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CORROSION CONTROL
GENERAL REFERENCE PROGRAM
FOR CATHODIC PROTECTED SYSTEMS

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EXECUTIVE SUMMARY

This manual serves as a guidance document and a field reference manual for the Western Municipal Water District (WMWD) Corrosion Control Program.

This manual serves as general “On-Site Field Manual” for WMWD staff, engineers, surveyors, contractors, and subcontractors to install, repair, and troubleshoot Cathodic Protection Systems for the assets owned by WMWD.

The manual begins by providing a description on the topic of corrosion and the terms associated with cathodic protection systems. The manual also provides a discussion on the different types of cathodic protections system and “New Installation of Cathodic Protection Systems” with a section pertaining to the drawings and details associated with the new installation of these systems.

This manual also provides a general Preventative Maintenance Program for WMWD Cathodic Protection Systems. The unscheduled preventative maintenance is listed under the “Repair and Troubleshooting” section and provides guidance for both Galvanic Systems and Impressed Current Systems.

The manual concludes with a section that focuses on all the various testing associated with testing Cathodic Protection Systems. These tests follow the national standards such as NACE and ASTM specifications which are also listed in the final section of this manual.

Contents

1 GENERAL CORROSION CONTROL PROGRAM

1.1 INTRODUCTION

The purpose of establishing a General Corrosion Control Program is to protect the existing assets owned by Western Municipal Water District (WMWD) and to achieve the maximum protection against corrosion for the water distribution systems supplying water to the public. The costs for repairing or replacing assets are extremely high as a result of corrosion. In order to mitigate these issues, the corrosion control program focuses on the Cathodic Protection Systems required to mitigate the corrosion of water tanks and pipelines.

This General Corrosion Control Program consists of identifying all Capital Assets owned and operated by WMWD and providing basic general information on what corrosion is and how it is mitigated through the installation of Cathodic Protection Systems. Currently, there are thirty two water tanks with various pipelines that are the Capital Assets discussed in this manual.

The new installation of Cathodic Protection Systems is addressed in this manual and includes the various drawings owned by WMWD related to Cathodic Protection Systems. The Cathodic Protection Systems discussed in this manual include both Galvanic Systems and Impressed Current Systems.

As part of the effort to mitigate the corrosion of existing assets, two sections focus on the scheduled Preventative Maintenance Program along with one section focusing on the Repair and Troubleshooting of existing Cathodic Protection Systems.

This manual is not considered an all-in-one inclusive manual for most situations that arises in the field work of mitigating corrosion for Cathodic Protection Systems. However, this manual does provide information related to national and federal specifications commonly used for Cathodic Protection Systems. The final section in this manual provides the related specifications for NACE and ASTM related to WMWD Cathodic Protection Systems

2 CORROSION CONTROL TERMINOLOGY

2.1 DEFINITION OF CORROSION

Understanding the principles of cathodic protection systems is based upon understanding the nature of the corrosion process. The corrosion of metals is an electrochemical process. That is, it is an electrical circuit where the exchange of electrons (electricity) is conducted by chemical reactions in part of the circuit. These chemical reactions occur at the surface of the metal exposed to the electrolyte. Oxidation reactions (corrosion) occur at the surface of the anode and reduction reactions occur at the surface of the cathode. Corrosion control systems which relocate these oxidation reactions, by making the protected structure a cathode in a larger corrosion cell, is called a "cathodic" protection system." The cathodic protection anodes are installed to become the anode in this larger corrosion cell and provide the location for all oxidation reactions in the cell. To describe the principles of operation of cathodic protection in detail, the exact nature of the corrosion process must be described in detail.

2.2 OXIDATION

Regardless of the root cause, corrosion of reinforcing steel is ultimately due to oxidation of the iron. Oxidation refers to the loss of at least one electron when two different substances interact. Due to its molecular structure, iron atoms readily yield electrons to materials that more readily accept electrons. Oxidation of iron in reinforced concrete is due to the presence of both water and oxygen. The process involves a series of reactions which lead to the formation of iron oxide, more commonly known as rust. The chemical equation below demonstrates oxidation of an iron atom, with the iron atom breaking down to a positively charged iron ion and yielding two free negatively charged electrons. Fe Fe2+ + 2e−

2.3 REDUCTION

Reduction is the opposite of oxidation. When a substance is reduced, it means that it has gained electrons via a chemical reaction. In terms of corrosion of reinforced concrete, reduction occurs in the formation of rust which frees electrons to travel to the cathode, where they react with water to form hydroxide ions. The free electrons that become available after the iron is oxidized bond with oxygen and water to form negatively charged hydroxide ions.

2.4 ELECTROCHEMICAL REACTION

An electrochemical reaction is a chemical reaction between substances that involves the transfer of electrons between the substances to generate an electric current, also known as an oxidation-reduction or redox reaction. In the case of corrosion, the potential (or charge buildup of electrons or voltage) is generated via the oxidation of the iron atoms into iron oxides. The current generated is referred to as the corrosion current, and the rate at which it flows determines the corrosion rate of the reinforcing steel.

2.5 ELECTRICAL RESISTIVITY

Electrical resistivity is defined as a measure of the resistance of a material to flow of electric current. When discussing corrosion in concrete the electrical resistance of the concrete is one of the controlling factors of the rate of corrosion. Resistivity is a material property. A material with a certain resistivity will produce a certain resistance depending on the available cross-sectional area and length the current has to flow. As the resistivity of the concrete cover increases (such as when the cement hydrates or the concrete dries out) it becomes more difficult for the corrosion current to pass through.

2.6 ANODE

An anode is the electrode in electrolysis at which negative ions are discharged, positive ions are formed, or other oxidizing reactions occur. It is the part of a corrosion cell in reinforced concrete where the iron-oxide forms on the reinforcing steel. Corrosion is an oxidation process in which the iron atoms lose electrons and react with oxygen and water to form rust. The reddish orange material is the iron oxide, or rust, formed as a result of the electrochemical corrosion reactions.

2.7 CATHODE

The cathode is the part of the corrosion cell where no visual change is seen on the reinforcing steel. It is the electrode at which electrons are consumed and chemical reduction occurs. No physical change occurs at the cathode in reinforced concrete. It is simply the location where hydroxides form. The cathode is frequently located immediately adjacent to the anode, which is why we often see badly corroded steel adjacent to clean steel.

3 TYPES OF CORROSION

Several types of corrosion can occur on water systems, the following lists of common forms of corrosion.

1. Uniform
2. Pitting
3. Stress Corrosion
4. Dissimilar Metal (Galvanic Corrosion)
5. Concentration Cells
6. Crevice
7. Stray Current
8. Dezincification
9. Graphitization
10. Impingement Attack
11. Cavitation

The corrosion of a metal may appear uniform due to microscopic anodic and cathodic areas formed on what appears to be a homogeneous metal surface.

In fact, a metal consists of numerous grains, some of which will be anodic to adjacent grains due to the different metallurgical make up. Pitting corrosion is initiated by a localized anodic point on the metal surface. The penetration of the metal continues at this point, because a relative large area around the pit is cathodic to the pit itself. Stress corrosion and corrosion fatigue result from tensile stresses on the metal surface. Stress corrosion often takes place at the grain boundaries where the metal has been stressed by cold working, or elevated temperature, such as within the heat affected zone adjacent to a weld seam.

Dissimilar or galvanic metal corrosion occurs due to the interconnection of more active metal to a more noble metal. The more active metal will be the anode in the corrosion cell where the failure will occur. The following chart lists the practical galvanic series of metals from active to more noble:

Metal	Volts*
Commercially pure magnesium	-1.75
Magnesium alloy	-1.50
Zinc	-1.10
Aluminum alloy	-1.05
Commercially pure aluminum	-0.80
Mild steel	-0.20 to -0.50
Cast iron	-0.50
Lead	-0.50
Mild steel in concrete	-0.20
Copper, brass, bronze	-0.20
High silicon cast iron	-0.20
Mill scale on steel	-0.20
Carbon, graphite, coke	+0.30

* Typical potential normally observed in neutral soils and water, measured with respect to a copper/copper sulfate reference electrode.

Oxygen concentration cells are typical on underground pipelines. When the pipe is placed in the bottom of the trench during installation, the trench bottom generally is undisturbed soil while the rest of the trench is well aerated backfill soil. With the passage of time, the area at the bottom of a pipe can become oxygen starved in relation to the other sections of pipe.

Since oxygen is required for the reactions at the cathode, the top of the pipe is cathodic to the bottom. The corrosion is concentrated along the bottom surface of the pipe. Crevice corrosion can occur in crevices formed by the interconnection of metallic components where the area inside the crevice is anodic to the adjacent surface. Dezincification results from the removal of zinc from brass alloys, with copper remaining as the zinc is dissolved. Graphitization occurs on cast iron and ductile iron piping when the iron silicon metal in the alloy corrodes, leaving behind a graphite product which remains hard, but brittle, and subject to fracture from soil stress and water hammer. Impingement attack is caused by an erosion process where the water flow removes the protective films from the metal surface. Cavitation is usually associated with high velocity and sudden changes in velocity that causes gas pockets to form at low pressure points. As the gas bubble collapses, the metal surface can be severely corroded. This type of corrosion can occur inside piping at a constricted area such as a valve or joint, and is often encountered on water pump impellers.

3.1 PITTING CORROSION

Pitting corrosion is the localized, deep deterioration of metal surfaces. We often observe pitting of reinforcing steel due to the localized formation of anodes on the reinforcing steel. Corrosion will aggressively occur at the anode, resulting in deep pits in the steel. The cathode typically forms in an area in close proximity to the anode though it can be distributed over fairly large areas. At the cathode, corrosion of the steel does not occur and the bar retains its original shape. Pitting corrosion is a serious concern as it can result in complete degradation of the reinforcing steel at a localized area, ultimately leading to a break in the reinforcing steel and loss of continuity. When left unchecked, pitting corrosion can severely impact the strength capacity of structure and cause unexpected failures of structural members.

3.2 GALVANIC CORROSION

The two major factors affecting the rate of corrosion in an electrochemical corrosion cell are the electrical characteristics of the electrolyte(resistivity), and the voltage difference between the anode and the cathode. The resistivity of the electrolyte is normally not a controllable characteristic, but it is measurable. The voltage or potential of the metal anode and cathode is also a measurable characteristic. The voltage measured is the voltage difference between the two electrodes. Since this voltage is dependent only on a voltage difference, there must be a reference that all other electrodes can be measured against, to give a relational table, or series, of the potential of any given electrode. As earlier stated metals all have different potentials, and any given metal has different potentials in different electrolytes.

For an electrode to be used as a reference to measure other electrodes, the metal and the electrolyte in contact with the metal must be specified. Once this is done, the electrode becomes a reference electrode. Many types of reference electrodes have been used. In the laboratory the hydrogen/hydrogen (hydrogen electrode, hydrogen electrolyte) is common. For field use, the copper/copper sulfate (copper electrode, fully saturated copper sulfate electrolyte) is in common use, except in salt water, where silver/silver chloride (silver electrode, silver chloride electrolyte) is used and must be adjusted by the factor or the chloride contact of the electrolyte. These references are merely stable electrodes with a known potential used to measure the potential of unknown electrodes. Using these references, the potential value of any metal in any electrolyte can be recorded for future reference and compared to other electrodes. A table of such measurement is called a galvanic series of measurements. Each table must specify the reference electrode used to accomplish the measurements, and the electrolyte the unknown electrodes were in, to allow for interpretation by corrosion experts. This series can then be used to determine which electrode will be the anode (and corrode) in an electrochemical corrosion cell.

Galvanic corrosion in reinforced concrete is accelerated corrosion of a metal because of an electrical contact with a more noble metal or a more noble non-metallic conductor in a corrosive electrolyte. When reinforcing steel is electrically connected to a less noble metal such as zinc, galvanic corrosion of the zinc occurs. However, galvanic corrosion does not simply occur because the zinc is attached to the steel. Halogens must be present in concentrations exceeding the corrosion threshold in order to initiate the process, typically chlorides in reinforced concrete.

3.3 IMPRESSED CURRENT CORROSION

As in galvanic anode systems, impressed current systems supply current for cathodic protection of a metal surface. However, in the case of an impressed current system, the protective current is supplied by a rectifier (or other DC power source) instead of by the natural potential difference of the anode to the structure. The potential difference between the anode and cathode is forced from a non-reactive anode bed byte action of additional energy from a rectifier to force the electron flow that would be normally produced in the corrosion reaction. The energy for the “electron energy pump "action of the rectifier is provided by ordinary alternating current. The effect of these electrons at the structure being protected is the same as that derived from the sacrificial anode type of cathodic protection system. However, the anode material serves only as a source of electrons and anodic (oxidation) electrochemical reactions.

