the source can be connected directly to the structure on the same side of the fitting as the voltmeter positive connection, avoiding Step e.
g. Connect the negative terminal of the ammeter to the structure on the same side as the voltmeter positive connection.
h. Turn on the voltmeter to the highest scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the voltage measured should be in the upper two-thirds of the voltage scale.
i. Observe the reading on the voltmeter. If the reading is “jittery” or unstable, and dynamic stray current effects are not anticipated, check all test lead connections to ensure no high resistance connections exist in the measurement circuit.
j. For structures where dynamic stray current effects are anticipated, the voltage level will fluctuate with time. At these locations, the voltmeter should be set to record the minimum, maximum, and average voltage values over a period of at least 5 minutes.
k. Record the potentials on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the location of the structure connections, the time that the readings were taken and the polarities of the voltages observed. A sketch of the measurement circuit showing all polarities should be added to the Test Data Sheet to clarify the measurement circuit.
l. Adjust the DC Current Source to the lowest current output utilizing the control circuits.
m. Turn on the DC Current Source. Adjust the current output utilizing the control circuits until the current flow produces an easily measureable voltage value on the voltmeter. Measure and record the current flow in the test circuit utilizing the built in ammeter or a portable ammeter. Measure and record the structure-to-electrolyte “on” and “instant off” potentials with the voltmeter connections as indicated in Steps a and b and Steps c and d. Repeat the measurement and recording of at least 3 sets of the “current on” and “instant off” test current and potential values.

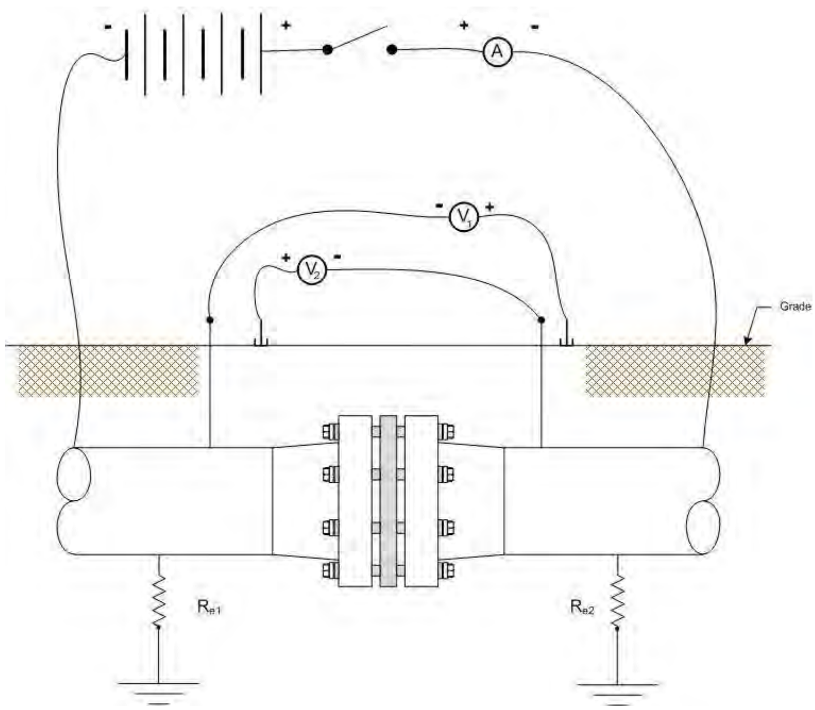


Figure 7. Internal Resistance Test.

Calculate the average change in structure-to-electrolyte potential on each side of the fitting caused by the test current. It is very important to note the polarities obtained during the measurements. With the test set up shown, the changes in structure-to-electrolyte potentials will be of opposite polarities. The internal resistance of the isolation fitting is calculated as follows:

$$R_{int} = (\Delta V_1 + \Delta V_2) / \Delta I_{test}$$

1.6. Supporting Documents

1. Exhibit A, Blank Field Data Sheet.

REGION OF PEEL

Field Data Sheet

Sheet: ________ of ________

Personnel: ______________________________

Date: ______________

Location/Circuit No.: ______________________________

Project No.: ______________

Location Description: ______________________________

Test Equip.: ______________

SKETCHES, CALCULATIONS, ETC.

TEST													
SCALE													
TIME													

D4. Galvanic Anode Current Measurement Procedure

1. General

This procedure provides guidelines for field testing necessary to measure cathodic protection current flow from a galvanic anode.

1.1. Purpose

The purpose of this procedure is to provide guidance for consistent and accurate measurement of galvanic anode current.

1.2. Definitions

1. Remote Earth – A location on the earth far enough from the affected structure that the soil potential gradients associated with the currents entering the earth from the affected structure are insignificant. Note: The remote earth must be electrically continuous with the electrolyte in contact with the structure.
2. Structure-to-Electrolyte Potential – The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.
3. Electrolyte – A chemical substance, such as soil, water or concrete, containing ions that migrate in an electric field.
4. Electrode – A conductor used to establish contact with an electrolyte and through which current is transferred to or from the electrolyte.
5. Reference Electrode – An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials. Also known as a half-cell.
6. Bond – A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.
7. Anode – The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the electrolyte at the anode.
8. Cathode – The electrode of an electrochemical cell at which reduction occurs. Electrons flow toward the cathode in the external circuit.
9. Cathodic Protection – A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.
10. Current Density – The current to or from a unit area of an electrode surface.
11. Stray Current – Current flowing through a path other than the intended path.
12. Open Circuit Potential – The potential between two electrically isolated metallic structures.
13. Instant-Off Potential – The half-cell potential of a structure taken immediately after the applied current is interrupted or stopped.
14. IR Drop – The voltage across a resistance when current is applied in accordance with Ohm’s Law.
15. Electrical Isolation – The condition of being electrically separated from other metallic structures or the environment.
16. Long-Line Current – Current through the electrolyte between an anodic area and a cathodic area that returns along the structure.

17. Polarization – The change from the open-circuit electrode potential as a result of current across the electrode/electrolyte interface.
18. Potential Gradient – A change in the potential with respect to distance, expressed in millivolts per unit distance.
19. Resistance to Electrolyte – The resistance of a structure to the surrounding electrolyte.
20. Test Lead – A wire or cable attached to a structure for connection of a test instrument to make measurements.
21. Voltage – An electromotive force or a difference in electrode potentials expressed in volts.

1.3. Equipment

The user must be knowledgeable of the capabilities and limitations of the equipment, follow the manufacturer's instruction manual, and be skilled in the use of the instruments in order to avoid errors in measurements. The following presents typical equipment requirements to measure structure-to-electrolyte potentials.

1. Voltmeter, D.C.: Multi-scale, minimum 10 megohm input impedance (or equivalent input resistance), capable of reading positive and negative values without removing the test leads and covering at least the following full-scale ranges:

   0 to 5 mV; 0 to 500 mV; 0 to 5 V; 0 to 50 V; 0 to 500 V.
   Meters shall be accurate within 1% of full scale.
   Meters with selectable input impedance (input resistance for analog meters) are preferable.

2. Ammeter, D.C.: Multi-scale, covering the following full-scale ranges:

   0 to 5 A; 0 to 10 A; 0 to 100 A.

3. Millammeter, D.C.: Multi-scale, covering the following full-scale ranges:

   0 to 5 mA; 0 to 500 mA.

4. Shunts: An alternative to the ammeter and millammeter is a voltmeter mith external shunts. Meter and shunt combinations should be accurate to within one percent of full scale.

5. D.C. Current Source With Controls: Six or twelve volt automotive type wet cell battery or equivalent. For circuits having high internal resistance, two or more batteries may be required. For circuits having very low internal resistance adequate controls are necessary to limit the test current and avoid damage to the testing instruments.

6. Test Wires: Single conductor cable, stranded copper, with a minimum 600 volt insulation in perfect condition. Provide sufficient length(s) as required to establish test circuits with appropriate terminal lugs and clamp or clip terminations.

7. Reference Electrode: Saturated copper-copper sulfate reference half-cell with a ceramic or wooden porous plug, diameter of approximately $1\frac{3}{8}$ or 3 inches. A thin wetted sponge may be utilized to improve the electrical contact between the reference electrode and the electrolyte when necessary.

8. Miscellaneous hand tools necessary for disconnecting and reconnecting test leads.

1.4. Safety Considerations

1. Appropriate safety precautions, in accordance with Region of Peel requirements, shall be observed when making electrical measurements. The following, in addition to the Region of Peel requirements, should be considered:

   a. Be knowledgeable and qualified in electrical safety precautions before installing, adjusting, repairing, removing, or testing energized equipment, including cathodic protection equipment.

   b. Use properly insulated test leads, clips and terminals to avoid contact with unanticipated high voltage. Attach test clips one at a time using a single-hand technique for each connection.

   c. Use caution when long test leads are extended near overhead high-voltage alternating current power lines, which can induce hazardous voltages onto the test leads. High-voltage direct current power conductors do not induce voltages under normal operations, but transient conditions can cause hazardous voltages.

   d. Use caution when making tests at electrical isolation devices. Before proceeding with tests, use appropriate voltage detection instruments or voltmeters with insulated test leads to determine whether hazardous voltages exist.

   e. Avoid testing when thunderstorms are in the area. Remote lightning strikes can create hazardous voltage surges that travel along the structure under test.

   f. Use caution when running test leads across streets, sidewalks, and other locations subject to vehicular or pedestrian traffic. When conditions warrant, use appropriate barricades, flagging, or other warning methods.

   g. Prior to entering excavations or confined spaces, inspect to determine that they are safe in accordance with all Region of Peel confined space entry procedures.

   h. Observe applicable electrical codes and safety regulations during all testing.

1.5. Procedure

"This procedure does not encompass all possible field conditions to obtain accurate current measurements. No general set of test procedures will be applicable to all situations."

Prepare a test data template for recording of the field data. Identify the locations for galvanic anode current measurements. A sample test data template is included in the Supporting Documents.

Conduct a Pre-Testing "tailgate" meeting with the testing personnel, if necessary, to review the locations for test data collection.

Visually examine the location to be tested to ensure that there is no appreciable degree of debris, water, dirt, vegetation, ballast, or other material that may affect the accuracy of the measurement. Record on the data sheet the weather conditions for the previous 48 hours.

There are three common procedures employed to measure the current flow from a galvanic anode. They are: 1. Indirect measurement with a shunt; 2. Direct measurement with a zero resistance ammeter and; 3. Direct measurement with an ammeter. Each procedure is presented below.