In practice, materials such as graphite, high silicon cast iron (HSCI), platinum or mixed metal oxide, are used for impressed current cathodic protection system anodes because they are slowly consumed (they have a very low kilogram (pound) per amp year weight loss). To provide a uniform electrolyte, a lower resistance to earth, and venting of gases and acids, a special backfill is used. This earth contact backfill is normally coke breeze or claimed fluid petroleum coke. Anodes in impressed current systems must be periodically inspected and replaced if consumed or otherwise damaged. As is the case for any electrical equipment, rectifiers used for impressed current cathodic protection systems require preventive maintenance and recurring operational checkouts to ensure proper operation. Impressed current system anode leads must have a special insulation to preclude the copper lead wire from becoming part of the anode system. Since the power source is forcing everything connected to the positive terminal to act as an anode (and corrode) any defect or nick in the insulation of the anode lead wire would result in copper metal loss ending in failure of the anode system.

Impressed current systems are fundamentally the same as galvanic anode systems in their operation, except that in impressed current systems a rectifier or other direct current power source is used to increase the potential of the electrons from the anodes to provide the desired protective current. In addition to an anode and a connection to the structure being protected, an impressed current cathodic protection system uses a rectifier or other power source. A battery, solar cell, direct current generator, or thermoelectric generator may be used as a power source. However, nearly all impressed current cathodic protection systems use alternating current or solar powered rectifiers as a power source.

3.4 SOIL CORROSIVITY

A major factor in determining soil corrosivity is electrical resistivity. The electrical resistivity of a soil is a measure of its resistance to the flow of electrical current. Corrosion of buried metal is an electrochemical process in which the amount of metal loss due to corrosion is directly proportional to the flow of electrical current (DC) from the metal into the soil. Corrosion currents, following Ohm's Law, are inversely proportional to soil resistivity. Lower electrical resistivities result from higher moisture and soluble salt contents and indicate corrosive soil.

4 TYPES OF CATHODIC PROTECTION SYSTEMS

4.1 GALVANIC PROTECTION SYSTEM

Galvanic systems are also known as sacrificial anode systems because an anode (usually zinc or magnesium) corrodes instead of the protected metal. Because the anode corrodes instead of the metal that it is protecting, the anode is said to sacrifice itself. Sacrificial anodes are connected directly to the structure to be protected by either welding or mechanical connection of lead wires.

Galvanic systems are generally limited to those tank components that are well coated with a dielectric material because the available current output of these systems is low. Attempts to protect long runs of uncoated piping or uncoated tanks generally is not practical because the useful life of the anodes is too short or the number of anodes needed is too great.

4.2 IMPRESSED CURRENT PROTECTION SYSTEM

Impressed current systems are sometimes called rectifier systems because they utilize a device (a rectifier) to convert an external AC power source to the required DC power source. In this type of system, anodes are installed in the soil around the structure to be protected and the DC power is supplied to the anodes through buried wires. The power to the rectifier cannot be interrupted except when conducting maintenance or testing activities. Normally, a dedicated and protected circuit is provided for the impressed current system so that the power cannot be inadvertently cut off.

In impressed current systems the protected structure is bonded to the DC power system to complete the electrical circuit. It is critical that the anodes are connected to the positive terminal and the protected structure to the negative terminal of the rectifier. Reversal of the lead wires will make the components of the tank system anodic and can cause a rapid failure of the tank system due to corrosion induced by the rectifier. In addition, it is critical that all wire connections and splices are well insulated. Any breaks in the wiring insulation will allow current to leave the wire at that point and a rapid failure of the wire can occur due to corrosion.

The level of CP provided by an impressed current system can be adjusted since the voltage produced by the rectifier can be changed. Because conditions that affect the level of CP needed are likely to change over time, adjustment of the rectifier is frequently necessary.

5 PREVENTATIVE MAINTENANCE OF CATHODIC PROTECTION SYSTEMS

5.1 CLOSE-INTERVAL potential SURVEY

A series of structure-to-electrolyte potentials determine if adequate cathodic protection is achieved at all points along the structure. Figure 5.1 illustrates a close interval potential profile.

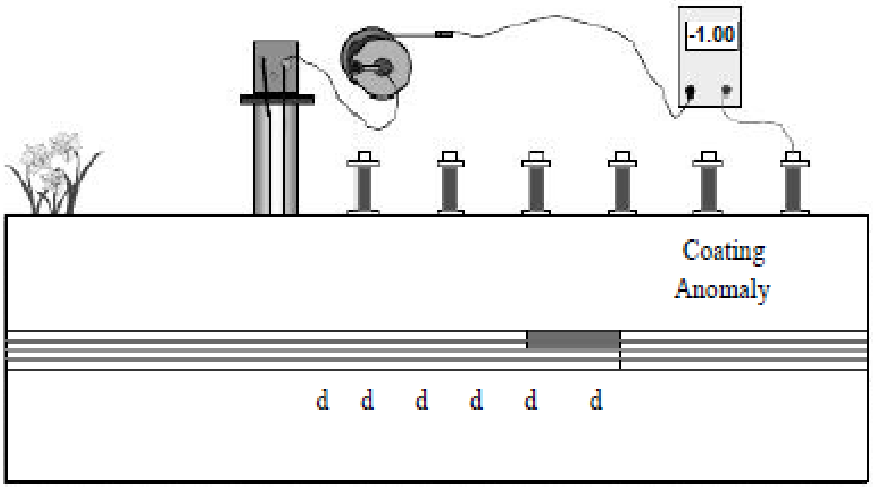


FIGURE 5-1, Close Interval Potential Survey

In a close interval survey (CIS), the structure-to-electrolyte potential data are collected at close spacing [1 to 5 m (3 to 15 ft)]. This is usually done by carrying a voltmeter or datalogger and a wire-dispensing device. Some wire dispensing devices are equipped with distance measuring capability so that the technician knows where they are when the data is entered into the data logger. Others simply use a measuring chain or calibrated rope and "station" the pipeline using the company's pipeline as-built information. A close interval potential survey can be completed on both cathodically protected and non-cathodically protected structures.

One or two reference electrodes, mounted at the end of a short pole(s), are used. A small-gauge wire, usually 30 to 34 AWG size, is attached to a test station or other abovegrade electrically continuous structure and the operator walks over the pipeline, making contact between the electrode(s) and the earth at closely spaced intervals. The operator records voltage and above grade identifying items along the way so the location of the data can be pinpointed.

When testing multiple pipelines that are bonded together, the survey data will represent an average potential of all the pipelines. If the target CP criteria is the –0.850 VCSE polarized potential criteria, then typically an interrupted CIS where the influencing current sources are interrupted and both ON and IR-drop-free ("instant-off") potentials are completed. For the 100 mV polarization criteria, after the ON/OFF potential data has been collected, the current sources are de-energized and a period of time allowed for the structure to depolarize. Once depolarized, a second CIS is completed collecting depolarized pipe-to-electrolyte potentials at the exact reference electrode locations as during the initial CIS. This data can then be overlaid on the same graphs with the ON/OFF data to confirm whether or not the 100 mV criteria has been satisfied

5.2 WATER TANK CALIBRATION CP SYSTEMS

The water tank calibration is a comprehensive and thorough survey to ensure that cathodic protection is maintained over the entire surface of the tank to be protected in accordance with Chapter 6 criteria, and there are no excessive voltages on any part of the tank interior that could damage the coating. Water tank calibration comprises an interrupted potential survey on impressed current systems and a non-interrupted potential survey on galvanic systems. The interruption cycle must have an ON cycle that is a minimum of four times longer than the OFF cycle where the OFF cycle is normally one second. On a galvanic system, measurement errors must be accounted for using sound engineering practices, including reference cell placement, anode positions, and coating condition. If the system design permits, this may also include an interrupted potential survey.

Test measurement for galvanic systems water tank cp component tests

5.2.1 Measure anode-to-structure current using (in order of preference) a clamp-on millimeter, a multimeter measuring millivolts across a calibrated shunt, or a multimeter connected in series measuring milliamperes.

5.2.2 Test measurement for impressed current systems water tank cp component tests

5.2.3 Perform the rectifier operational checkout (5.1-4.).

5.2.4 Calculate the rectifier efficiency by dividing the calculated output DC power by the factored input AC power.

5.3 RECTIFIER OPERATIONAL INSPECTION

The purpose of the rectifier operational inspection is to determine the serviceability of all components required to impress current to the anodes of the impressed current system. The inspection should be thorough to ensure dependable current until the next inspection.

5.3.1 Visually check all rectifier components, shunt box components, safety switches, circuit breakers, and other system power components.

5.3.2 Tighten all accessible connections and check temperature of all the components.

5.3.3 Using a dependable hand-held meter, measure the output voltage and current, and calibrate the rectifier meters, if present.

5.3.4 For rectifiers with more than one circuit, measure the output voltage and current for each circuit using a dependable hand-held meter, and calibrate the rectifier meters, if present.

5.3.5 For rectifiers with potential voltmeters, using a dependable hand-held meter, measure the potentials for each voltmeter, and calibrate that rectifier meter. Using a known good reference electrode, measure the potential difference to the installed permanent reference electrode by placing both electrodes together in the electrolyte with CP current off. If the difference is more than 10 mV, replace the permanent reference electrode.

5.3.6 Calculate the cathodic protection system circuit resistance of each circuit by dividing the rectifier DC voltage output of each circuit by the rectifier DC ampere output for that circuit.

5.3.7 For all close-interval corrosion surveys, or if otherwise required, calculate the rectifier efficiency. This also includes timing the revolutions of the kWh meter and annotating the meter factor from the face of the kWh meter.

5.4 IMPRESSED CURRENT ANODE BED

The impressed current anode bed survey is a non-interrupted survey of the ground bed to determine the condition of the anodes. It should be comprehensive and thorough to identify any possible problem with the impressed current anodes. It may also be used to predict failure and to program replacement. This survey would normally be done together with the close-interval corrosion survey. As a minimum, an impressed current anode bed survey should include ON potential over-the-anodes at intervals, unless the system has incorporated other means for monitoring the anodes (e.g., individual anode leads in an anode junction box).

5.4.1 REMOTE SHALLOW ANODE GROUNDBEDS

5.4.1.1 Measure anode-to-soil potentials at 0.6-meter (2-foot) intervals along the length of the anode bed, beginning 3 meters (10 feet) before the first anode, and ending 3 meters past the last anode in the ground bed.

5.4.1.2 Plot test results on graph paper to give a visual indication of the anode bed condition.

5.4.1.3 DISTRIBUTED SHALLOW ANODE GROUND BEDS

5.4.1.4 Measure one anode-to-soil potential with the reference cell located directly over each anode.

5.4.2 DEEP ANODE GROUNDBEDS

5.4.2.1 In lieu of anode potential measurements, measure anode circuit current using (in order of preference) a clamp-on millimeter, a multimeter measuring millivolts across a calibrated shunt, or a multimeter connected in series measuring milliamperes.

5.4.2.2 Measure the anode current for each anode if separate leads are available.

5.5 IMPRESSED CURRENT SYSTEM CHECK

The impressed current system check is an operational check of the impressed current system to ensure the system is operating at the same level as the last close-interval corrosion survey or corrosion survey. This is a non-interrupted check and the potential measurements should be compared to previous ON cycle potential measurements. The locations for the potential measurements must be taken from the last close-interval corrosion survey, or corrosion survey, whichever is most recent, to reasonably ensure that the current output of the system is still being applied and is still sufficient.

5.5.1.1 Measure rectifier DC voltage and DC ampere outputs.

5.5.1.2 Ensure the DC ampere output of the rectifier meets the current (ampere) requirement found on the last close-interval or corrosion survey. If necessary, adjust the rectifier output, and measure outputs again. Repeat procedure as necessary.

5.5.1.3 Calculate the rectifier system circuit resistance by dividing the rectifier DC output voltage by the rectifier DC output current. If the rectifier has more than one circuit, calculate the resistance of each circuit.

5.5.1.4 Take potential measurements at the locations of the three lowest and three highest potential measurements identified in the most recent close-interval or corrosion survey.

5.5.1.5 Compare the potential measurements to previous measurements at the same locations and determine if changes have occurred. If potential measurements do not satisfy criteria in Chapter 6, and the rectifier current output meets the current requirement from the last survey, adjust or supplement the CP system as necessary. Conduct a corrosion survey 30 days after adjustment or modification to the cathodic protection system.

5.6 GALVANIC ANODE CHECK

The galvanic anode system check is conducted to determine its operational condition. It is normally conducted as part of the close-interval survey, corrosion survey, or water tank calibration surveys

5.6.1 Measure the potential of the structure with the reference electrode located directly over the structure, adjacent to an anode (structure-to-earth, DC volts).

5.6.2 Measure the potential of the structure with the reference electrode located directly over the structure, midway between anodes (remote structure-to-earth, DC volts). In this case, remote is as far as possible from the anodes, directly over the protected structure.

5.6.3 Disconnect the anode lead from the structure and measure potential of the anode with the reference electrode located directly over the anode (anode-to-earth, DC volts).

5.6.4 Measure structure-to-anode current (anode output current, mA).

5.6.5 Compare measurements to those previously taken at the same location. Loss of anode-to-earth potential indicates a failed anode or failed anode lead. Loss of anode output current with stable anode-to-earth potential indicates consumption of the anode and pending failure. Loss of structure-to-earth potential with stable anode-to-earth potential and anode output current indicates loss of isolation.

5.7 RESISTANCE BOND CHECK

The resistance bond check is an operational check of two metallic structures connected with some type of semi-conductor or resistor, to ensure that the structures affected by the bond are maintained at proper levels and interference is mitigated. This bond may include reverse current switches, diodes, resistors, or other protective devices whose failures would jeopardize structure protection. These bonds may be between different sections of a protected structure, or may be between a protected structure and any other metallic structure (unprotected or protected with a different cathodic protection system). This is a non-interrupted check and the potential measurements should be compared to previous ON cycle potential measurements taken at the same locations. The locations for the potential measurements and meter connections must be the same and the operational status of any cathodic protection systems must be known.

5.7.1.1 Measure rectifier DC voltage ampere output of the cathodic protection system on either (or both) sides of the resistance bond.

5.7.1.2 Measure the DC ampere current flow through the bond and annotate the direction of the current flow.

5.7.1.3 Measure potential of the metallic structures on both sides of the bond.

5.7.1.4 Evidence of proper functioning may be current output, normal power consumption, a signal indicating normal operation, or satisfactory cathodic protection levels on the structures, according to the function or design of the bond.

5.7.1.5 Compare measurements to measurements previously taken at the same locations to determine if changes have occurred.

5.7.1.6 If the potential measurements, current flow, current direction, or other measurement has changed from the last check, adjust or repair the component as necessary, and repeat the test of the bond.

5.8 LEAK SURVEY

The leak survey is a comprehensive, thorough survey to identify the cause of all leaks and the action required to prevent future leaks from occurring, or to reduce the leak rate.

5.8.1.1 Measure the pH of the soil where it contacts the pipeline or ta

5.8.1.2 Measure the “as found” potential of the pipe or tank where it contacts the soil. “As found” means before any adjustments of existing cathodic protection systems, addition of any form of cathodic protection, or installation of isolation or bonding components.

5.8.1.3 Determine the cause of the leak.

5.8.1.4 Evaluate the condition and determine appropriate repairs to the pipe or tank coating system.

5.8.1.5 Measure the “as left” S/E potential of the pipe or tank where it contacts the soil. “As left” means after all actions are taken to prevent future leaks. If these actions are taken after backfill operations, surface potentials are acceptable.

5.8.1.6 If the leak survey determines the cause to be corrosion, determine the type of corrosion.

5.9 FIELD EQUIPMENT PREVENTATIVE MAINTENANCE

5.9.1 REFERENCE ELECTRODES

5.9.1.1 The copper-sulfate solution inside the reference electrode should be clear. If the solution appears cloudy, this may indicate that the solution has become contaminated and the reference electrode should be compared with the known standard as described in paragraph e below. Should it be necessary to replace the solution, only distilled water and new copper-sulfate crystals should be used. Excess copper-sulfate crystals must be present in order to assure a saturated solution. Under average conditions, it is usually a good idea to empty and replace the solution every two or three months.

5.9.1.2 The porous ceramic tip must be maintained moist at all times. If the tip is allowed to dry out, it may lose its porosity and a good low resistivity contact with the soil will not be possible. Periodic replacement of the tip may be necessary.

5.9.1.3 The copper rod inside the reference electrode should periodically be cleaned with non-metallic sandpaper. Do not use black metal oxide sandpaper, steel wool or any other metallic abrasive as this can cause the copper rod to become contaminated. If the copper rod becomes contaminated, it is best to replace the reference electrode.

5.9.1.4 The copper-sulfate solution must be free of contamination or errors will be introduced in the readings you observe. If the reference electrode is submerged in water or placed in moist soils that are contaminated, it is likely that the solution will become contaminated.

5.9.1.5 The reference electrode that is used in the field must be periodically calibrated. How often the reference electrode needs to be calibrated depends upon several different factors. Among the more important factors that should be considered are the frequency of use and the exposure of the reference electrode to contaminants. As a general rule, calibration should be checked once every week if the reference electrode is used daily. If the reference electrode is only periodically used, calibration should be checked prior to each use.

5.9.2 CALIBRATION OF REFERENCE ELECTRODES

Calibration of the reference electrode is accomplished by comparing it with another reference electrode that has never been used. The unused reference electrode that is to act as the calibration standard should be properly set up (ready for use) and must not have ever been used in the field so that no chance of contamination exists. Consideration should be given to obtaining a reference electrode that is certified by the manufacturer to be properly calibrated for periodic calibration of the field electrode. To calibrate the field electrode:

5.9.2.1 Place the voltmeter on the 2 volt DC scale (or lower) and connect the leads to the reference electrodes as shown in the illustration below.

5.9.2.2 Place both the field electrode and the standard electrode in a shallow nonmetallic container that has one to two inches of tap water in the bottom of it. Do not use distilled water. The reference electrodes must be placed vertically in the container with the ceramic tip of each submerged in the water.

5.9.2.3 Observe the potential measurement displayed on the voltmeter. If more than 10 mV potential exists between the two reference electrodes, the field reference electrode should be properly cleaned and refilled with new solution until the potential difference is 10 mV or less. If you are unable to achieve a 10 mV or less potential difference after cleaning/reconditioning, the field electrode must be discarded and a new one obtained.

5.9.2.4 In order to lessen the chance of cross contaminating the calibration electrode, you should leave the calibration electrode in the water for the shortest time necessary to complete the test.

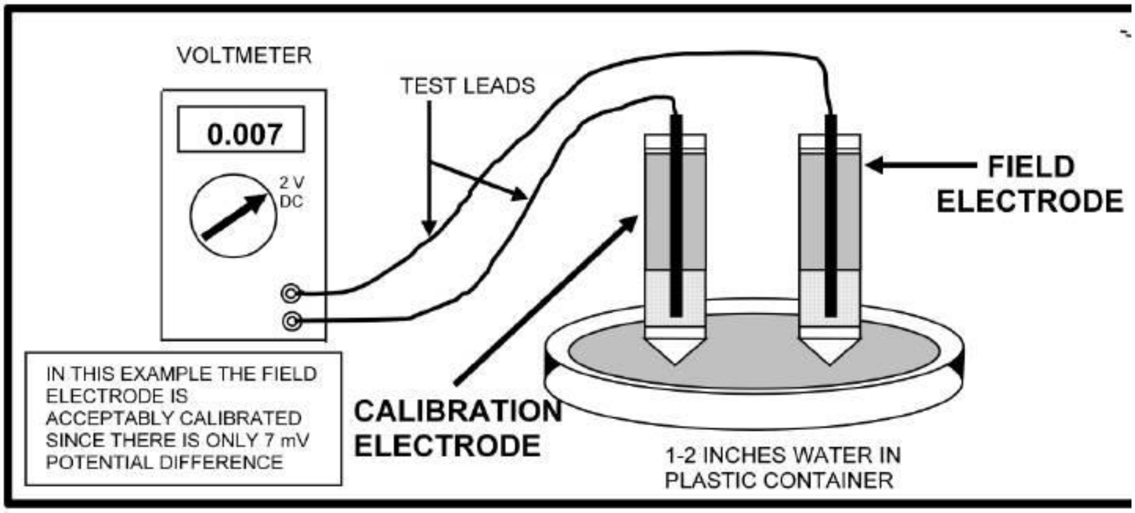


FIGURE 5-1: Sample Reference Electrode Calibration Setup

6 REPAIR & TROUBLESHOOTING OF CATHODIC PROTECTION SYSTEMS

6.1 GALVANIC CATHODIC PROTECTION SYSTEMS

Galvanic cathodic protection is inherently maintenance-free. The current is merely a result of the potential difference of the two metals. Recurring maintenance checks are performed to ensure continued satisfactory performance. Galvanic anodes sacrifice themselves to protect the structure. They normally consume themselves at a constant rate and failure can be predicted by current measurement versus time.

6.1.1 Common Problems. The most common problem in sacrificial anode systems are shorts around or failure of dielectrics on isolated protected structures. Due to the very limited voltage, sacrificial anodes usually cannot supply sufficient current to protect the structures if isolation is lost. On well-coated structures, the contact resistance to earth is high. Other metals in the earth that are not coated have a very low contact resistance, providing a low resistance path for anode current. Maintaining the dielectrics in an isolated system is essential to continued satisfactory performance of sacrificial anode systems.

6.1.2 Lead Wires. Failure of the anode lead wires is uncommon, since copper exposed by nicks or insulation defects are cathodically protected by the anodes. However, these wires can be cut by extraneous excavations. Exercising control over digging permits in the areas of the anode ground beds may ensure that if the wires are cut, they can be repaired on site, before backfilling occurs. Troubleshooting to locate the break at a later date is usually not successful, and replacement of a prematurely failed anode is more economical in almost all cases. A sudden zero anode current output reading indicates probably failed lead wires.

6.1.3 Anode Consumption. When sacrificial anode systems reach the end of their useful life, potential, current, and voltage measurements begin to change. When performing recurring maintenance, a significant drop in anode current indicates imminent failure of the anode. Potential measurements over the protected structure will begin to show dips or drops in the areas of failed anodes. A significant drop in anode potential indicates a failed anode. Anode current may actually reverse after failure, due to the copper center tap of the anode being cathodic to the protected structure. When drops in the potential of the protected structure begin to occur, a closer inspection should be made to determine the extent of the damage to the anodes.

6.1.4 Improper Use. Except on small or extremely well coated structures, such as underground storage tanks or short pipelines with butyl rubber/extruded polyethylene coatings, it is normally not economical to replace a distributed galvanic anode system. When galvanic anodes begin to fail on a distributed system, impressed current cathodic protection should be considered.

6.2 IMPRESSED CURRENT SYSTEMS

Impressed current cathodic protection systems require a higher level of maintenance than sacrificial (galvanic) CP systems. More things can, and do, go wrong. There are five major components to the operational impressed current system: the rectifier, the anode bed, the structure lead, the anode lead (header cable),and the structure. There are two major components to the operational sacrificial system: the anode and the structure lead. If adequate cathodic protection does not exist on the protected structure, then troubleshooting must be accomplished to determine the cause of this lack of protective current.

6.2.1 DC Voltage. Measure the DC voltage output of the rectifier with a handheld multimeter. With power ON, scale on DC volts, measure voltage from N4 to P4 (Figure 6-2). One of three conditions may exist: voltage may be near zero (proceed to paragraph 1) below), near half of normal (proceed to paragraph 2) below), or near normal (proceed to paragraph 3) below).

6.2.1.1 No DC voltage indicates that one of the components in the rectifier is faulty or there has been a loss of AC power (proceed to paragraph 6.2.5.).

6.2.1.2 Half the normal voltage output indicates defective diodes/selenium plates or improper AC input. Proceed to paragraph 6.2.5. to check the AC input to the stacks and paragraph 8.2.-G. to troubleshoot the diodes/selenium plates.

6.2.1.3 Normal DC voltage indicates a break in the anode lead, failed anodes, or a break in the structure lead (proceed to paragraph 6.2.1.3.2.). If the voltage is normal and the rectifier voltmeter reads significantly different, the connections or the voltmeter are faulty (proceed to paragraph 6.2.1.3.1.).

WARNING: AC voltage is still present inside the rectifier with the rectifier circuit breaker or power switch OFF. All connections inside the rectifier cabinet should be made with alligator clip leads connected with the power to the rectifier OFF. If needlepoint leads are used with power ON, use prudent electrical safety practices for working with live circuits.

6.2.1.3.1 With power OFF, check for loose connections from P2 to P3, N2 and N5through N7, including any press-to-test switch or button, and continuity of all wires between those points. This will require disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation. Repair or replace loose connections and replace damaged or broken wires. If problems are not found, proceed to the step b. below.

6.2.1.3.2 With power OFF, remove voltmeter from rectifier. This will require disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Disconnect one end of the resistors on reverse side of meter. Measure the resistance of the resistors with a handheld multimeter on the ohms scale and compare to the value of the resistor (if no resistors are present, replace meter). Replace resistor or meter as required.