1. Indirect Measurement with a Shunt. This procedure is most commonly employed when a shunt is permanently installed in the anode circuit inside a test station as shown in Figure 1. If a temporary shunt is installed in the circuit for measurement, the additional resistance added to the circuit should be considered.

   a. Connect a test wire from the negative terminal of the voltmeter to the anode side shunt terminal.
   b. Connect a test wire from the positive terminal of the voltmeter to the structure side shunt terminal.
   c. Turn on the voltmeter to the highest millivolt scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the voltage measured should be in the upper two-thirds of the voltage scale.
   d. Observe the reading on the voltmeter. If the reading is "jittery" or unstable, and dynamic stray current effects are not anticipated, check all test lead connections to ensure no high resistance connections exist in the measurement circuit.
   e. For structures where dynamic stray current effects are anticipated, the voltage level will fluctuate with time. At these locations, the voltmeter should be set to record the minimum, maximum, and average voltage values over a period of at least 5 minutes.
   f. Record the millivolt measurements on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the type of shunt utilized, the shunt factor, the time that the readings were taken and the polarities of the voltages observed. A sketch should be added to the Test Data Sheet when appropriate to clarify the measurement circuit.
   g. Calculate the current flow through the test circuit and record on the data sheet. The current flow is calculated as shown below:

      I_{anode} (A) = $E_{mVshunt}$ (mV) x Shunt Factor (A/mV)

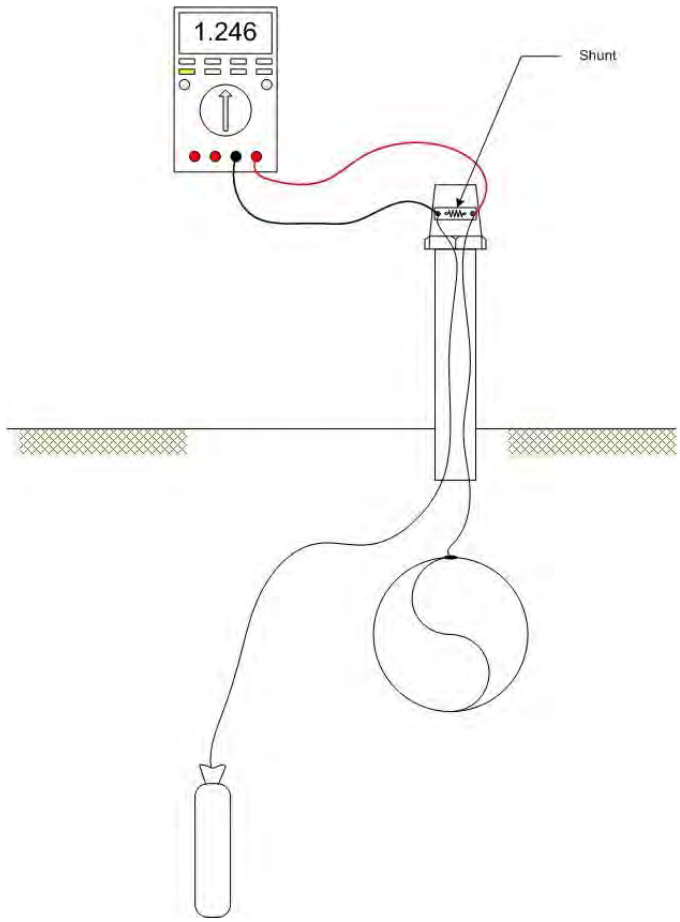
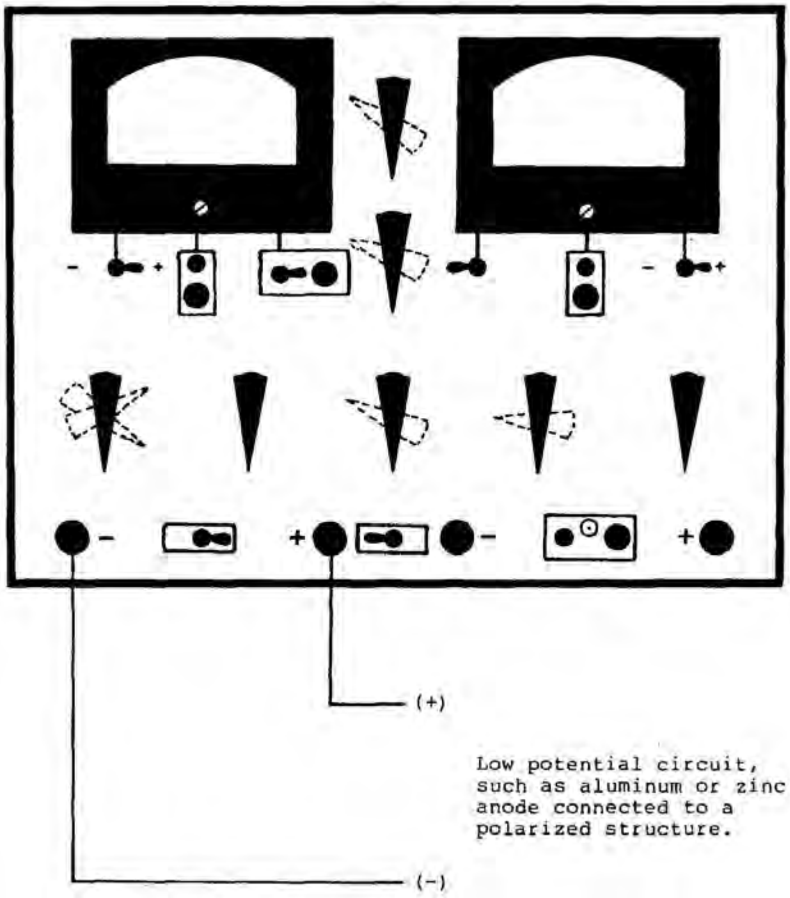


Figure 1. Indirect Current Measurement with a Shunt.

2. Direct Measurement with a Zero Resistance Ammeter. A zero resistance ammeter allows the measurement of current flow in a circuit without any addition of resistance. The operating principle of a zero resistance ammeter is as follows: A DC current source with an adjustable output is connected in series with an ammeter, the anode test lead and the pipe test lead. A galvanometer is connected across the anode test lead and the pipe test lead. When the galvanometer is balanced (zero deflection) the current produced by the DC current source is equal and opposite to that produced by the galvanic anode. The current produced by the DC current source then represents the value of the current flow in the circuit with zero added resistance. The MC Miller Model B3A-2 multimeter has built-in circuitry that can act as a zero resistance ammeter. The procedures and sketches below, excerpts from the Model B3A-2 Reference Guide, can be adapted to the use of alternate instrumentation.

Zero-Resistance Ammeter (Left Terminals)



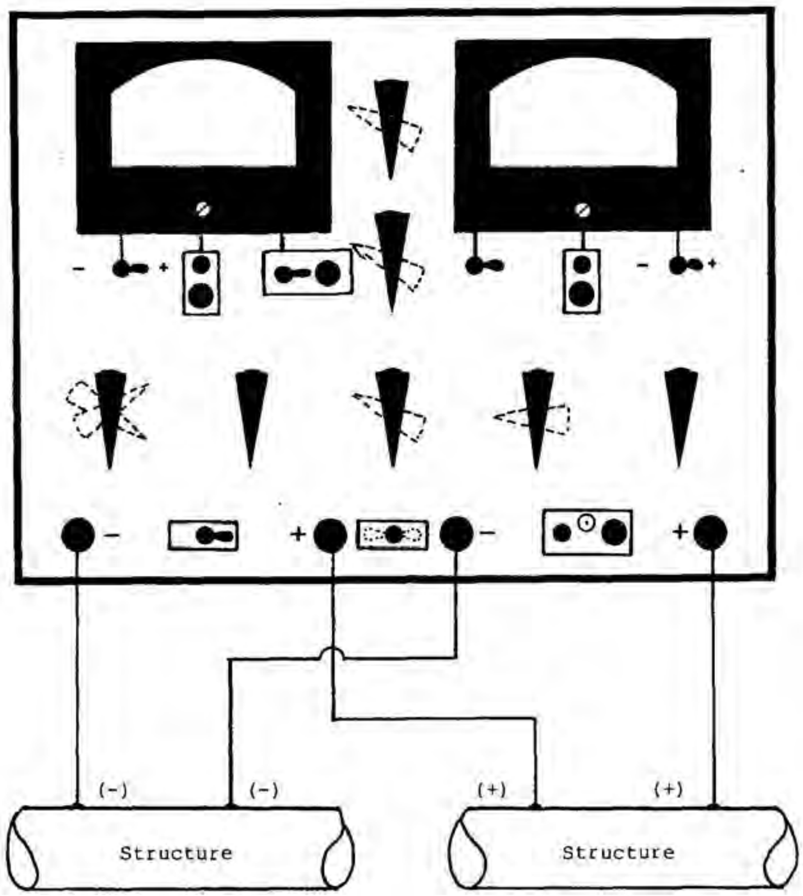
11 Zero-Resistance Ammeter (Left Terminals) Fig. #6

In certain circuits where open circuit voltage is less than about 500mV, the insertion of an ammeter with 20mV IR drop could cause considerable error. For example, a zinc anode installation connected to a polarized structure might have an open circuit voltage of less than 200mV. The zero-resistance ammeter circuit eliminates IR drop within the meter.

A zero-resistance type milliammeter/ammeter circuit is built into the B3A2. The circuit is set up with the "To Left Term/Norm" toggle switch in the "To Left Term" position. With the left meter being used to measure the current, the amps toggle switch is thrown to the "Amps With Controls" position and the battery toggle switch to the "1.5V" or "3V" position. The current is then "pumped" through the circuit and ammeter by using the batteries, controls and rheostat until the right-hand meter (which is connected across the left terminals) is adjusted to zero. The right range switch should be in the "2mV", "10mV" or "20mV" position for the most accurate results. The ammeter shunt, internal wiring, etc., now appear to have zero resistance in the circuit. The zero-resistance ammeter circuit can be used for measurements from a few milliamperes to about 2 amperes.

This circuit is somewhat "tricky" to use in that as the coarse and fine controls are turned the current flow is first reduced then increased to the original value and then increased further until the right-hand meter reads zero. Use caution at first until the action is understood. When making zero-resistance measurements, the positive lead of the current source must be connected to the positive terminal of the left meter.

Zero-Resistance Ammeter (4 Terminal Method)



12 Zero-Resistance Ammeter (4 Terminal Method) Fig. #7

Zero-resistance current measurements can also be made with the "To Left Term/Norm" toggle switch in the "Norm" position, in which case the effects of both the ammeter and lead resistances can be completely nullified. Four test leads are required, but otherwise the procedure is the same as described in the section "Zero-Resistance Ammeter (Left Terminals)."

If the right-hand meter deflects toward zero as current is increased but does not reach zero because of battery limitations, the actual zero-resistance current can be calculated using data obtained during the test. For example, assume that before commencing the test the open circuit voltage is 350mV and that the voltage between the two structures decreases to 240mV when the ammeter reads 2.00A.

$$Zerro-Resistance\ Current = \left(\frac{Open\ Circuit\ Voltage}{Change\ of\ Voltage}\right) \times Current\ Reading$$

$$6.36\,Amps = \left(\frac{350\,mV}{350\,mV - 240\,mV}\right)$$

3. Direct Measurement with an Ammeter. This method is typically the least desirable method for measurement of current with low driving voltages. The shunt resistance within the ammeter and the resistance of the test leads can create significant inaccuracy of the measured current value. The procedure to measure galvanic anode current directly with an ammeter, shown in Figure 2, is as follows:

a. Connect a test lead from the positive terminal of the ammeter to the pipeline test lead. The test lead should be as short as possible and at least a #12 AWG cable.
b. Connect a test lead from the negative terminal of the ammeter to the anode test lead. The test lead should be as short as possible and at least a #12 AWG cable.
c. Turn on the ammeter to the highest scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the measured value should be in the upper two-thirds of the scale.
d. Observe the reading on the ammeter. If the reading is "jittery" or unstable, and dynamic stray current effects are not anticipated, check all test lead connections to ensure no high resistance connections exist in the measurement circuit.
e. For structures where dynamic stray current effects are anticipated, the current level will fluctuate with time. At these locations, the ammeter should be set to record the minimum, maximum, and average current values over a period of at least 5 minutes.
f. Record the current measurements on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the time that the readings were taken and the polarity utilized to measure the current. A sketch should be added to the Test Data Sheet when appropriate to clarify the measurement circuit.