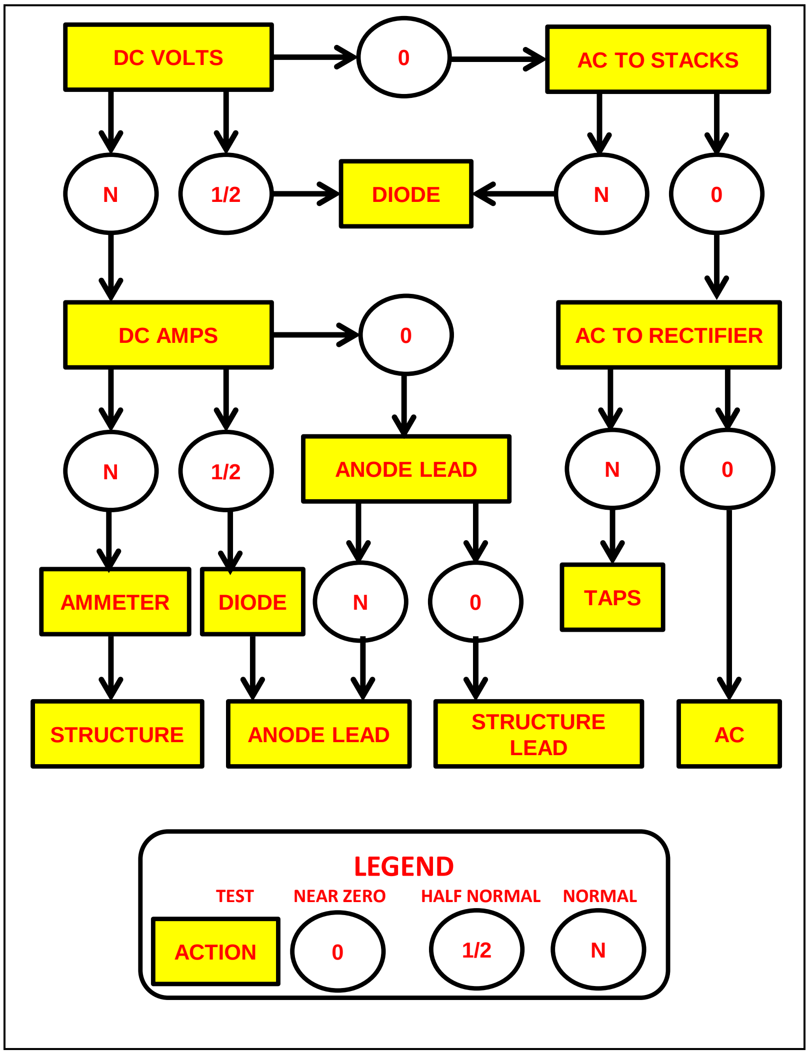


FIGURE 6-1: TROUBLESHOOTING BLOCK DIAGRAM

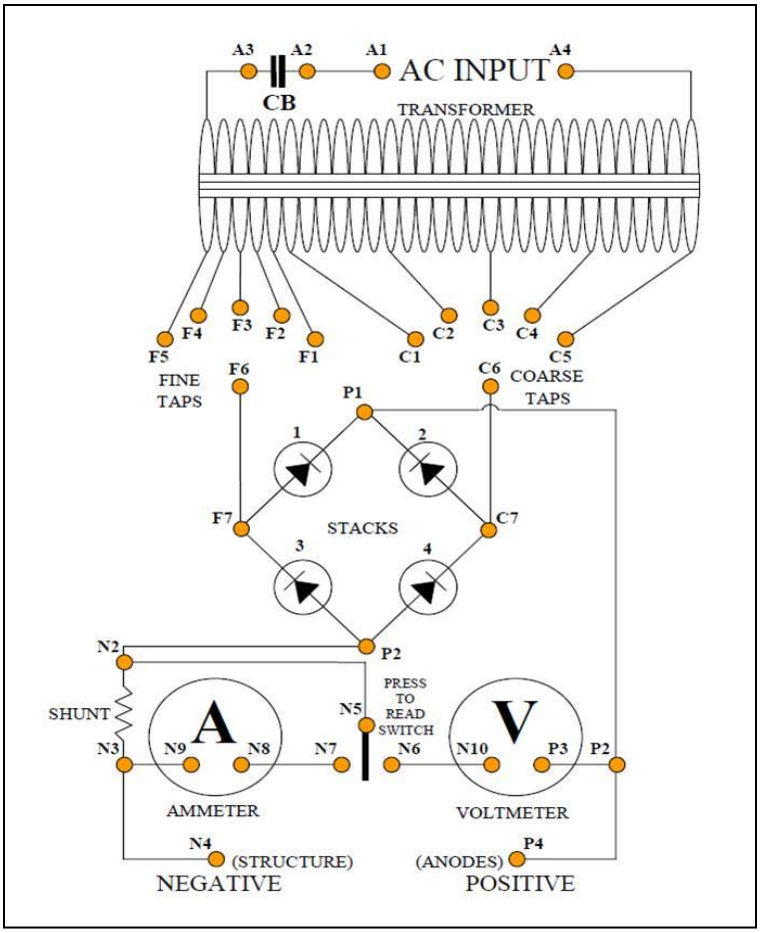


FIGURE 6-2: TYPICAL RECTIFIER WIRING DIAGRAM

6.2.2 DC Current

Measure the DC current output of the rectifier with a handheld multimeter on the mV scale. Measure mV from N2 to N3. Multiply the indicated reading by the appropriate multiplication factor (Figure 6-3). One of three conditions may exist: the current may be near zero (proceed to paragraph 6.2.2.1) below), near half of normal (proceed to paragraph 2) below), or be near normal (proceed to paragraph 3) below).

6.2.2.1 Normal DC voltage with near zero current indicates a break in the anode lead, failed anodes, or a break in the structure lead (proceed to paragraph 6.2.3).

6.2.2.2 Half the normal current output indicates either a defective diode/selenium plate; a break in the header cable between anodes; or, if there are multiple anode leads, loss of one anode lead or anode bed. Measure the DC voltage output of the rectifier with a handheld multimeter on the DC volts scale. Measure voltage from N4 to P4. If voltage is also half of normal, proceed to paragraph 8.2.7. to troubleshoot the diodes/selenium plates. If voltage is normal, proceed to paragraph 9.2.8. to troubleshoot the anode bed.

6.2.2.3 If the current is normal and the rectifier ammeter reads significantly different, either the shunt, the connections, or the ammeter is faulty (proceed to paragraph a. below). If the current is normal, the rectifier ammeter reads normal, and structure potentials are still significantly changed from normal (proceed to paragraph d. below).

6.2.2.3.1 Measure the DC current with a handheld multimeter connected in series and with the meter on the DC amps scale. Disconnect anode header cable at P4 and measure current from P4 to anode lead. Compare the measured current value to the current value taken in paragraph 6.2.2. If values are significantly different, replace the shunt. If values are the same, proceed to the next paragraph.

WARNING: AC voltage is still present inside the rectifier with the rectifier circuit breaker or power switch OFF. All connections inside the rectifier cabinet should be made with alligator clip leads connected with the power to the rectifier OFF. If needlepoint leads are used with power ON, observe prudent electrical safety practices for working with live circuits.

6.2.2.3.2 With power OFF, check for loose connections from N2 through N9,including any press-to-test switch or button, and continuity of all wires between those points. This will require disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation. Repair or replace loose connections and replace damaged or broken wires. If problems are not found, proceed with to the next paragraph.

6.2.2.3.3 With power OFF, remove ammeter from rectifier. This will require disconnection of AC power from the rectifier cabinet and possibly removal of the rectifier from the cabinet. Disconnect one end of the resistors on reverse side of meter. Measure the resistance of the resistors with a handheld multimeter on the ohms scale and compare to the value of the resistor (if no resistors are present, replace meter).Replace resistor or meter as required.

6.2.2.3.4 Normal current values accompanied by loss of potential shifts indicate a change in the protected structure. If the protected structure is isolated, check all dielectrics and repair or replace faulty ones. If the protected structure is not isolated, check for additions to the protected structure, or new structures in the area which are continuous with the protected structure, increase current to protect larger structure(s),isolate other structure(s), or install additional impressed current system(s) as required.

6.2.3 Anode Lead Wires

With power OFF, disconnect anode lead(s) at P4.Using an alternative isolated metallic structure (isolated from structure being tested; if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods, and connect to P4 (positive terminal). For a short period of time, turn power ON and note AC current (paragraph 8.2.2). One of two conditions exists: either current is now present (changed); or it is not present (not changed).

Note: If the structure being tested is the inside of a water tank or tower, and the lack of water will not allow current flow (no electrolyte), fill the tank, and then retest.

6.2.3.1 Current is Present. If current exists, the anode lead is broken or the anodes have failed (proceed to paragraph 8.2.8).

6.2.3.2 Current is Not Present. If no current exists, the structure lead may be broken (proceed to paragraph 8.2.4).

SHUNT SIZE		MEASURE	X	FACTOR	=	AMPS
50 mV	100A	____mV	X	2	=	____A
50 mV	75A	____mV	X	1.5	=	____A
50 mV	50A	____mV	X	1	=	____A
50 mV	45A	____mV	X	.9	=	____A
50 mV	40A	____mV	X	.8	=	____A
50 mV	35A	____mV	X	.7	=	____A
50 mV	30A	____mV	X	.6	=	____A
50 mV	25A	____mV	X	.5	=	____A
50 mV	20A	____mV	X	.4	=	____A
50 mV	15A	____mV	X	.3	=	____A
50 mV	10A	____mV	X	.2	=	____A
50 mV	5A	____mV	X	.1	=	____A
a mV	*b* A	____mV	X	$\frac{b\ A}{a\ MV}$	=	____A

FIGURE 8-3: RECTIFIER SHUNT MULTIPLICATION FACTORS

6.2.4 Structure Lead

For this test, the temporary or alternative anode should remain connected to terminal P4 as described previously in paragraph 8.2.3. With power OFF, disconnect structure lead at N4.

Using an alternative isolated metallic structure (isolated from structure being tested, if doubt exists, measure continuity to structure lead), such as a metal culvert or fence, or install temporary ground rods, and connect to N4 (negative terminal). For a short period of time, turn power ON and note AC current (paragraph 8.2.1). One of two conditions exist, either current is now present (changed) (proceed to paragraph 6.2.4.1) below); or it is not present (not changed) (proceed to paragraph 6.2.4.2) below).

6.2.4.1 Since current is now present, the structure connection is broken. Use the fault detector and cable locator, connected directly to the structure lead at N4, to trace the structure lead from the rectifier towards the structure. This can be extremely difficult in some cases. An alternative method is to locate the first structure connection (from drawings, markers, or induction methods). Excavate to the structure and measure continuity back to the rectifier using a cathodic protection multi-combination meter continuity check circuit. Use the fault detector and cable locator, connected directly to the structure lead, to trace the lead from the structure towards the rectifier. If this is still unsuccessful, replace the structure lead from the rectifier to the structure.

Note: When using the direct connection method, it is essential to have a low-resistance isolated ground for the fault detector or cable locator to put a strong locator signal on the cable under test.

6.2.4.2 If current still does not exist (not changed), the temporary anode bed is not sufficient. Supplement the temporary anode bed, then repeat paragraph 6.2.3.

6.2.5 AC Voltage to Stacks

Measure the AC voltage input to the stacks of the rectifier with a handheld multimeter on the AC volts scale. Measure voltage from F6 toC6 (tap bars). One of two conditions may exist: voltage may be near zero (proceed to paragraph 6.2.5.1) below), or near normal (proceed to paragraph 6.2.52) below).

6.2.5.1 Voltage Near Zero. This indicates loss of AC power to the rectifier, bad fuses or circuit breakers, or a bad transformer (or connections) in the rectifier (proceed to paragraph 6.2.6).

6.2.5.2 Voltage Near Normal. This indicates faulty diodes/selenium plates or bad connections inside the rectifier (proceed to paragraph 6.2.7). If the rectifier does not have taps, proceed to paragraph 6.2.6; if that test is normal, the rectifier must be removed from the cabinet for checkout. Refer to specific rectifier manual to troubleshoot the diodes/selenium plates and the transformer. For general reference, see paragraph 9.2.-G. for the stacks and paragraph 6.2.9 for the transformer.

6.2.6 Fuses

Check all fuses and measure AC voltage input to the rectifier. With power OFF, remove all fuses at the rectifier and any fusible disconnect. Measure the continuity of fuses with a handheld multimeter. Set scale to ohms; measure resistance of each fuse. Corrosion on fuse end caps or fuse holders will also cause loss of voltage. Replace any fuse with measurable resistance, or clean and reinstall fuses if corrosion is found. If a disconnect exists, measure the AC voltage with a handheld multimeter on the AC volts scale. Measure the voltage on the rectifier side of the disconnect. If a disconnect does not exist, measure the AC voltage from the circuit breaker of the rectifier with a handheld multimeter on AC volts scale. For 110/120 volt, single-phase rectifiers turn power to the rectifier OFF, open cabinet and connect meter to A3 (output of circuit breaker) and ground (cabinet). Turn power to the rectifier ON and the rectifier circuit breaker ON; measure voltage from the rectifier circuit breaker. For 220/240 volt, single-phase rectifiers, use the same procedures, but connect meter to A4 and (instead of cabinet ground) the output side of the circuit breaker on the second power lead (not shown on drawing). If voltage is present, proceed to paragraph 1) below. If voltage is not present, proceed to paragraph 2) below.

6.2.6.1 Voltage is Present. This indicates either the transformer or the connections inside the rectifier are faulty (proceed to paragraph 6.2.9.).

6.2.6.2 Voltage is Not Present. This indicates loss of AC Power to the rectifier. Measure the AC voltage to the circuit breaker of the rectifier with a handheld multimeter on the AC volt scale. For 110/120 volt, single-phase rectifiers turn power to the rectifier OFF, open cabinet and connect meter to A1 and A4. Turn power to the rectifier ON; measure voltage to rectifier. For 220/240 volt, single-phase rectifiers, use the same procedures, but connect meter to A4 and input side of the circuit breaker (A1) on thesecond power lead (not shown on drawing). If voltage is not present, proceed to paragraph 6.2.10; or if voltage is present, replace circuit breaker or fuse.

6.2.7 Diodes

Check the diodes/selenium plates of the rectifier with a handheld multimeter on the diode check scale. With power OFF, remove the tap bars or shorting wires and the anode lead (P4) and/or the structure lead (N4). Check the diode/selenium plate sets by connecting one test lead to N4 and the other to F6 (diode 3), then to C6 (diode 4). Both should beep or not beep. Reverse test leads and repeat connections. The beep should be opposite (both should not beep or beep). Repeat the test using P4instead of N4 to test diodes/selenium plate sets (diodes 1 and 2).

Note: An ohms scale may be used. A good diode has very high resistance in one direction and low resistance in the other direction. With power OFF, check for loose connections from F6 to F7, C6 to C7, P1 toP2, P2 to P4, and N1 through N4, and continuity of all wires between those points. Repair or replace loose connections and replace damaged or broken wires, if possible. If no problems are found, replace the stacks.

6.2.8 Anode Beds

Before a great deal of time is expended troubleshooting an anode bed, it should be determined from records if there is sufficient anode material to attempt locating and repairing the fault. Generally, if the current and time is calculated to amp years, comparing that number to the weight of the installed anodes and the weight loss of the anode material will indicate if the anodes are expended or have significant life remaining. Another indicator is if a gradual failure occurred over a period of time, the anodes have failed. If the failure was sudden, a cable break can be expected. If failed anodes are found, replace the anode bed. If a broken anode lead is found, repair the cable. The first step to locating the break is to find the location of any excavations that have occurred in the area of the anode cable. There are two methods of troubleshooting anode beds, depending upon whether all anodes have failed (no current), or some (or most) of the anodes have failed. If one or more anodes are functioning, see paragraph 6.2.8.1) below. If no anodes are functioning, see paragraph 6.2.8.2) below.

6.2.8.1 If one or more anodes are functioning, the best method is first to locate the functioning anodes, then an anode bed gradient graph to isolate and locate the problem.

Note: If separate anode lead wires in a junction box were installed, use these to measure the anode current and determine the functioning anodes.

Perform a close interval survey over the anode bed. For the purpose of troubleshooting, you may adjust the rectifier to the highest voltage setting that would not result in coating damage to the structure, to allow easier location of the anodes. Measure the potentials over the anodes with a handheld multimeter on the DC volts scale. With power ON, connect the positive lead of the multimeter to the structure lead(N4) of the rectifier. Using a copper/copper sulfate reference cell connected to the negative lead of the multimeter, locate the point of highest voltage on the surface of the ground (this will be directly over an anode). Repeat by locating all operational anodes. Mark each anode found and compare to system drawings. Starting in a straight line 3meters (10 feet) from the first anode, perform a potential test every 0.6 meters (two feet)over the entire length of the anode bed, to a point 3 meters (10 feet) past where the last anode is (or is supposed to be) located. Using graph paper, and using vertical lines to represent the measured potentials, and horizontal lines to represent the 0.6-meter (two-foot) intervals, graph all readings. This will show the condition of all anodes, and will indicate if a broken header cable (anode lead) or failed anodes exist. It will show a broken cable between functional and non-functional anodes. If anodes are failing, the gradients will peak differently, or the gradients will fall, then rise intermittently.

6.2.8.2 If no anodes are operational, use the fault detector and cable locator, connected directly to the anode cable P4, to trace the anode lead from the rectifier towards the anode bed. This can be extremely difficult in some cases. An alternative method is to locate the first anode (from drawings, markers, or induction methods).Excavate to the first anode and measure continuity back to the rectifier using a cathodic protection Multi-Combination meter continuity check circuit. Use the fault detector and cable locator, connected directly to the anode to trace the anode lead from the anode towards the rectifier. If this is still unsuccessful, replace the anode lead from the rectifier to the anode.

Note: When using the direct connection method, it is essential to have a low-resistance isolated ground for the fault detector or cable locator to put a strong locator signal on the cable under test.

6.2.9 Rectifier Taps

Measure the AC voltage on the taps of the rectifier with a handheld multimeter on the AC volt scale. Remove the tap bars or shorting wires. Measure the voltage from F5 to F4, F4 to F3, F3 to F2, F2 to F1, and F1 to C1. All readings should be approximately the same. Measure the voltage from C5 to C4, C4 toC3, C3 to C2, C2 to C1. All readings should be approximately the same. Any lead that tests different must be checked for connection (proceed to paragraph 6.2.9.1) below).

Note: On some rectifiers, F1 to C1 may be a unique voltage.

6.2.9.1 With power OFF, check for loose connections from F1 through F5 and C1through C5, including any tap bar or shorting wire, and continuity of all wires between those points. Note that loose connections are characterized by heat, discoloration of the connection, and melted insulation. Repair or replace loose connections and replace damaged or broken wires, if possible. If only one tap is inoperative, a different tap setting may be operational, and testing will reveal functioning taps. If replacement of wire is not possible, replace the transformer. If no problems are found, proceed to paragraph 2) below.

6.2.9.2 With power OFF, check for loose connections from A2 through A4 and continuity of all wires between those points. Repair or replace loose connections and replace damaged or broken wires, if possible. If replacement of wire is not possible, replace the transformer.

Note: Checkout of transformers or pole fuses require personnel certified for work on high voltage lines and proper equipment beyond the scope of these procedures.

6.2.10 Rectifier Input Voltage

First verify that the circuit breaker has not tripped or the fuse has not blown. If properly operating, measure the AC voltage from the circuit breaker or fuse where power is supplied to the rectifier with a handheld multimeter on the AC volts scale. For 110/120 volt, single-phase systems, open the circuit breaker panel or fuse panel and connect meter to the output of circuit breaker or the output side of the fuse (not shown on drawing) and ground or neutral bar. For220/240 volt, single-phase systems, use the same procedures, but connect the meter to the output lugs of the circuit breakers or the output side of the fuses. If voltage is not present, proceed to paragraph 6.2.10.1. If voltage is present, locate the break in the power feed from that point to the rectifier circuit breaker (or rectifier fusible disconnect, whichever was last tested).

6.2.10.1 Measure the AC voltage to the circuit breaker or fuse supplying power to the rectifier with a handheld multimeter on the AC volt scale. For 110/120 volt, single-phase systems open the circuit breaker panel or fuse panel and connect the meter to the main lugs of the circuit breaker panel or the input side of the fuses (not shown on drawing)and ground. For 220/240 volt, single-phase systems, use the same procedures, but check individual legs separately. If voltage is not present, locate the circuit breaker panel or transformer supplying power to the panel and repeat paragraph 8.2.J.; if voltage is present, replace the circuit breaker or fuses.

6.3 TROUBLESHOOTING INTERFERENCE IN CATHODIC PROTECTION SYSTEMS

Cathodic protection interference, whether caused by the influence of cathodic protection systems or by other current sources, can be effectively controlled. Examples of typical corrective actions are presented in this manual to illustrate some of the methods employed and to show how to perform field measurements to determine the continuing effectiveness of the corrective measures. Correction of actual interference problems is beyond the scope of this manual. When interference is suspected, assistance in correcting the problem can be obtained through the local Engineering Field Division.

6.3.1 Correcting Interference. One method of correcting interference is to bond the foreign structure to the protected structure. Thus, both are protected. Figure 6-4shows correction of an interference problem by bonding. A test station is usually installed at such a location to either verify the continuity of the bond, or to measure the current flowing through the bond. Extra wires to each structure allow potential testing of individual structures using a non-current carrying conductor results in a four-wire test station. Current measurements are normally taken using a calibrated shunt. Other methods include using a clamp-on ammeter (or millimeter), or disconnecting and measuring in series using a low input resistance ammeter.

6.3.2 Direct Bonding. Direct bonding is often not desirable, either because the existing cathodic protection system cannot supply enough current to protect both structures, or the foreign structure is not owned by the same organization as the one supplying the current, and minimization of extra current is desired. In this case, a resistive bond is installed between the structures and adjusted so that only that amount of current is supplied to the foreign structure which is required to bring its potential to the same level as it would have been without the interference present. Figure 9-4 shows such an installation. Test stations are normally installed where resistive bonds are used in order to facilitate testing of the corrective action and adjustment or replacement of the resistor. Direct bonding usually is not possible if the protected structure is well coated and the foreign structure is bare or poorly coated. Resistors may fail due to substantial interference currents and the possibility of surges or fault currents. If failure of the resistor would result in loss of adequate protection to a structure that requires cathodic protection, the resistance bond would be considered a “critical bond.” Critical bonds must be tested on a recurring schedule of not less than 60 days.

6.3.3 Continuity. Bonding, as shown in Figure 6-5, is also used to insure continuity of buried structures, both for the prevention of interference and for the proper operation of cathodic protection systems.

6.3.4 Installing a Sacrificial Anode. In some cases, interference is controlled by installing a sacrificial anode or anode bed on the foreign structure to raise the potential of the foreign structure and provide a lower resistance path for discharge current to flow from the installed anodes instead of the foreign structure. The use of a sacrificial anode to control interference is shown in Figure 9-6. This method normally works well when the interference current is fairly low and the foreign structure has a relatively good coating. This method may be combined with coating the cathode (protected structure) near the discharge area to lower the interference current.