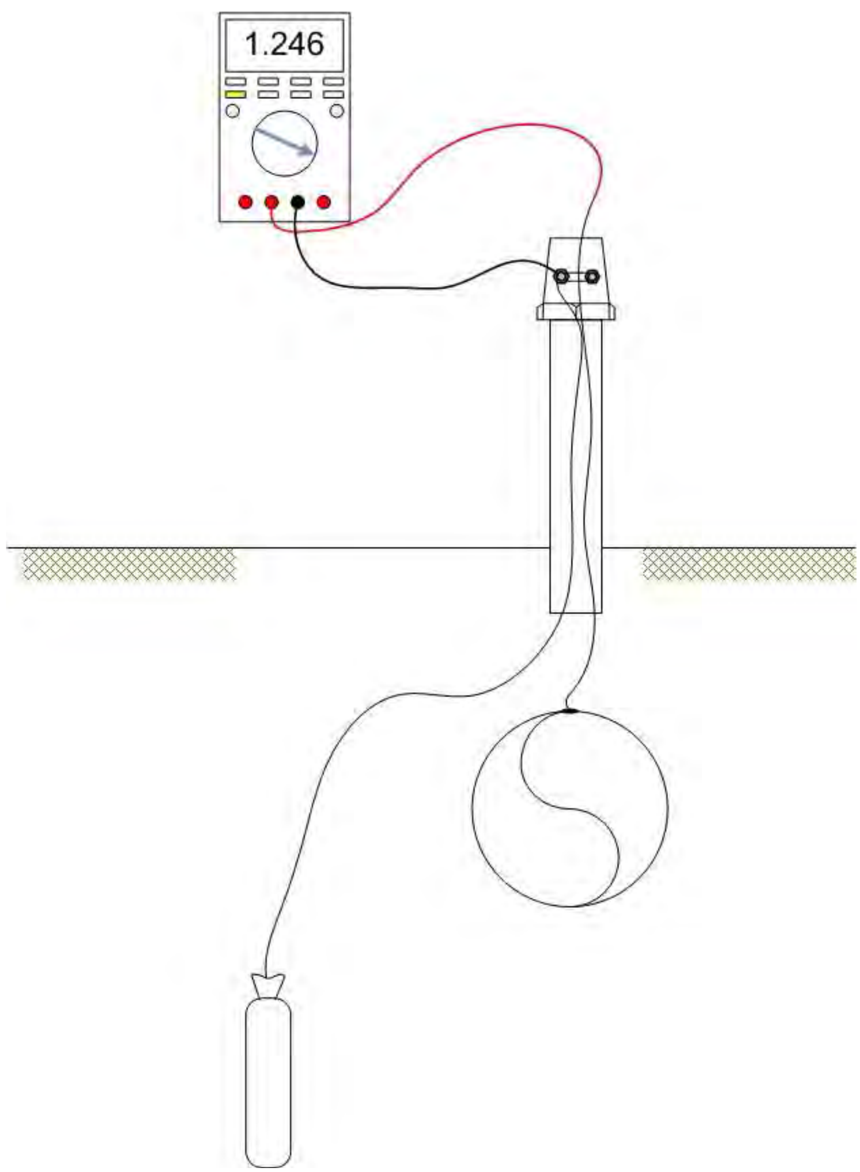


Figure 2. Direct Current Measurement with an Ammeter.

1.6. Possible Sources of Measurement Error

In order to make sound judgments based on current flow measurements, it is very important that the Technician understands possible sources of error inherent in the measurements and utilizes his/her knowledge and experience to avoid or reduce these errors.

Measurement Circuit. When the circuit is complete, current will flow due to the voltage difference between the structure and the anode. The total resistance regulates the amount of current flow in the circuit in accordance with Ohm’s Law. Any increase in the total circuit resistance caused by the measurement procedure will result in a corresponding reduction (error) in current flow through the circuit. Therefore, it is important to minimize or eliminate any added resistance in the measurement circuit. This is especially important when utilizing an ammeter to directly measure the current. The test leads should be at least an AWG # 12 cable and kept as short as possible.

1.7. Supporting Documents

1. Exhibit A, Blank Field Data Sheet.

Exhibit A

REGION OF PEEL

Field Data Sheet

Sheet: ________ of ________

Personnel: ____________________

Date: ____________________

Location/Circuit No.: ____________________

Project No.: ____________________

Location Description: ____________________

Test Equip.: ____________________

SKETCHES, CALCULATIONS, ETC.

TEST													
SCALE													
TIME													

D5. Pipeline Resistance Measurement Procedure

1. General

This procedure provides guidelines for field testing necessary to determine the approximate linear resistance of a pipeline and to measure the current flow on the pipeline for maintenance testing.

1.1. Purpose

The purpose of this procedure is to provide guidance for consistent and accurate measurement of structure resistance and current flow.

1.2. Definitions

1. Remote Earth – A location on the earth far enough from the affected structure that the soil potential gradients associated with the currents entering the earth from the affected structure are insignificant. Note: The remote earth must be electrically continuous with the electrolyte in contact with the structure.
2. Structure-to-Electrolyte Potential – The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.
3. Electrolyte – A chemical substance, such as soil, water or concrete, containing ions that migrate in an electric field.
4. Electrode – A conductor used to establish contact with an electrolyte and through which current is transferred to or from the electrolyte.
5. Reference Electrode – An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials. Also known as a half-cell.
6. Bond – A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.
7. Anode – The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the electrolyte at the anode.
8. Cathode – The electrode of an electrochemical cell at which reduction occurs. Electrons flow toward the cathode in the external circuit.
9. Cathodic Protection – A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.
10. Current Density – The current to or from a unit area of an electrode surface.
11. Stray Current – Current flowing through a path other than the intended path.
12. Long-Line Current – Current flowing between an anodic and cathodic area on a structure that are separated by a considerable distance.
13. Open Circuit Potential – The potential between two electrically isolated metallic structures.
14. Instant-Off Potential – The half-cell potential of a structure taken immediately after the applied current is interrupted or stopped.

15. IR Drop – The voltage across a resistance when current is applied in accordance with Ohm's Law.
16. Attenuation – Electrical losses in a conductor caused by current flow in the conductor.
17. Conductivity – A measure of the ability of a material to conduct an electric charge.
18. Discontinuity – A condition in which the electrical path through a structure is interrupted.
19. Driving Potential – A difference in potential that produces current flow through a resistance.
20. Electrical Isolation – The condition of being electrically separated from other metallic structures or the environment.
21. Polarization – The change from the open-circuit electrode potential as a result of current across the electrode/electrolyte interface.
22. Potential Gradient – A change in the potential with respect to distance, expressed in millivolts per unit distance.
23. Resistance to Electrolyte – The resistance of a structure to the surrounding electrolyte.
24. Test Lead – A wire or cable attached to a structure for connection of a test instrument to make measurements.
25. Voltage – An electromotive force or a difference in electrode potentials expressed in volts.

1.3. Equipment

The user must be knowledgeable of the capabilities and limitations of the equipment, follow the manufacturer's instruction manual, and be skilled in the use of the instruments in order to avoid errors in measurements. The following presents typical equipment requirements to measure structure-to-electrolyte potentials.

1. Voltmeter, D.C.: Multi-scale, minimum 10 megohm input impedance (or equivalent input resistance), capable of reading positive and negative values without removing the test leads and covering at least the following full-scale ranges:

   0 to 5 mV; 0 to 500 mV; 0 to 5 V; 0 to 50 V; 0 to 500 V.
   Meters shall be accurate within 1% of full scale.
   Meters with selectable input impedance (input resistance for analog meters) are preferable.

2. Ammeter, D.C.: Multi-scale, covering the following full-scale ranges:

   0 to 5 A; 0 to 10 A; 0 to 100 A.

3. Millammeter, D.C.: Multi-scale, covering the following full-scale ranges:

   0 to 5 mA; 0 to 500 mA.

4. Shunts: An alternative to the ammeter and millammeter is a voltmeter mith external shunts. Meter and shunt combinations should be accurate to within one percent of full scale.

5. D.C. Current Source With Controls: Six or twelve volt automotive type wet cell battery or equivalent. For circuits having high internal resistance, two or more batteries may be required. For circuits having very low internal resistance adequate controls are necessary to limit the test current and avoid damage to the testing instruments.

6. Test Wires: Single conductor cable, stranded copper, with a minimum 600 volt insulation in perfect condition. Provide sufficient length(s) as required to establish test circuits with appropriate terminal lugs and clamp or clip terminations.

7. Miscellaneous hand tools necessary for disconnecting and reconnecting test leads.

1.4. Safety Considerations

1. Appropriate safety precautions, in accordance with Region of Peel requirements, shall be observed when making electrical measurements. The following, in addition to the Region of Peel requirements, should be considered:

    a. Be knowledgeable and qualified in electrical safety precautions before installing, adjusting, repairing, removing, or testing energized equipment, including cathodic protection equipment.

    b. Use properly insulated test leads, clips and terminals to avoid contact with unanticipated high voltage. Attach test clips one at a time using a single-hand technique for each connection.

    c. Use caution when long test leads are extended near overhead high-voltage alternating current power lines, which can induce hazardous voltages onto the test leads. High-voltage direct current power conductors do not induce voltages under normal operations, but transient conditions can cause hazardous voltages.

    d. Use caution when making tests at electrical isolation devices. Before proceeding with tests, use appropriate voltage detection instruments or voltmeters with insulated test leads to determine whether hazardous voltages exist.

    e. Avoid testing when thunderstorms are in the area. Remote lightning strikes can create hazardous voltage surges that travel along the structure under test.

    f. Use caution when running test leads across streets, sidewalks, and other locations subject to vehicular or pedestrian traffic. When conditions warrant, use appropriate barricades, flagging, or other warning methods.

g. Prior to entering excavations or confined spaces, inspect to determine that they are safe in accordance with all Region of Peel confined space entry procedures.

h. Observe applicable electrical codes and safety regulations during all testing.

1.5. Procedure

"This procedure does not encompass all possible field conditions to obtain accurate structure resistance and current measurements. No general set of test procedures will be applicable to all situations."

Prepare a test data template for recording of the field data. Identify the locations for structure resistance and current measurements. A sample test data template is included in the Supporting Documents.

Conduct a Pre-Testing "tailgate" meeting with the testing personnel, if necessary, to review the locations for test data collection.

Visually examine the location to be tested to ensure that there is sufficient access to the structure for testing. Record on the data sheet the weather conditions for the previous 48 hours.