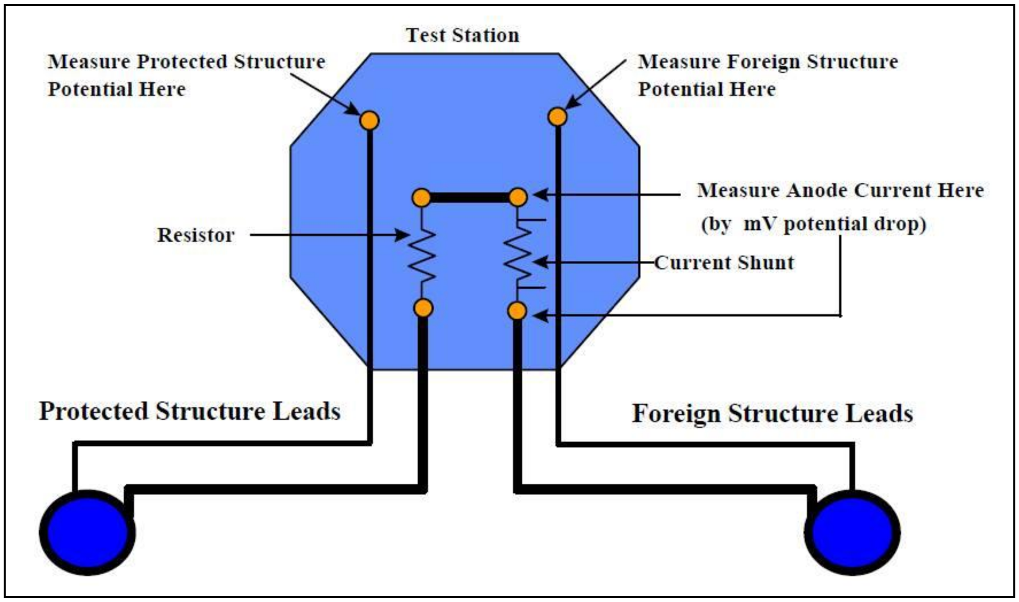


FIGURE 6-4: Correction of Interference by Resistive Bonding

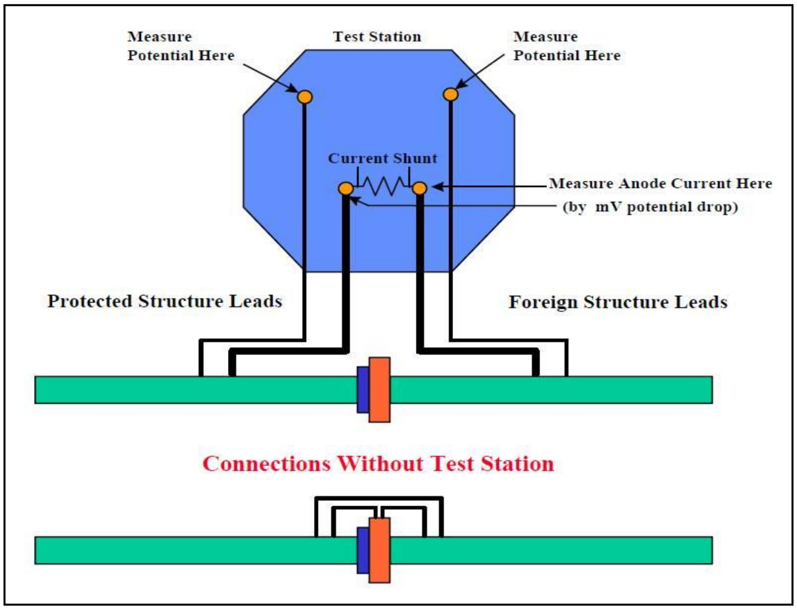


FIGURE 6-5: BONDING FOR CONTINUITY

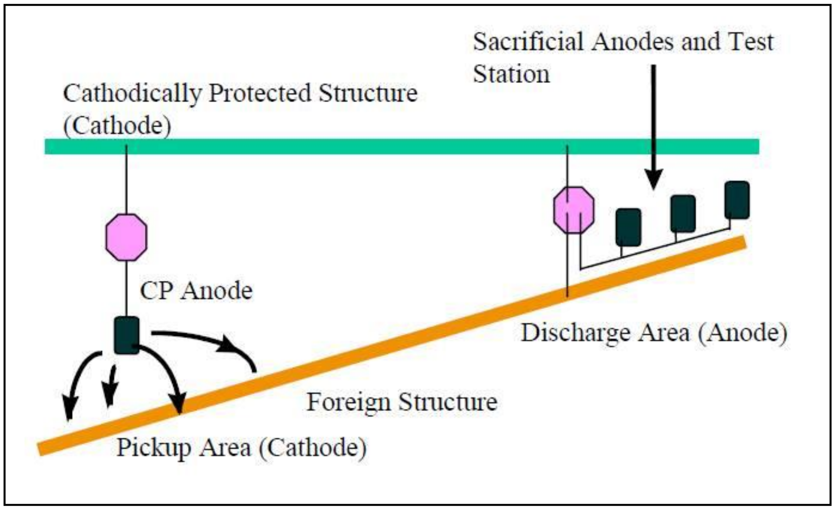


FIGURE 6-6: USING GALVANIC ANODES TO CONTROL INTERFERENCE

6.3.5 Additional Coating. Applying additional coating to the protected structure in the area of the current discharge on the foreign structure raises the resistance of the stray current path, reducing the magnitude of the interference current. This method will usually just lower the interference current, and is used with other methods to stop interference. When interference current levels are very low, this method may be adequate to stop the interference. Although normally used at pipeline crossings, this method could apply to any interference problem. During the installation of a protected structure, additional coatings can be easily installed in areas where stray currents may be expected—for example, at all foreign pipeline crossings or foreign structure crossings (metal fences, metal culverts, electrical grounds). During installation a butyl rubber or similar mastic in combination with extruded polyethylene may be used on the protected structure in these areas. As a retrofit to an existing structure, a primer and tape wrap system may be used, with the additional requirement to excavate and clean the protected structure. This method of interference control is most economically used during the design and installation of the protected structure. As an alternative to applying additional coating, non-conductive barriers are sometimes used between crossing pipelines for similar reason. Barriers do not require uncovering, cleaning, and coating the protected pipeline if it is sufficiently deeper than the foreign structure, and may be more economical in some cases. Barriers must be much larger. Coating the protected structure for 12 meters (40 feet) on each side of a foreign pipeline crossing would be as effective as an 24-meter (80-foot) diameter barrier. This method of interference control is most economically used during the design and installation of the foreign structure.

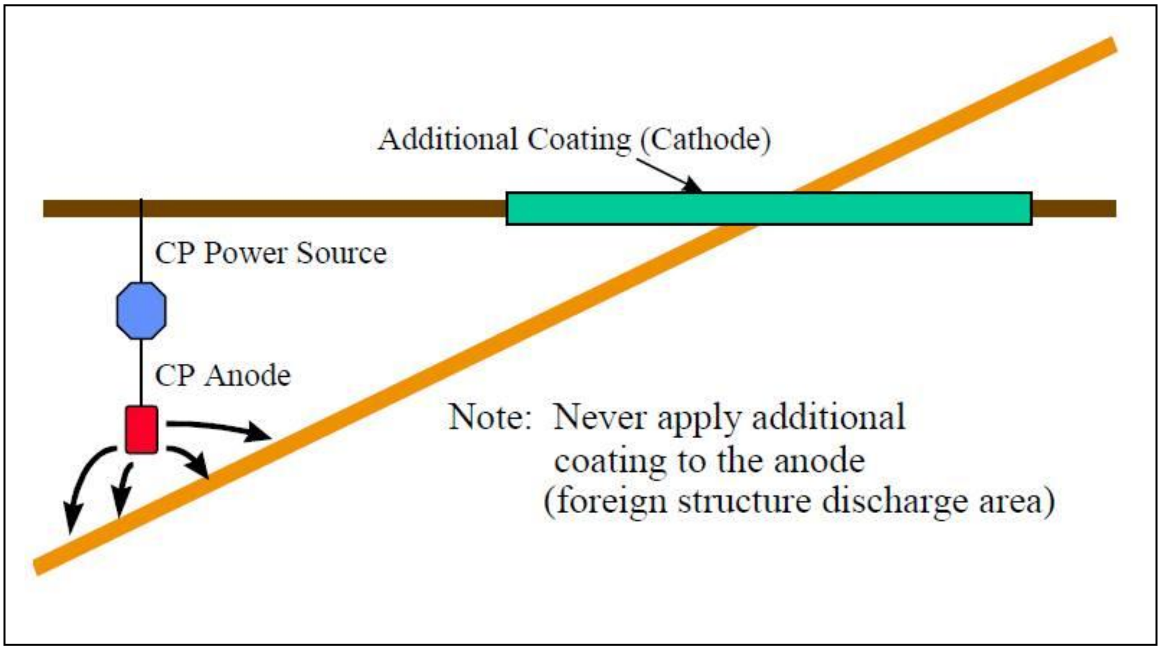


FIGURE 6-7: USING COATING CATHODE TO CONTROL INTERFERENCE

6.3.6 Installation of Nonmetallic Sections or Isolations. Installation of nonmetallic sections or isolations on the foreign structure in the stray current pickup area and between the pickup area and the discharge area may significantly reduce the amount of interference current by substantially raising the resistance of the stray current path. This type of action is usually adequate for metal fences. By isolating sections of fences using two non-contacting fence posts, wooden fence posts or dielectric materials between the fence hardware and the fence posts. Isolations can be made in the current pickup area and between the pickup area and the discharge area, sometimes supplemented with a sacrificial anode in the discharge area(s). This may be considered as part of a design for an impressed current installation if there is a continuous metallic fence in the area where an impressed current anode bed is to be installed or if a metallic fence is to be installed in an area with an existing anode bed.

6.3.7 Application of a Small Impressed Current System. For interference problems which are more serious, and where bonding or resistance bonding is not possible or practical, consider the application of a small impressed current system on the foreign structure in the discharge area to protect the foreign structure from stray current corrosion. As shown in Figure 6-6, substituting a rectifier and impressed current anodes for the sacrificial anodes, the corrosion is stopped by the application of sufficient cathodic protection to the discharge area. Caution should be used to balance the two systems, since this installation may interfere with the original protected structure that was causing the stray current corrosion.

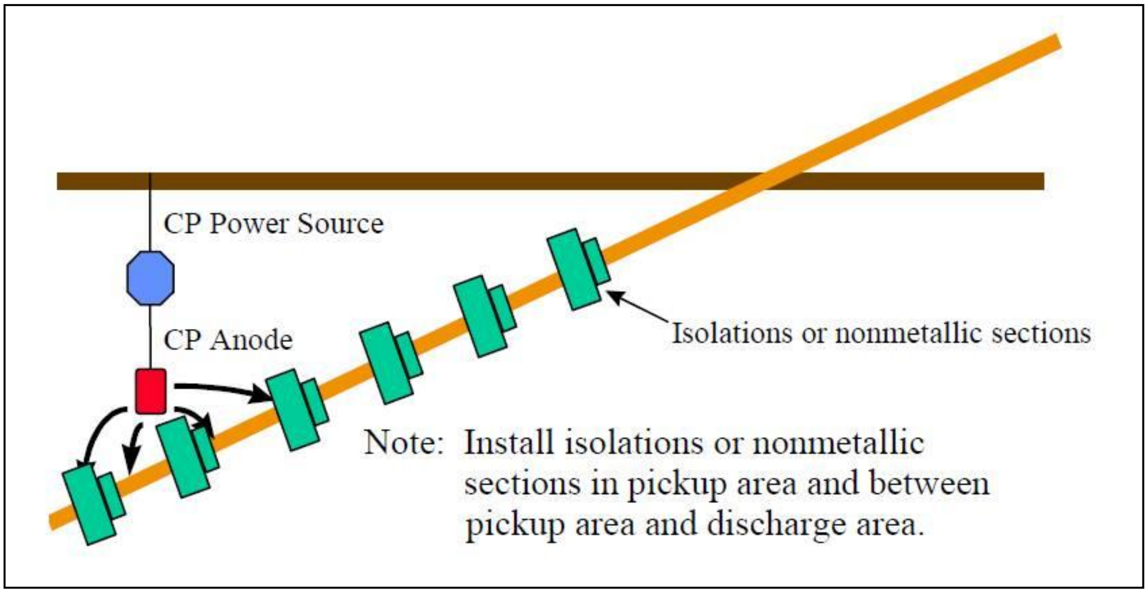


FIGURE 6-8: USING ISOLATION ON FOREIGN STRUCTURE TO CONTROL INTERFERENCE

6.3.8 Combination of Techniques. In many cases, a combination of the preceding mitigation techniques may be prudent. The magnitude of stray current, the soil resistivity, the protected structure coating efficiency, the foreign structure coating efficiency, and the type of foreign structure should be considered to ascertain the most cost effective choice for mitigation techniques.

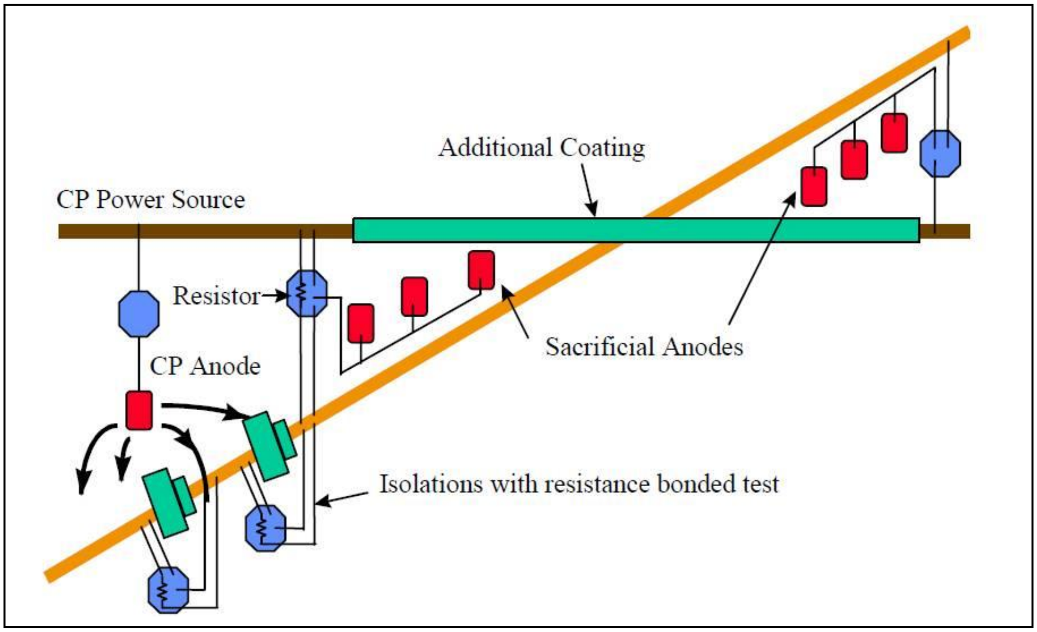


FIGURE 6-9: USING COMBINATION OF MITIGATION TECHNIQUES TO CONTROL INTERFERENCE

7 TESTING OF CATHODIC PROTECTION SYSTEMS

7.1 CATHODIC PROTECTION TESTS

There are three test criteria that can be utilized to indicate if adequate CP is being provided to the structure being evaluated:

7.1.1 -850 mV On

A structure-to-soil potential of –850 mV or more negative with the protective current applied. This is commonly referred to as “850 on” or the “on potential”. This criterion is normally the only one available for galvanic systems since the protective current usually cannot be interrupted.

Voltage drops other than those across the structure to electrolyte boundary must be taken into consideration whenever this criterion is applied. Voltage drops may have a significant impact on the potentials observed when testing impressed current systems with the protective current applied. Therefore, the 850 on criterion is not applicable to impressed current systems.

7.1.2 -850 mV Off

A structure-to-soil potential of –850 mV or more negative with the protective current temporarily interrupted. This is referred to variously as “850 off”, “polarized potential” or “instant off potential”. This criterion is applicable to impressed current and galvanic systems where the protective current can be interrupted. Caution must be exercised when testing impressed current systems to ensure that no active sacrificial anodes are also installed near the protected structure. If there are active sacrificial anodes influencing the observed potential, the 850 off criterion is not applicable unless the sacrificial anodes can also be interrupted.

The instant off potential is the second value that is observed on a digital voltmeter the instant the power is interrupted. The first number that appears immediately after power interruption must be disregarded. After the second number appears, a rapid decay (depolarization) of the structure will normally occur. In order to obtain instant off potentials, a current interrupter or a second person is necessary. If a current interrupter is not available, have the second person throw the power switch at the rectifier off for three seconds and then back on for 15 seconds. Repeat this procedure until you are sure an accurate instant off reading has been obtained.

This criterion is considered by most to be the best indicator that adequate CP has been provided. Therefore, consideration should be given to adjusting the rectifier output upward, under the guidance of a corrosion expert, until the -850 off criterions has been met if this is feasible.

7.1.3 100 mV Polarization

A polarization voltage shift of at least 100 mV. Commonly referred to as “100 mV polarization” or “100 mV shift”. This criterion is applicable to galvanic and impressed current systems where the protective current can be temporarily interrupted. Either the formation or the decay of at least 100 mV polarization may be used to evaluate adequate CP. The “true” polarized potential may take a considerable length of time to effectively form on a structure that has had CP newly applied. If the protective current is interrupted on a metallic structure that has been under CP, the polarization will begin to decay nearly instantaneously. For this reason, it is important that the protective current not be interrupted for any significant length of time. Generally, not more than 24 hours should be allowed for the 100 mV depolarization to occur. On a well-coated structure complete depolarization may take as long as 60-90 days. Complete depolarization of uncoated structures will usually occur within 48 hours although it could take as long as 30 days.

The base reading from which to begin the measurement of the voltage shift is the instant off potential. For example, a structure exhibits an on voltage of –835 mV. The instant off voltage is -720mV. In order to meet the 100 mV polarization criteria, the structure-to-soil potential must decay to at least –620 mV (final voltage).

The use of native potentials to demonstrate the formation of 100 mV polarization is generally only applicable when a system is initially energized or is re-energized after a complete depolarization has occurred. This is because it is necessary to leave the reference electrode undisturbed (or returned to the exact position) between the time the native and the final voltage are obtained.

It is only necessary to conduct a 100 mV polarization test on that component of the UST system where the lowest (most positive) instant off structure-to-soil potential exists. If the criterion is met at the test point where the structure-to-soil potential is lowest (most positive), it can be assumed that it will be met at all other test locations.

7.2 VOLTAGE (IR) DROP TESTS

The effect voltage drops have must be considered whenever structure-to-soil potentials are obtained during the survey of a CP system. The concept of voltage drops is a difficult and controversial subject and a full discussion is beyond the scope of this document. However, stated in the simplest terms, a voltage drop may be thought of as any component of the total voltage measurement (potential) that causes an error.

The term IR drop is sometimes used and it is equivalent to voltage drop. IR drop is derived from Ohm’s Law which states that $V = I R$. In this equation, V stands for voltage, I represents current (amperage) and R stands for resistance. Because the observed voltage is equal to the amperage (I) multiplied by the resistance (R) a voltage drop is commonly referred to as an IR drop. There are various sources of voltage drops and two of the more common are discussed below.

7.2.1 Current Flow

Whenever a current flows through a resistance, a voltage drop is necessarily created and will be included whenever a measurement of the electrical circuit is conducted. In order to effectively eliminate this voltage drop when testing impressed current systems, it is necessary to interrupt the protective current. The magnitude of the voltage drop obtained on impressed current systems is evaluated by conducting both on and instant off potential measurements.

To illustrate how this type of voltage drop contributes to the potential observed when measuring impressed current systems consider the following example. A potential of -950 mV is observed when the rectifier is on. A potential of -700mV is observed when the power is interrupted. Taking the absolute values (negative is dropped), the voltage drop component of the on potential is 250 mV (950 - 700 = 250). Figure 7-1 is a graphical representation of this voltage drop and also shows how the instant off potential will degrade over time until the native potential is reached.

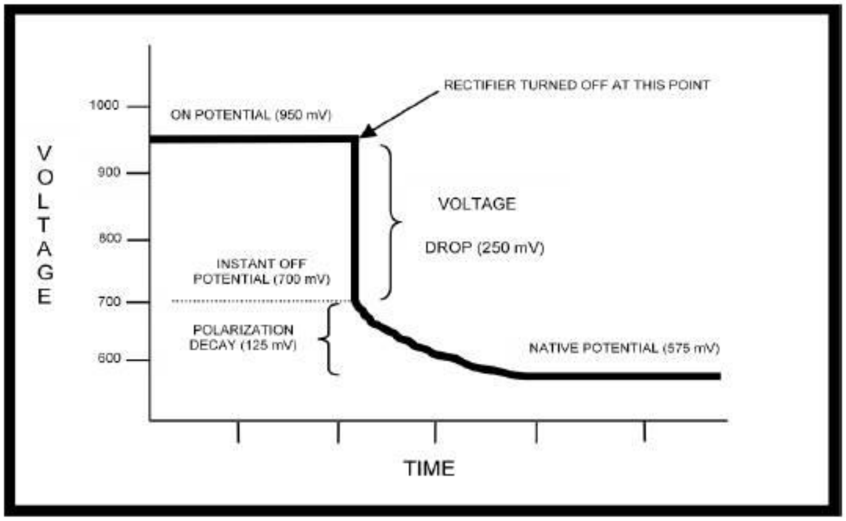


FIGURE 7-1:Voltage Drop in “ON” Potential

7.2.2 Raised Earth

All active anodes will have a voltage gradient present in the soil around them producing a “raised earth effect”. An abnormally high (more negative) potential will be observed if the reference electrode is within the voltage gradient of an active anode. The magnitude or area of influence of the voltage gradient is dependent predominantly on the voltage output of the anode and the resistance of the soil. Unfortunately, there is no “rule of thumb” guidance that can be given to determine how far away you must be from an anode in order to be outside the voltage gradient. If you suspect the potential you obtain may be affected by raised earth, you should take a remote reading and compare the two.

Because of the raised earth effect, it is necessary to place the reference electrode as far away from any active anode (and still be directly over the structure) when obtaining local potentials on galvanic systems. Since the protective current cannot typically be interrupted in galvanic systems, any effect this type of voltage drop may have is evaluated by placing the reference electrode remote. Placement of the reference electrode remote ensures that the reference electrode is not within the voltage gradient of an active anode. Since it is desirable to eliminate any effect voltage drops may have, it is necessary to obtain both local and remote structure-to-soil potentials on galvanic systems. Any effect raised earth may have when testing impressed current systems is eliminated by temporarily interrupting the power.

7.3 STRAY CURRENT TESTS

An unintended current that is affecting the structure you are trying to protect is referred to as a stray current. Stray currents can cause rapid corrosion failure of a buried metallic structure and are caused by an electric current flowing through the earth in an unintended path. If the metallic object you are trying to cathodically protect is buried near the path of the stray current, the current may “jump-on” the protected structure because it offers a lower resistance path for the current to flow. The affected structure will be cathodic where the stray current enters but will be highly anodic where the stray current returns to the earth. At the point where the current discharges, rapid corrosion of the structure intended to be protected will occur.

Although stray currents are relatively rare on UST systems, common sources include: a) railroad crossing signals (powered by batteries); b) traffic signals that have induction type sensors buried in the pavement; c) portable or fixed emergency power generators; d) electrical railway systems such as streetcars or subways in urban areas; e) DC welding operations and other types of industrial machinery or processes that utilize DC power.

If unsteady readings are observed on the protected structure and you have determined that it is not because of a bad electrical connection, you should suspect that stray current is affecting the protected structure. In some cases, a pattern can be seen in the potential whereby it alternates between two relatively stable readings. These patterns can sometimes help to identify the source of the stray current. If you suspect that stray current may be affecting the UST system, a thorough investigation must be conducted as soon as possible by a qualified corrosion expert since stray current can cause a rapid failure of the affected structure.

7.3.1 Cathodic Interference

When the impressed current CP system operating on the structure you are trying to protect causes an unintended current on some other nearby structure, this type of stray current is referred to as “cathodic interference”. Cathodic interference can cause a rapid failure of the water lines, natural gas lines, and other buried metallic structures at the facility where the CP system is operating. If you observe what you believe to be an abnormally high (more negative) potential on a buried metallic structure, you should suspect that the impressed current system operating on the UST system is causing cathodic interference.

Instances where cathodic interference may be present include: a) copper water lines that are not bonded to the impressed current system and have a polarized potential of greater than -200 mV; b) metallic flex connectors associated with fiberglass reinforced plastic piping that have abnormally high (more negative) potentials and are not bonded to the impressed current system; c) factory coated tanks are buried at a facility where there is an impressed current system operating and are not bonded to the negative circuit. When the factory coated tanks have zinc anodes and a potential more negative than -1100 mV (more negative than -1600 mV in the case of magnesium anodes) is observed, it is likely that cathodic interference is occurring. Because of the potential for stray current to impact factory coated tanks, it is required to bond them into the impressed current system.

When testing impressed current systems, it is of critical importance to also test metallic utility lines (natural gas, water lines, etc) to assure the impressed current system designed to protect the tank system is not causing cathodic interference with those utility lines. If it is suspected cathodic interference is affecting metallic utility structures, the owner of that utility (natural gas company, municipal water supplier, etc) should be contacted and made aware of the situation. A corrosion expert must be consulted whenever cathodic interference is suspected in order to properly investigate and make any repairs/modifications that may be necessary.

7.4 DISSIMILAR METALS / BIMETALLIC COUPLES TESTS

The effect bimetallic couples may have must also be considered whenever structure-to-soil potentials are obtained during the survey of a CP system. The concept of dissimilar metals/bimetallic couples and the impact they can have on the proper evaluation of CP systems is a difficult and controversial subject and a full discussion is beyond the scope of this document. However, you should be aware that bimetallic couples may substantially influence the structure-to-soil potentials of a tank system to the extent that the 100 mV polarization criterion is not applicable. Because the validity of the 100 mV criterion may be suspect, consideration should be given to only utilizing the -850 mV instant off criterion when evaluating impressed current systems. A brief discussion follows.

Caution must be exercised when evaluating steel UST systems that have metals of lower electrochemical potential electrically connected to them. Typically, bimetallic couples are only of concern on impressed current systems since those steel components protected by galvanic systems are electrically isolated from other metallic structures. Copper is the metal of lower potential that is commonly of concern. Sources of copper at UST facilities include the water service lines and the grounding system of the electrical power grid. Since the AC power supply to the submersible turbine pump should be continuous with the electrical service grounding system, which may in turn be continuous with the water lines, a significant amount of copper may be coupled to the steel UST system.

The effect this type of bimetallic couple has on the impressed current system can sometimes be clearly seen on those UST systems that store fuel for emergency power generators. Commonly these generator tank systems are installed with copper supply and return lines. When these tanks were retrofitted with an impressed current system, the copper lines were bonded into the CP system. In these instances, it is not uncommon to observe native structure-to-soil potentials on the UST system of -450 mV or more positive.

If the native structure-to-soil potential of the UST system is substantially lower than what you would normally expect, it is likely that a significant amount of copper is electrically bonded to the UST system. Typically, the expected native potential of a steel UST system should not be more positive than -500 mV. To illustrate the effect of the copper-steel couple, consider the following example: A steel UST system that is coupled to copper has a native structure-to-soil potential of

-300 mV with the bimetallic couple intact. If the copper couple is broken the UST system native potential is -600 mV. With the copper couple intact, the polarized (off) potential of the UST system -450 mV. Although the voltage shift satisfies the 100 mV polarization criterion (from -300 mV to -450 mV), it is likely that the steel UST system is not adequately protected. This is because the UST system is not polarized at least 100 mV beyond the native potential of the steel. Since the true native potential of the steel UST system in this example is -600 mV, you would need to reach a polarized (instant off) potential of -700 mV or more negative.

Because the unaffected native potential of steel UST systems is generally not known, the application of the 100 mV polarization criterion would be inappropriate when there is a significant amount of copper (or other more noble metal) electrically continuous. For this reason, it is always desirable to demonstrate that the UST system satisfies the 850 off criterion when evaluating a CP system.

7.5 OTHER TEST CONSIDERATIONS

Various other factors can affect the accuracy of structure-to-soil potentials. Listed below are some of the more common factors that you should keep in mind:

7.5.1 Contact Resistance – In order to obtain an accurate structure-to-soil potential, a good (low resistivity) contact between the reference electrode and the soil must be made. Sometimes, the soil at the surface is too dry and water needs to be added in order to lower the resistance between the reference electrode and the soil. In addition, if the porous ceramic tip of the reference electrode becomes clogged or contaminated it should be replaced since this in itself can cause a high contact resistance.

7.5.2 Contaminated Soil – You should ensure that the soil the reference electrode is placed in is free of contamination. Hydrocarbon contamination can cause a high resistance between the reference electrode and the soil.

7.5.3 Current Requirement Testing – When a current requirement test is conducted on galvanically protected tanks, the affected structure can exhibit an elevated (more negative) structure-to-soil potential during the test and for a period of time after the test is completed. This is due to a temporary polarization of the tested structure which will dissipate over a period of time ranging from a few minutes to perhaps a few days depending on several different factors. Therefore, time sufficient for the temporary polarization of the affected structure to “drain-off” after a current requirement test is conducted must be allowed before an accurate structure-to-soil potential can be obtained. In addition, any potential measured with the battery connected should be disregarded as this measurement contains a large voltage drop. Only instant off voltages are meaningful when the battery is connected.

7.5.4 Drought Conditions – On occasion, it has been observed that structure-to-soil potentials can be improved by running water into the backfill material of the tank bed when extended periods of no rain have occurred. This is commonly done by placing a water hose in one of the tank bed monitoring wells (or other access points) and allowing the water to run for a period of a few hours. This practice serves to lower the resistance of the backfill material. However, you should keep in mind that the resistivity of the soil is not appreciably lowered if the moisture content is 20 percent or higher. In drought conditions, a CP test must pass. If a CP test fails, and is believed to be from dry (highly resistive) soil, the CP tester or expert may elect to re-survey the system at a later date (within 30 days) to see if site conditions improve. This may be done only if continuity data suggests that all protected structures are isolated for galvanic systems and continuous for impressed current systems.