Pipeline Resistance Calibration. Set up the pipeline resistance calibration test in accordance with the sketch and instructions below:

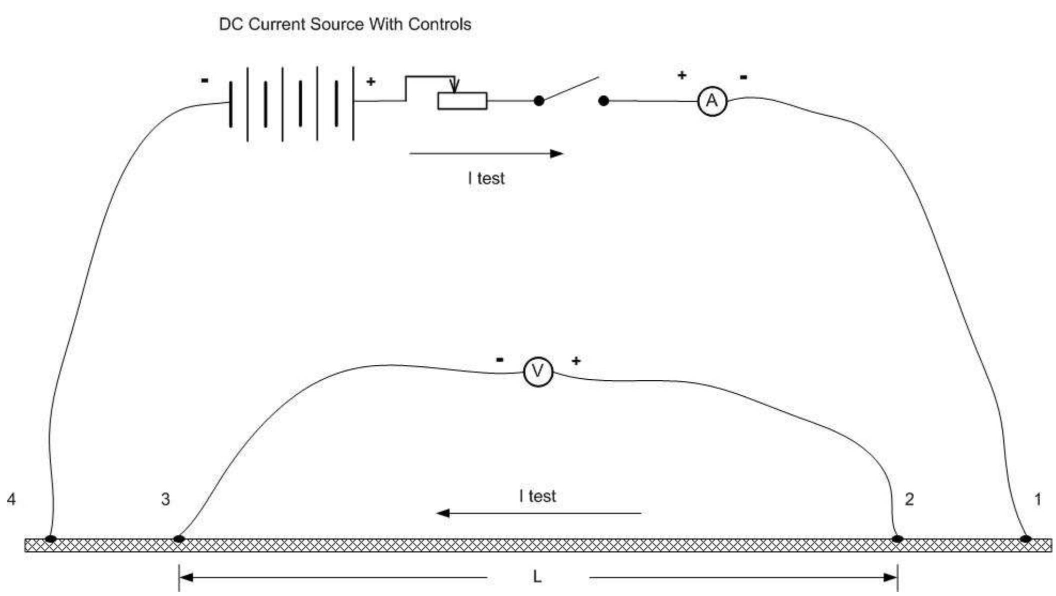


Figure 1. Pipeline Resistance Calibration Test Set Up.

1. Connect a test wire from the positive terminal of the voltmeter to the pipeline at test point 2.
2. Connect a test wire from the negative terminal of the voltmeter to the pipeline at test point 3.
3. Connect a test wire from the negative terminal of the DC Current Source to the pipeline at test point 4.

4. Connect a test wire from the positive terminal of the DC Current Source to the positive terminal of the ammeter. Note: Some DC Current Sources have a built-in ammeter and the positive terminal of the source can be connected directly to the pipeline at test point one, avoiding Step 5.
5. Connect the negative terminal of the ammeter to the pipeline at test point 1.
6. Turn on the voltmeter to the highest scale. Reduce the scale, if necessary, to obtain the desired resolution. Typically, the voltage measured should be in the upper two-thirds of the voltage scale.
7. Observe the reading on the voltmeter. If the reading is “jittery” or unstable, and dynamic stray current effects are not anticipated, check all test lead connections to ensure no high resistance connections exist in the measurement circuit.
8. For pipelines where dynamic stray current effects are anticipated, the voltage level will fluctuate with time. At these locations, the voltmeter should be set to record the minimum, maximum, and average voltage values over a period of at least 5 minutes.
9. Record the potentials on the Test Data Sheet. Note the scale used on the meter to obtain the readings, the location of the pipeline connections, the time that the readings were taken, and the polarities of the voltages observed. A sketch of the measurement circuit should be added to the Test Data Sheet when appropriate to clarify the measurement circuit.
10. Adjust the DC Current Source to the lowest current output utilizing the control circuits.
11. Turn on the DC Current Source. Adjust the current output utilizing the control circuits until the current flow produces an easily measureable voltage value on the voltmeter. Measure and record the current flow in the test circuit utilizing the built in ammeter or a portable ammeter. Measure and record the voltage drop and polarity in the pipeline utilizing the voltmeter. Temporarily disconnect the current flow in the circuit utilizing the control circuits or by turning off the DC Current Source then measure and record the “instant off” voltage drop and polarity in the pipeline. Repeat the measurement and recording of at least 3 sets of the “current on” and “instant off” test current and voltage drop values.
12. Calculate the pipeline resistance by dividing the change in voltage drop by the change in test current for each set of values (Ohm’s Law). Compare the calculated resistance values. The resistance values should not vary by more than approximately 5%. If a variance of greater than 5% exists, additional testing may be necessary to obtain a reliable resistance value. The overall pipeline resistance of the test section between test points 2 and 3 should be estimated as the average of the calculated resistance values. If multiple test sections exist on the same pipeline, resistance tests must be completed on each section. The measured pipeline resistance is compared to the theoretical resistance of an equivalent length of continuous pipeline. The measured resistance should not exceed 120% of the theoretical resistance. A pipeline current calibration factor, typically identified as K_f, is the inverse of the average unit resistance of the pipeline expressed as (A x Ft.)/mV.

Pipeline Current Measurement. The current flow on the pipeline can be calculated by measuring the voltage drop across a known resistance. Upon completion of the pipeline calibration testing described above, the current flow on the pipeline between test points 2 and 3 can be calculated by measuring the voltage drop between these two points in accordance with Step 8 above. If multiple test sections exist on the same pipeline, the current flow at the test sections can be calculated utilizing Step 8 and the structure current calibration factor as described in Step 12.

1.6. Possible Sources of Measurement Error

In order to make sound judgments based on pipeline current flow data, it is very important that the Technician understands possible sources of error inherent in the measurements and utilizes his/her knowledge and experience to avoid or reduce these errors.

Measurement Circuit. A typical pipeline current measurement circuit is shown between test points 2 and 3 in Figure 1. When the circuit is complete, a small current will flow due to the voltage difference between the two points on the pipeline as shown in the equivalent electrical circuit in Figure 2. Voltage drops occur across each of the resistive elements in the measurement circuit due to this current flow in accordance with Ohm's Law.

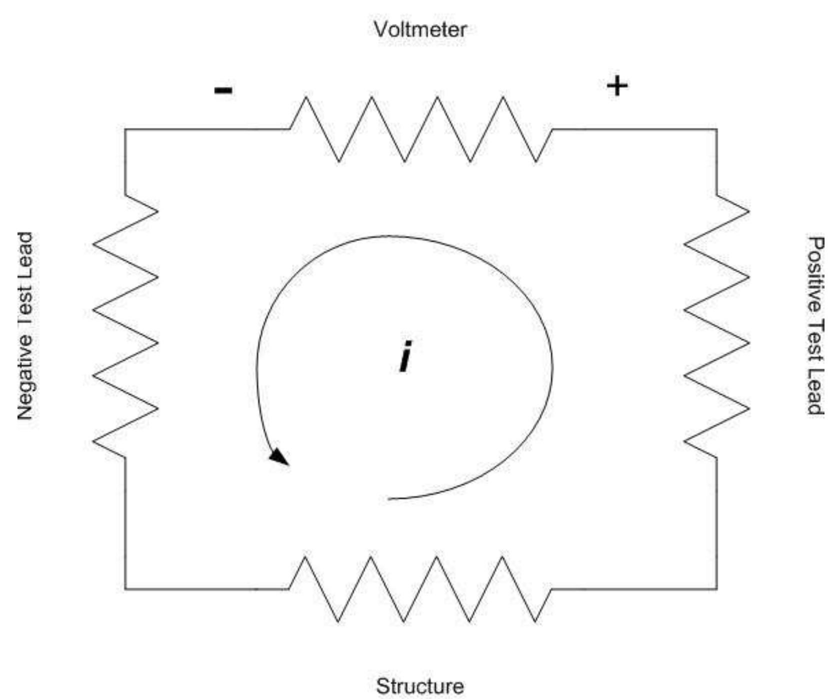


Figure 2. Equivalent Electrical Measurement Circuit.

The resistance of the test lead wires and the pipeline are sufficiently small that the voltage drop created by them in the measurement is insignificant in most cases. To minimize the possible error introduced by these resistances, the test leads should be kept as short as practical and a meter whose internal resistance/input impedance is several orders higher than the sum of the test leads (and contact resistance) and pipeline resistance is required so that the voltage drop across the meter resistance, for practical purposes, represents the entire voltage drop and limits the current flow in the measurement circuit. <u>It is</u>

very important to ensure a low resistance contact between the test leads and the pipeline to obtain accurate measurements.

Temperature. Temperature can have a significant effect on the resistance of a pipeline, particularly atmospherically exposed structures. For underground pipelines the temperature variation is typically small and the error introduced is insignificant. It is very important to note the temperature at the time the pipeline resistance is calibrated and the temperature during subsequent measurements. The relationship between resistance and temperature for metallic conductors is show by the equation below:

$$R = R_{ref} [1 + \alpha(T - T_{ref})]$$

Where,

R = Conductor resistance at temperature "T"

R_{ref} = Conductor resistance at reference temperature T_{ref}, usually 20° C, but sometimes 0° C.

α = Temperature coefficient of resistance for the conductor material.

T = Conductor temperature in degrees Celcius.

T_{ref} = Reference temperature that α is specified at for the conductor material.

For plain carbon steel, the temperature coefficient of resistance is approximately 0.003/ºC. For accurate calculations of current flow on a pipeline, the pipeline current calibration factor should be adjusted for the temperature difference between when the calibration factor was determined and when the subsequent measurements are taken.

1.7. Supporting Documents

1. Exhibit A, Blank Field Data Sheet.

Exhibit A

REGION OF PEEL

Field Data Sheet

Sheet: ________ of ________

Date: ________

Project No.: ________

Test Equip.: ________

Personnel: ________

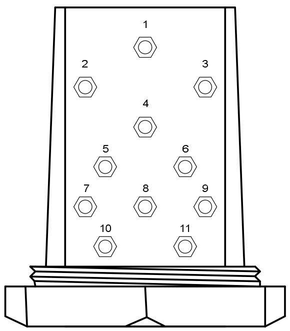
Location/Circuit No.: ________

Location Description: ________

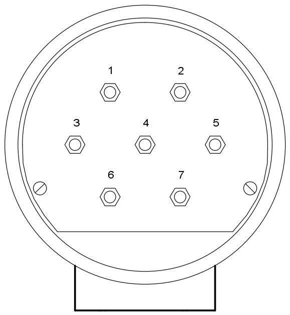
SKETCHES, CALCULATIONS, ETC.

TEST													
SCALE													
TIME													

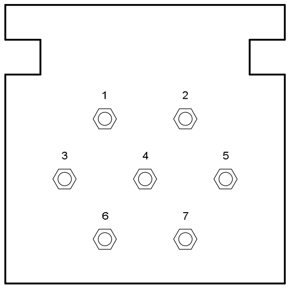
APPENDIX E
TEST STATION WIRING TABLES



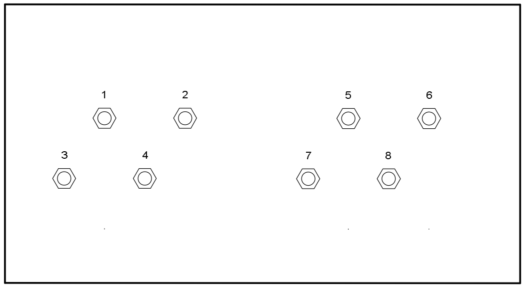
Cott Big Fink Style Test Station



Testox Series 800 Style Test Station



CP Test NM Style Test Station



Testox Series 1000 Style Test Station

Figure 1: Typical Test Station Configuration

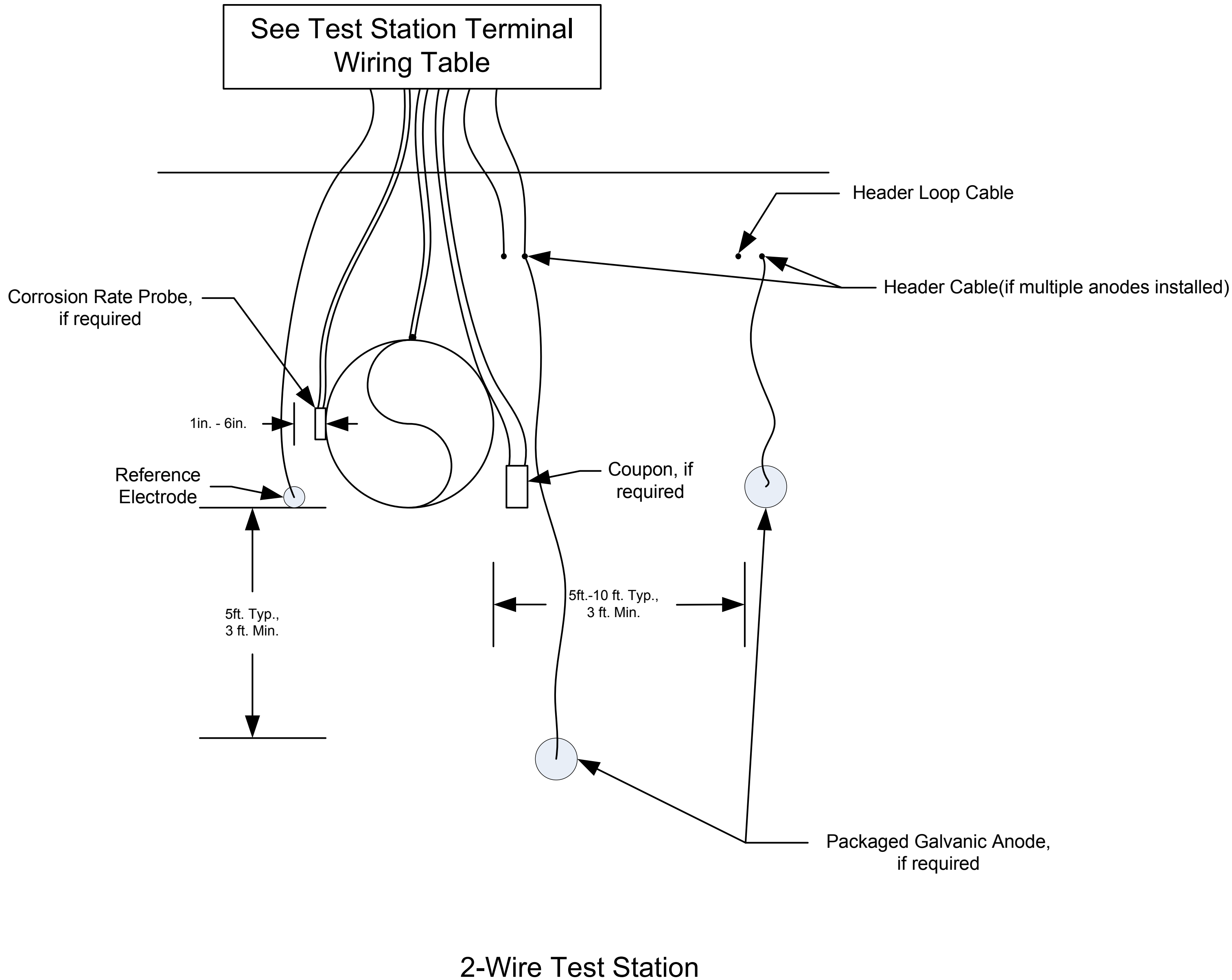


Figure 2. 2 Wire Test Station Wiring

Table 1: 2-Wire Test Station Wiring

Structure	AWG Cable Size	Cable Insulation	Test Station Terminal Connection			Remarks
			Big Fink	Testox 800	CP Test NM7	
Pipeline	10	RWU-90 Black	1 and 3	1 and 2	1 and 2	2 cables connected to pipeline
Magnesium Anode, if required	10	RWU-90 Blue for individual anodes, Red for Anode Header Cable	2	4	4	Bond to Terminal 1 pipeline cable with a bond strap or current measuring shunt
Zinc Anode, if required	10	RWU-90 White for individual anodes, Red for Anode Header Cable	2	4	4	Bond to Terminal 1 pipeline cable with a bond strap or current measuring shunt
Reference Electrode	12	HMWPE Black	5	3	3	Copper/Copper Sulfate electrode (delete if coupon installed)
Coupon, if required	14	RHW Purple	4 and 6	5 and 7	5 and 7	Coupon provided with integral zinc reference electrode. Zinc reference electrode cable is #14 RHW White
Corrosion Rate Probe, if required	14	THWN Green	3	2	2	Special connector for measurement of corrosion rate. Green wire is for connection of probe to pipe. Connect to pipe cable terminal that is not connected to anodes.

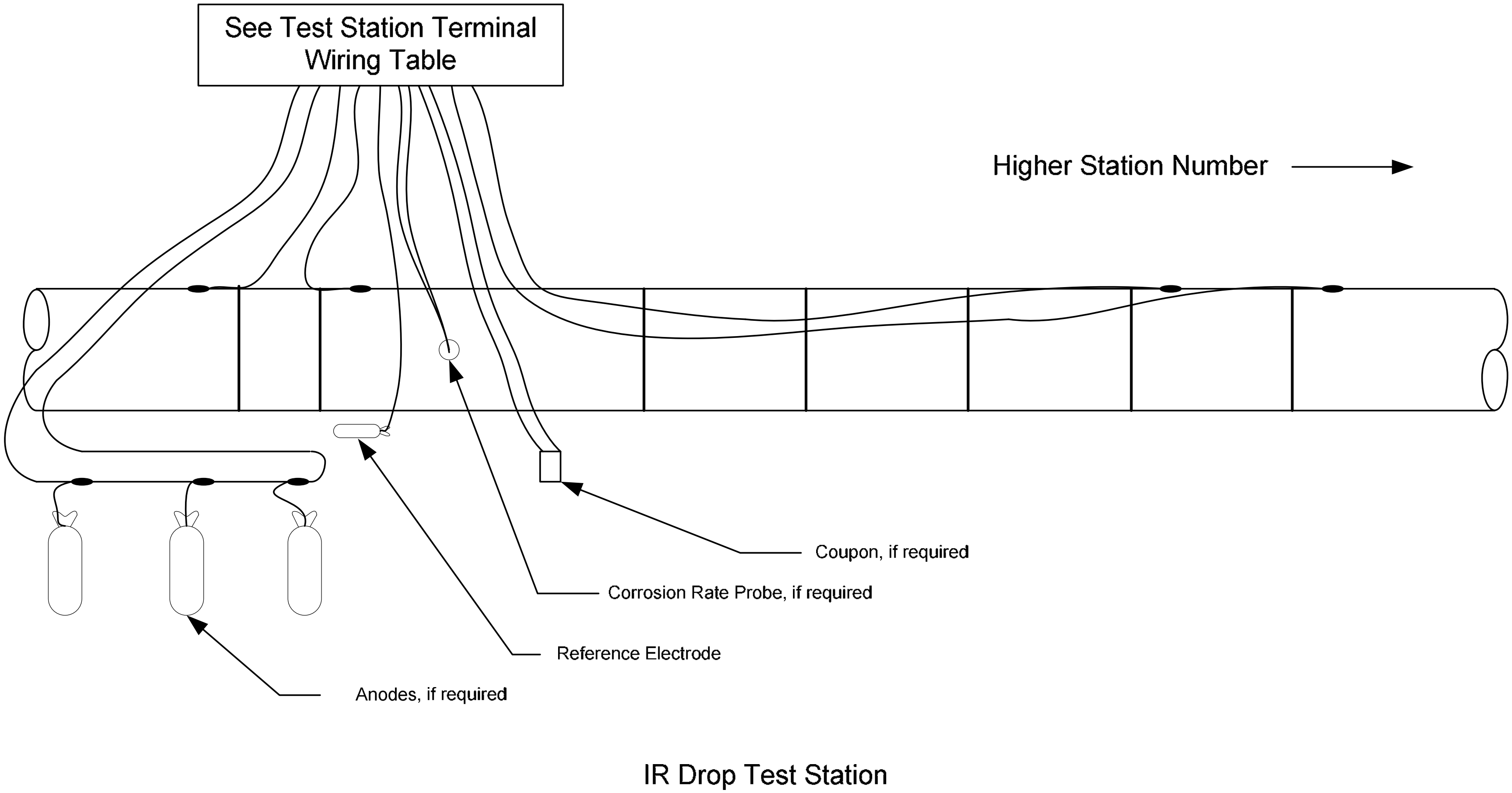


Figure 3. 4 Wire IR Drop Test Station Wiring

Table 2: 4-Wire IR Drop Test Station Wiring

Structure	AWG Cable Size	Cable Insulation	Test Station Terminal Connection			Remarks
			Big Fink	Testox 800	CP Test NM7	
Pipeline, Higher Station Number, Outside Cable	10	RWU-90 Yellow	2	1	1	
Pipeline, Higher Station Number, Inside Cable	12	RWU-90 Yellow	5	3	3	
Pipeline, Lower Station Number, Outside Cable	10	RWU-90 Black	3	2	2	
Pipeline, Lower Station Number, Inside Cable	12	RWU-90 Black	6	5	5	
Magnesium Anode, if required	10	RWU-90 Blue for individual anodes, Red for Anode Header Cable	1	4	4	Bond to Terminal 2 pipeline cable in Big Fink and Terminal 1 pipeline cable in Testox 800 or CP Test NM-7 with a bond strap or current measuring shunt
Zinc Anode, if required	10	RWU-90 White for individual anodes, Red for Anode Header Cable	1	4	4	Bond to Terminal 2 pipeline cable in Big Fink and Terminal 1 pipeline cable in Testox 800 or CP Test NM-7 with a bond strap or current measuring shunt
Reference Electrode	12	HMWPE Black	4	6	6	Copper/Copper Sulfate electrode (delete if coupon installed)
Coupon, if required	14	RHW Purple	5 and 7	3 and 6	3 and 6	Coupon provided with integral zinc reference electrode. Zinc reference electrode cable is #14 RHW White
Corrosion Rate Probe, if required	14	THWN Green	5	3	3	Special connector for measurement of corrosion rate. Green wire is for connection of probe to pipe. Connect to pipe cable terminal that is not connected to anodes.

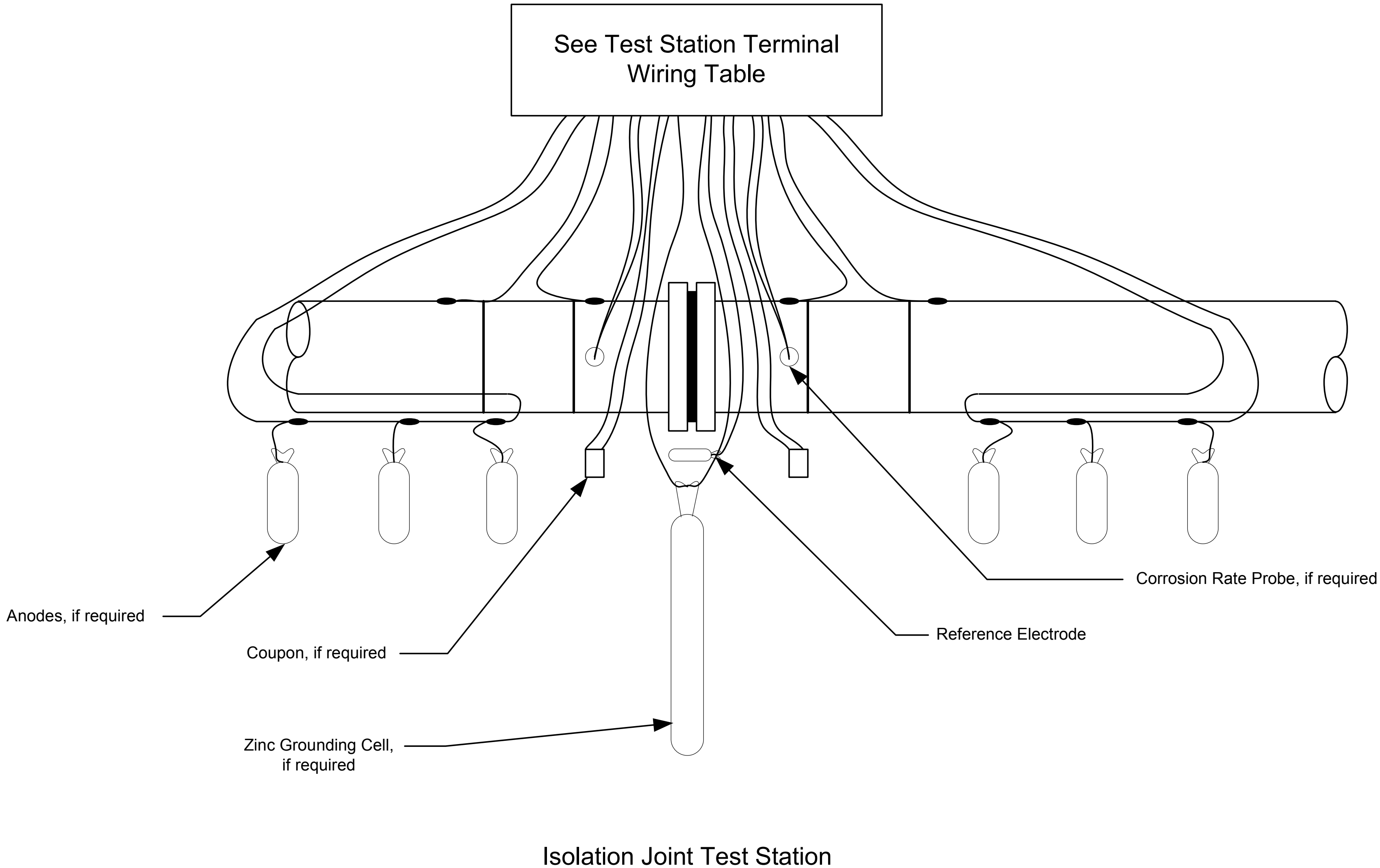


Figure 4: Isolation Joint Test Station Wiring

Table 3: Isolation Joint Test Station Wiring

Structure	AWG Cable Size	Cable Insulation	Test Station Terminal Connection			Remarks
			Big Fink	Testox 1000		
Pipeline, Higher Station Number, Outside Cable	10	RWU-90 Yellow	2	6		Testox 800 and CP Test NM-7 have insufficient terminals for all materials, if installed.
Pipeline, Higher Station Number, Inside Cable	8	RWU-90 Yellow	5	5		
Pipeline, Lower Station Number, Outside Cable	10	RWU-90 Black	3	1		
Pipeline, Lower Station Number, Inside Cable	8	RWU-90 Black	6	2		
Magnesium Anodes, if required	10	RWU-90 Blue for individual anodes, Red for Anode Header Cable	1 and 4	3 and 8		Bond to pipeline cable with a bond strap or current measuring shunt
Zinc Anodes, if required	10	RWU-90 White for individual anodes, Red for Anode Header Cable	1 and 4	3 and 8		Bond to pipeline cable with a bond strap or current measuring shunt
Reference Electrode	12	HMWPE Black	8	4 and 7		Copper/Copper Sulfate electrode (delete if coupon installed)
Coupons, if required	14	RHW Purple	5 and 7 9 and 6	2 and 4 5 and 7		Coupon provided with integral zinc reference electrode. Zinc reference electrode cable is #14 RHW White
Corrosion Rate Probe, if required	14	THWN Green	5 and 6	2 and 5		Special connector for measurement of corrosion rate. Green wire is for connection of probe to pipe. Connect to pipe cable terminal that is not connected to anodes.
Zinc Grounding Cell, if required	6	RWU-90 White	5 and 6	2 and 5		

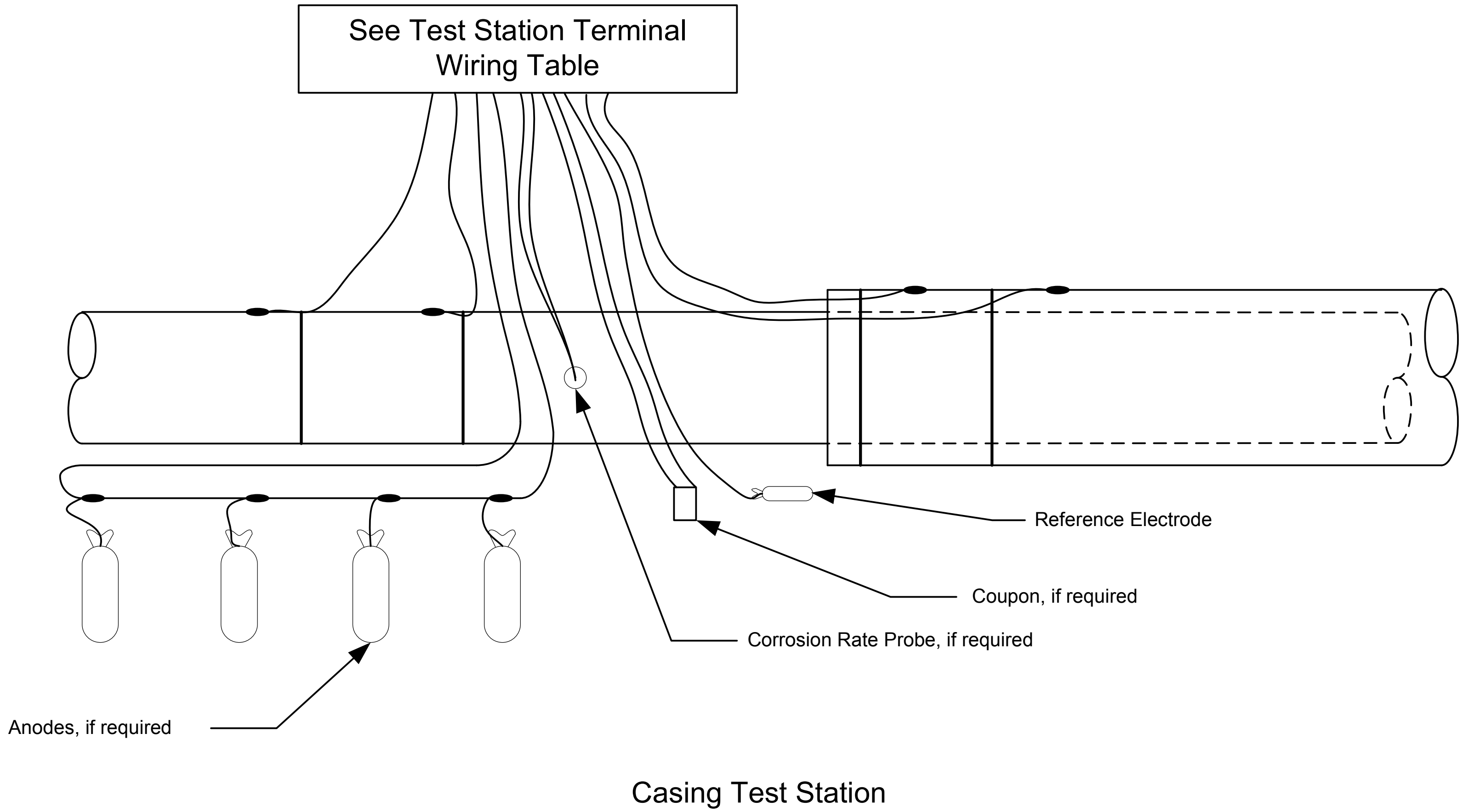
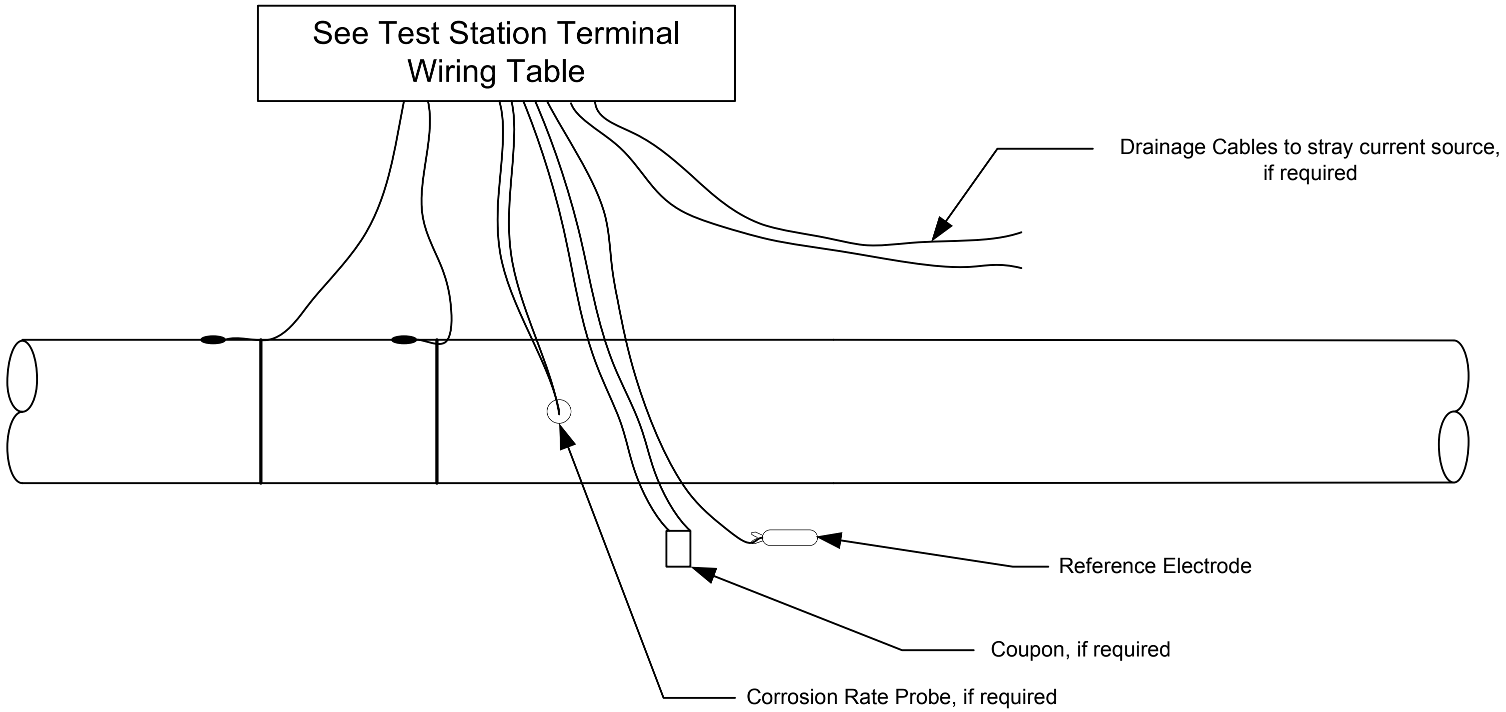


Figure 5: Casing Test Station Wiring

Table 4: Casing Test Station Wiring

Structure	AWG Cable Size	Cable Insulation	Test Station Terminal Connection			Remarks
			Big Fink	Testox 800	CP Test NM7	
Pipeline	10	RWU-90 Black	2 and 5	1 and 3	1 and 3	
Casing	10	RWU-90 Green	3 and 6	2 and 5	2 and 5	
Magnesium Anode, if required	10	RWU-90 Blue for individual anodes, Red for Anode Header Cable	1	4	4	Bond to Terminal 2 pipeline cable in Big Fink and Terminal 1 pipeline cable in Testox 800 or CP Test NM-7 with a bond strap or current measuring shunt
Zinc Anode, if required	10	RWU-90 White for individual anodes, Red for Anode Header Cable	1	4	4	Bond to Terminal 2 pipeline cable in Big Fink and Terminal 1 pipeline cable in Testox 800 or CP Test NM-7 with a bond strap or current measuring shunt
Reference Electrode	12	HMWPE Black	4	6	6	Copper/Copper Sulfate electrode (delete if coupon installed)
Coupon, if required	14	RHW Purple	5 and 7	3 and 6	3 and 6	Coupon provided with integral zinc reference electrode. Zinc reference electrode cable is #14 RHW White
Corrosion Rate Probe, if required	14	THWN Green	5	3	3	Special connector for measurement of corrosion rate. Green wire is for connection of probe to pipe. Connect to pipe cable terminal that is not connected to anodes.



Stray Current Drainage Test Station

Figure 6: 2 Wire Stay Current Drainage Test Station Wiring

Table 5: 2-Wire Stray Current Drainage Test Station Wiring

Structure	AWG Cable Size	Cable Insulation	Test Station Terminal Connection			Remarks
			Big Fink	Testox 800	CP Test NM7	
Pipeline	8	HMWPE Black	1 and 2	1 and 3	1 and 3	AWG #8 minimum cable size.
Stray Current Source	6	HMWPE Black	3 and 4	2 and 5	2 and 5	AWG #6 minimum cable size, only installed if bonding/drainage is required. Bond to the pipeline through a current measuring shunt.
Magnesium Anode, if required	10	RWU-90 Blue for individual anodes, Red for Anode Header Cable				Anodes typically not installed at a drainage test station
Zinc Anode, if required	10	RWU-90 White for individual anodes, Red for Anode Header Cable				Anodes typically not installed at a drainage test station
Reference Electrode	12	HMWPE Black	8	4	4	Copper/Copper Sulfate electrode (delete if coupon installed)
Coupon, if required	14	RHW Purple	2 and 5	3 and 6	3 and 6	Coupon provided with integral zinc reference electrode. Zinc reference electrode cable is #14 RHW White
Corrosion Rate Probe, if required	14	THWN Green	2	3	3	Special connector for measurement of corrosion rate. Green wire is for connection of probe to pipe. Connect to pipe cable terminal that is not connected to anodes.

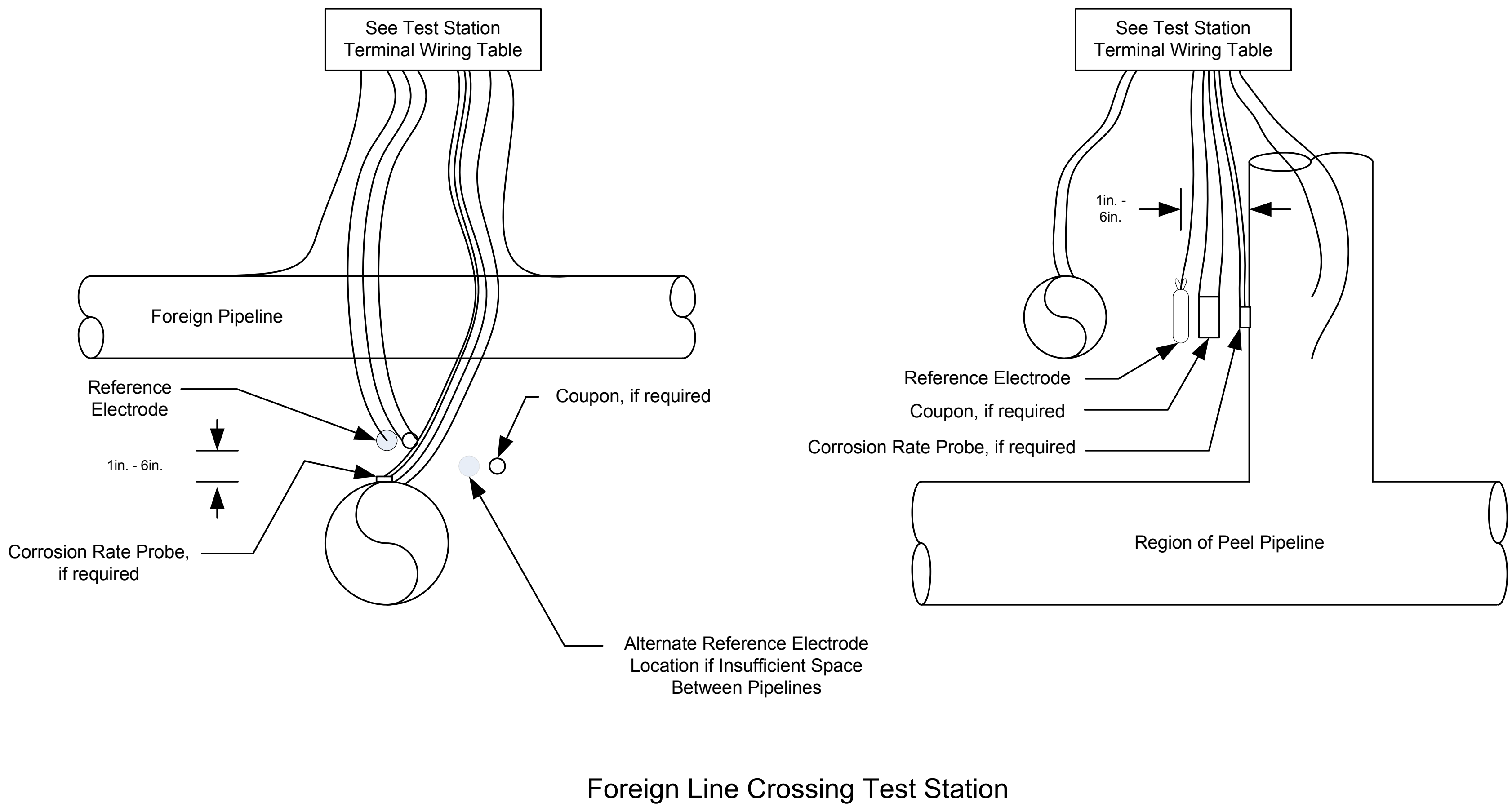


Figure 7: Foreign Line Crossing Test Station Wiring

Table 6: Foreign Line Crossing Test Station Wiring

Structure	AWG Cable Size	Cable Insulation	Test Station Terminal Connection			Remarks
			Big Fink	Testox 800	CP Test NM7	
Pipeline	10	RWU-90 Black	2 and 5	1 and 3	1 and 3	
Foreign Line	10	RWU-90 Orange	3 and 6	2 and 5	2 and 5	
Magnesium Anode, if required	10	RWU-90 Blue for individual anodes, Red for Anode Header Cable	1	4	4	Bond to Terminal 2 pipeline cable in Big Fink and Terminal 1 pipeline cable in Testox 800 or CP Test NM-7 with a bond strap or current measuring shunt
Zinc Anode, if required	10	RWU-90 White for individual anodes, Red for Anode Header Cable	1	4	4	Bond to Terminal 2 pipeline cable in Big Fink and Terminal 1 pipeline cable in Testox 800 or CP Test NM-7 with a bond strap or current measuring shunt
Reference Electrode	12	HMWPE Black	4	6	6	Copper/Copper Sulfate electrode (delete if coupon installed)
Coupon, if required	14	RHW Purple	5 and 7	3 and 6	3 and 6	Coupon provided with integral zinc reference electrode. Zinc reference electrode cable is #14 RHW White
Corrosion Rate Probe, if required	14	THWN Green	5	3	3	Special connector for measurement of corrosion rate. Green wire is for connection of probe to pipe. Connect to pipe cable terminal that is not connected to anodes.

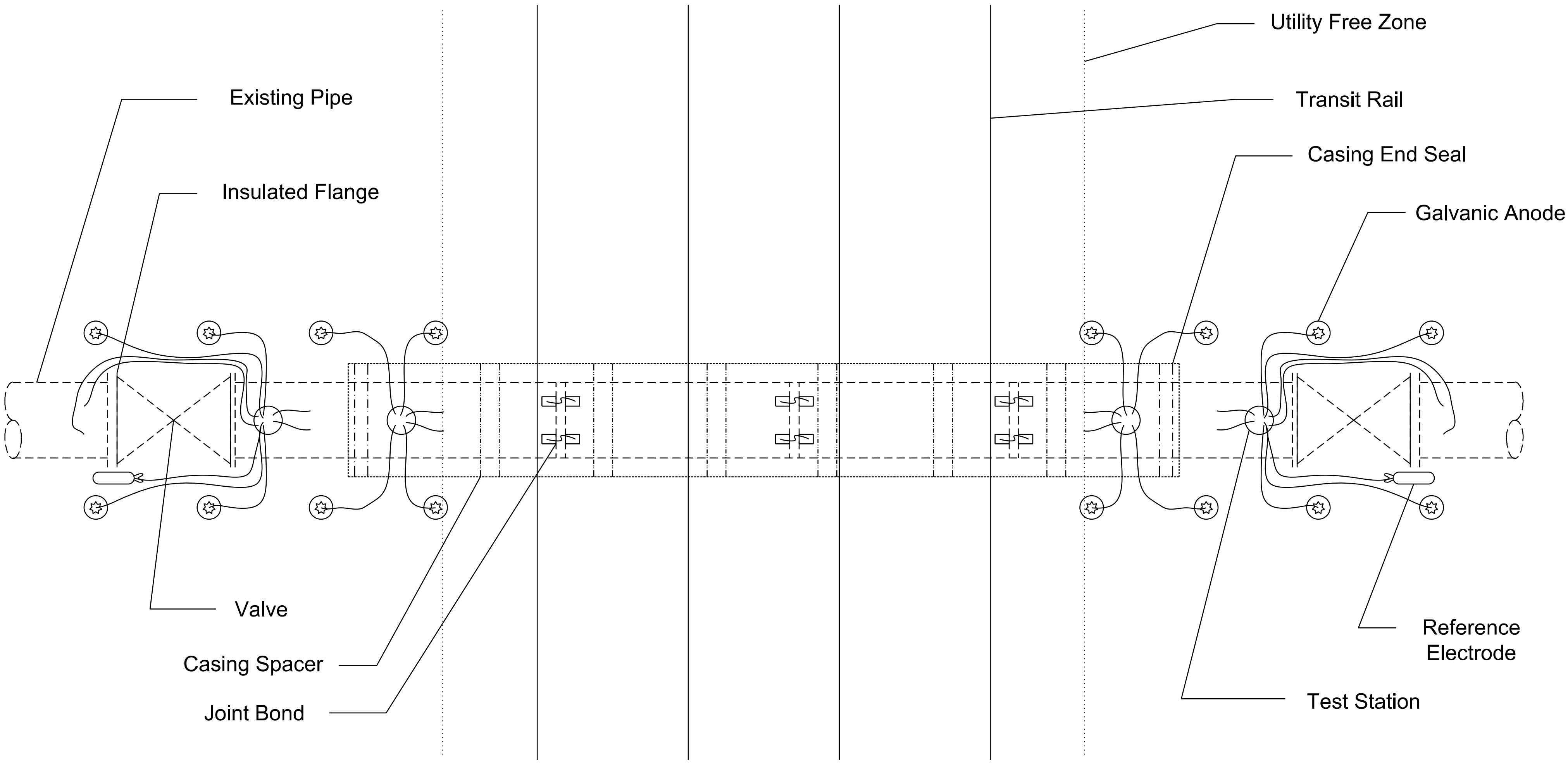
APPENDIX F

EXAMPLES

Example 1: New CPP Crossing

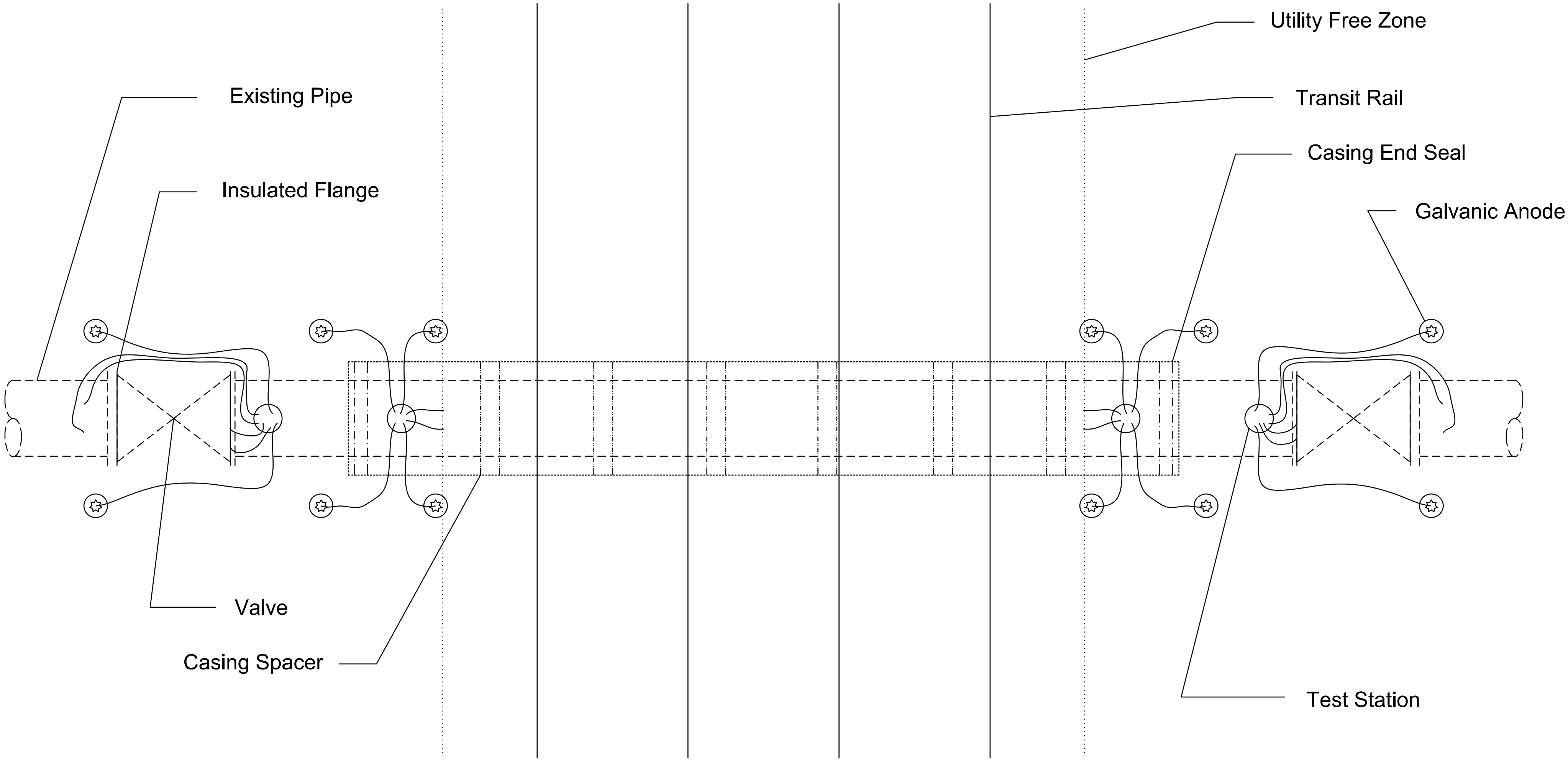
Example 2: New PVC Crossing

Example 3: New Parallel Metallic Pipe



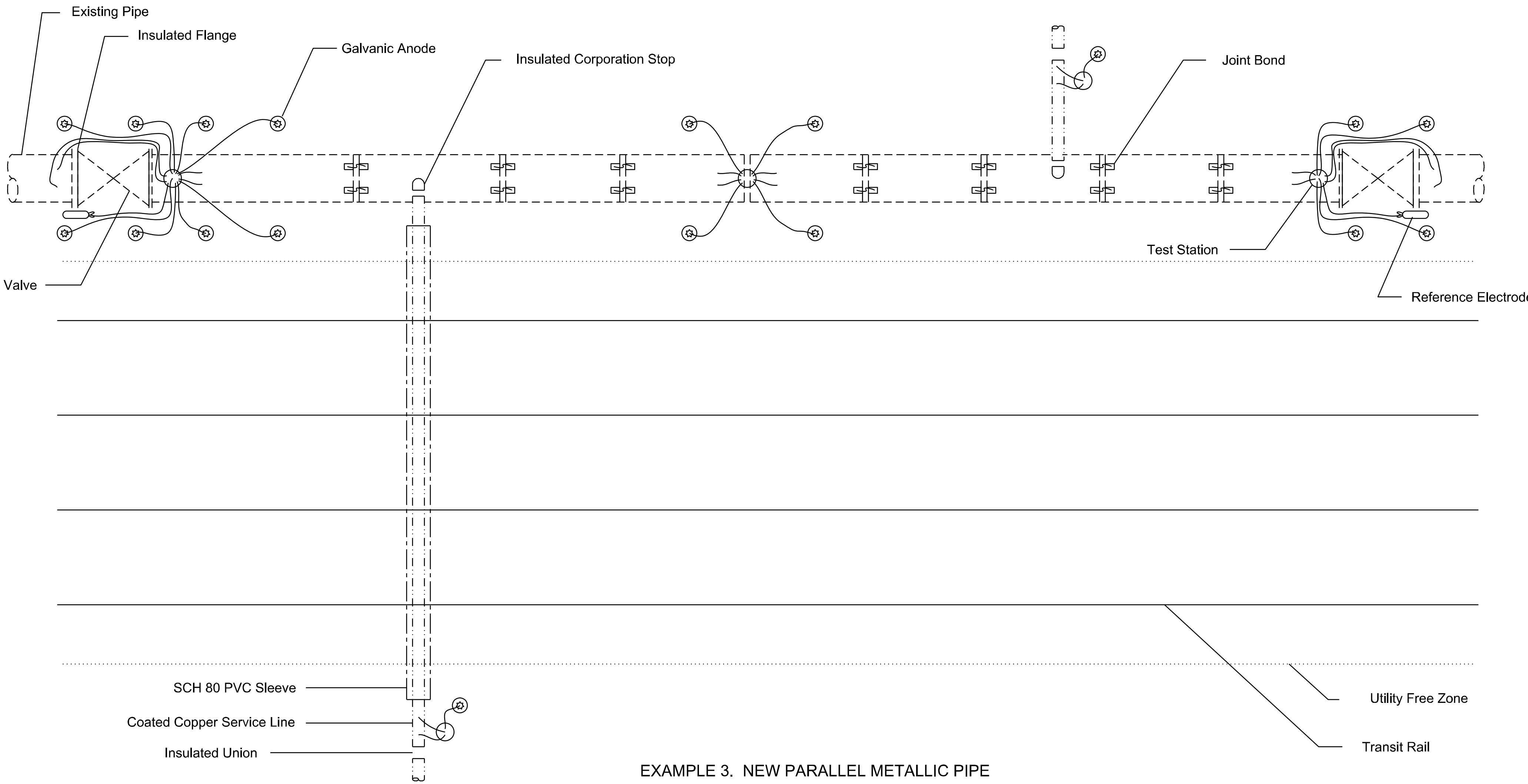
EXAMPLE 1. NEW PRESTRESSED CONCRETE CYLINDER PIPE CROSSING.

1. Electrical isolation at tie-in to existing pipe. Coat isolation fitting with petrolatum tape coating system.
2. Install valves on each side of the crossing to allow isolation of water flow.
3. Joint bonding and shorting straps for electrical continuity.
4. External coal tar epoxy coating on pipeline.
5. Fusion bonded epoxy or polyurethane coated valve.
6. Install pipe inside casing using insulating casing spacers and casing end seals.
7. Install test stations on each side of the crossing for the pipeline and the casing.
8. Install galvanic anodes for cathodic protection of new pipeline. Cathodic protection of the casing is optional.



EXAMPLE 2. NEW PVC PIPE CROSSING.

1. Electrical isolation at tie-in to existing pipe. Coat isolation fitting with petrolatum tape coating system.
2. Install valves on each side of the crossing to allow isolation of water flow.
3. Fusion bonded epoxy or polyurethane coated valve.
4. Install pipe inside casing using insulating casing spacers and casing end seals.
5. Install test stations on each side of the crossing for the valve and the casing.
6. Install galvanic anodes for cathodic protection of new valve. Cathodic protection of the casing is optional.



EXAMPLE 3. NEW PARALLEL METALLIC PIPE

1. Electrical isolation at tie-in to existing pipe. Coat isolation fitting with petrolatum tape coating system.
2. Install valves at each end of the new pipe to allow isolation of water flow.
3. Joint bonding and shorting straps for electrical continuity.
4. External coal tar epoxy coating on pipeline.
5. Fusion bonded epoxy or polyurethane coated valve.
6. Install pipe inside casing using insulating casing spacers and casing end seals.
7. Install test stations at each end and every 150 m.
8. Install galvanic anodes for cathodic protection of new pipeline.
9. Isolate copper service lines from the metallic main and at the meter. Install a ground rod on the downstream side of the insulating union at the meter. Coat and cathodically protect the service pipe.