7.5.5 Electrical Shorts – When a substandard reading is observed on a galvanically protected system, it is common to find that some other metallic object is electrically connected to the protected structure. For instance, on factory coated tanks, the nylon bushings installed in the tank bungs were sometimes removed when the various risers and other tank system components were installed or an electrical conduit was buried in contact with the tank shell or metallic piping.

7.5.6 Electromagnetic Interference – Overhead high voltage power lines, railroad crossing signals, airport radar systems and radio frequency transmitters (CB radios, cellular phones, etc.) can all cause an interference that will result in an inaccurate voltage reading.

7.5.7 Galvanized Metals - Buried metals that have a high electrochemical potential can also influence the voltage observed if the reference electrode is placed in close proximity to such metals. For instance, the steel of some of the manways that are installed to provide access to the tank appurtenances may be galvanized. If the reference electrode is placed in the soil of such a manway, an artificially high (more negative) potential may be observed. This is actually a raised earth effect although the galvanized metal is not acting to cathodically protect the buried structure of concern.

7.5.8 Parallel Circuits – Care should be taken to ensure that the person conducting the structure-to-soil testing does not allow their person to come into contact with the electrical components of the testing equipment. If the person touches the electrical connections, an error may be introduced due to the creation of a parallel circuit.

7.5.9 Pea Gravel – Because pea gravel or crushed stone typically has a very high electrical resistivity, it is necessary to ensure that it is saturated with water when attempting to measure structure-to-soil potentials with the reference electrode placed in the pea gravel. Evaluate any effect high contact resistance may have by changing the input resistance of the voltmeter. As an alternative way to evaluate the effect contact resistance may have, place the reference electrode remotely. If the remote reading is substantially more negative than the local, high resistance is indicated. Placement of a saturated sponge on the surface of the pea gravel may help overcome high contact resistance.

7.5.10 Photovoltaic Effect – It is known that sunlight striking the viewing window of a reference electrode can have an effect (as much as 50 mV) on the voltages observed when conducting testing. You should ensure that the viewing window of the reference electrode is kept out of direct sunlight. As an alternative, the viewing window can be covered with black electrical tape in order to prevent any sunlight from reaching the copper-copper sulfate solution.

7.5.11 Poor Connection – If the observed structure-to-soil potentials are unsteady and the voltmeter will not stabilize, you should suspect a bad connection somewhere. Ensure that all electrical connections are clean and tight and good contact is made between the test lead and the structure.

7.5.12 Shielding – Sometimes, a buried metallic structure that is between the reference electrode and the structure you are attempting to test will cause the reference electrode to be unable to “see” the structure you are testing. Shielding is commonly cited when low potentials are observed with the reference electrode placed locally over factory coated tanks due to the various tank risers, pump heads, piping, electrical conduits and metallic manways that are typically located over the tank.

7.5.13 Temperature – The temperature of the reference electrode affects the voltages that are observed when conducting CP testing. You may need to make a correction to the observed potential in some extreme and/or marginal cases. The “standard” temperature is considered to be 77° F. For every degree less than 77 add 0.5 mV from the observed voltage. For every degree above 77 subtract 0.5 mV from the observed voltage. To illustrate this, consider the following (in order to simplify the calculation, the negative sign is dropped from the structure-to-soil potential): A voltage of 845 mV is observed when the temperature is 57° F. In this case the corrected voltage would then be 855 mV (20° X 0.5 mV = 10 mV. Therefore: 845 mV + 10 mV = 855 mV).

7.6 CONTINUITY TESTS

When conducting an evaluation of a CP system, it is normally necessary to establish that the cathodically protected components are either electrically isolated or electrically continuous depending on the type of CP system. The “fixed cell-moving ground” method and the “point-to-point" method are the two commonly utilized ways to test continuity and are discussed in more detail below.

7.6.1 Fixed Cell - Moving Ground Method – The most commonly accepted method of conducting a continuity survey is referred to as fixed cell – moving ground. In this method, the reference electrode is placed at a location remote from any of the cathodically protected structures. Potentials of all the metallic structures present at the site are then measured without moving the reference electrode. Because the conditions found at the reference electrode/electrolyte interface can change over a short period of time (causing the observed potential to change), it is important to conduct this type of testing as quickly as possible.

When determining whether electrical continuity or isolation is provided, the following guidelines are generally accepted for fixed cell – moving ground surveys:

7.6.1.1 If two or more structures exhibit potentials that vary by 1 mV or less, the structures are considered to be electrically continuous.

7.6.1.2 If two or more structures exhibit potentials that vary by 10 mV or greater, the structures are considered to be electrically isolated.

7.6.1.3 If two or more structures exhibit potentials that vary by more than 1 mV but less than 10 mV, the result is inconclusive and further testing (point-to-point) is necessary.

7.6.2 Point-to-Point Method - An easier and usually more accurate way to test continuity is the "point-to-point" method. With this method, a reference electrode is not utilized. The two structures that are to be tested are simply touched with each lead of the voltmeter and the voltage difference (if any) is observed. For example, if you are trying to establish that electrical isolation exists between a tank and the fill riser associated with that tank, you would simply touch the fill riser with one of the voltmeter leads and the tank shell with the other voltmeter lead and observe the voltage difference.

When determining whether electrical continuity or isolation is provided, the following guidelines are generally accepted for point-to-point surveys:

7.6.2.1 If the voltage difference observed between the two structures is 1 mV or less, the two structures are considered to be electrically continuous with each other.

7.6.2.2 If the voltage difference observed between the two structures is 10 mV or greater, the two structures are considered to be electrically isolated from each other.

7.6.2.3 If the voltage difference observed between the two structures is greater than 1 mV but less than 10 mV, the result is inconclusive and further testing beyond the scope of this document is necessary.

7.7 CONTINUITY TESTS OF GALVANIC SYSTEMS

In order for sacrificial anodes to function efficiently, the protected component must be electrically isolated from any other metallic structures that may be connected to or in contact with the protected structure. This is generally accomplished through the use of dielectric bushings and unions and by making sure that no additional metallic structures come into contact with the protected structure. On those systems where adequate CP has not been achieved, it is common to find that some unintended metallic structure is electrically continuous with the protected structure. Frequently, an electrical conduit is in contact with a factory coated tank or the tank bung nylon bushings are missing or damaged. If metallic tank hold down straps were improperly installed, they will wear through the epoxy coating on the tank over time and cause premature anode failure. With metallic piping, the shear valve anchoring bracket usually provides an electrical bond with the dispenser cabinet and all of the other metal connected to it. When this is the case, the anodes are trying to protect much more metal than intended and the life of the anodes is shortened.

It may be observed that continuity exists for two or more piping runs at a facility. The practice of “bonding” metallic piping runs together is common and is acceptable so long as the CP system was designed and installed according to industry standards. The “bonded” piping runs should be isolated from tanks, electrical conduits, shear valve brackets and other non-protected structures.

Continuity testing is required regardless of the structure-to-soil potentials results (pass, fail, inconclusive). The CP tester or expert may use their discretion on how many continuity readings are needed. When a structure to soil potential results in a “fail” or “inconclusive”, additional continuity readings must be taken. Common structures to test continuity with include but are not limited to; tanks, fill risers, ATG risers, Submersible Turbine Pump (STP) risers, Stage II vapor recovery risers, vent lines, electrical conduit, unions, shear valve anchor brackets, dispensers, and product piping.

7.8 CONTINUITY TESTS OF IMPRESSED CURRENT SYSTEMS

All protected components of the system must be electrically continuous in an impressed current CP system. Various bonds may be required in order to ensure that continuity has been provided. Failure to establish continuity in an impressed current system can result in accelerated corrosion of the electrically isolated components.

The most common method of continuity testing on an impressed current system is a point-to-point method in which the rectifier is turned off, and the negative (structure) wire must be disconnected from the rectifier. More complex methods are beyond the scope of this document and are more commonly used by a corrosion expert.

Carefully check all bonds when evaluating an impressed current system as these are of critical importance. Commonly, tanks are bonded into the negative circuit by attachment to the tank vent lines above ground. Because of this, it is easy for the integrity of the bonds to be compromised. It is equally important to ensure that the positive lead wire(s) have continuity. Any break in the insulation or dielectric coating of the positive circuit will allow current to discharge from the break and cause rapid corrosion failure of the wire. This is why it is absolutely critical that all buried positive circuit splices are properly coated and insulated.

7.9 SOIL RESISTIVITY TESTS

Many factors in the operation of cathodic protection systems are dependent upon the resistivity of the electrolyte. The corrosivity of the environment is generally higher when the resistivity is low. The output of both sacrificial anodes and impressed current anodes is also dependent upon the resistivity of the environment. The resistivity of fresh water and seawater normally does not change sufficiently to affect the operation of cathodic protection systems. However, the resistivity of soil environments depends upon the amount of moisture present and is subject to wide variations. These commonly experienced variations in soil resistivity affect the operation of cathodic protection systems, manifesting in variations in structure-to-electrolyte potentials or rectifier outputs measured during routine system inspections. Electrolyte resistivity measurements are taken to determine the cause of improper system operation.

A correlation between electrical resistivity and corrosivity toward ferrous metals is:

Soil Resistivity in ohm-centimeters			Corrosivity Category
over		10,000	mildly corrosive
2,000	to	10,000	moderately corrosive
1,000	to	2,000	corrosive
below		1,000	severely corrosive

Other soil characteristics that may influence corrosivity towards metals are pH, soluble salt content, soil types, aeration, anaerobic conditions, and site drainage.

7.9.1 SOIL TESTING METHODS

7.9.1.1 FOUR-PIN METHOD

The most commonly used method of measuring soil resistivity is the four-pin method. A current is passed through two electrodes, and a drop in potential through the soil due to the passage of the current is measured with a second pair of electrodes. A specialized instrument is used to supply the current and measure the potential drop. To reduce the influence of any stray currents in the area, the instrument supplies alternating current. The arrangement of electrodes is shown in Figure 7-2.

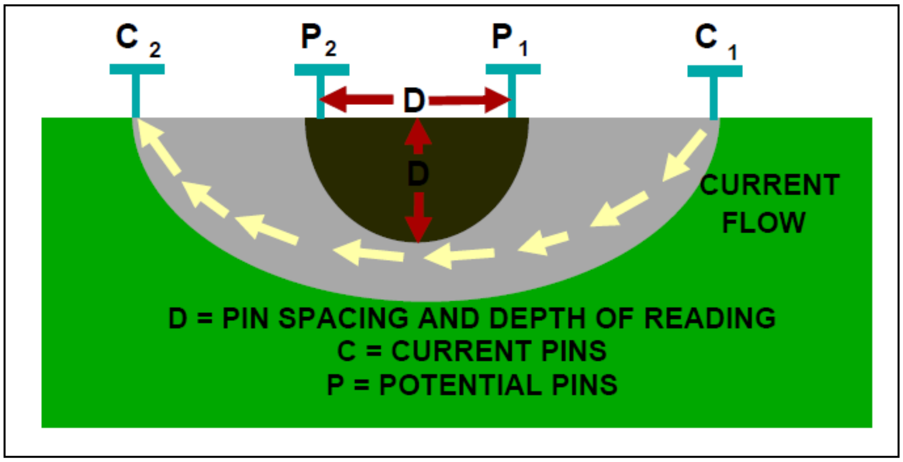


FIGURE 7-2: FOUR PIN METHOD SOIL RESISTIVITY

The soil resistivity is calculated from the indicated reading by using the following formula:

Resistivity (ohm-cm) = 191.5 × pin spacing (in feet) × meter reading

In this method, the average resistivity of the soil between the two center electrodes to a depth equal to the pin spacing is measured. If the pin spacing is increased, then the average soil resistivity to a greater depth is measured. If the average resistivity increases as the pin spacing increases, then there is a region of higher soil resistivity at depth. If the average soil resistivity decreases with depth, then there is region of lower soil resistivity at depth. For multipliers for common distances and distances for even multipliers, see Figure 7-3.

Common Distances		Even Multipliers	
Distance Between Rods	Reading Multiplier	Distance Between Rods	Reading Multiplier
2’6”	479	2’7”	500
5’	958	5’3”	1000
7’6”	1,436	7’10”	1,500
10’	1,915	10’5”	2,000
12’6”	2,394	13’1”	2,500
15’	2,872	15’8”	3,000
20’	3,830	20’11”	4,000
30’	5,745	31’4”	6,000

FIGURE 7-3: FOUR-PIN SOIL RESISTIVITY MEASUREMENT READING MULTIPLIERS

7.9.1.2 TWO-PIN METHOD

In the two-pin method of soil resistivity measurement, the potential drop is measured between the same pair of electrodes used to supply the current. The equipment used to make this type of measurement is often called the "Shepard's Canes," after its inventor. As shown in Figure 7-4, the probes are placed 0.3 meters (one foot) apart. If the soil is too hard for the probes to penetrate, the reading is taken at the bottom of two augured holes. The instrument is calibrated for a probe spacing of one foot and gives a reading directly in ohm-cm. Although this method is less accurate than the four-pin method and measures the resistivity of the soil only near the surface, it is often used for preliminary surveys, as it is quicker than the four-pin method.

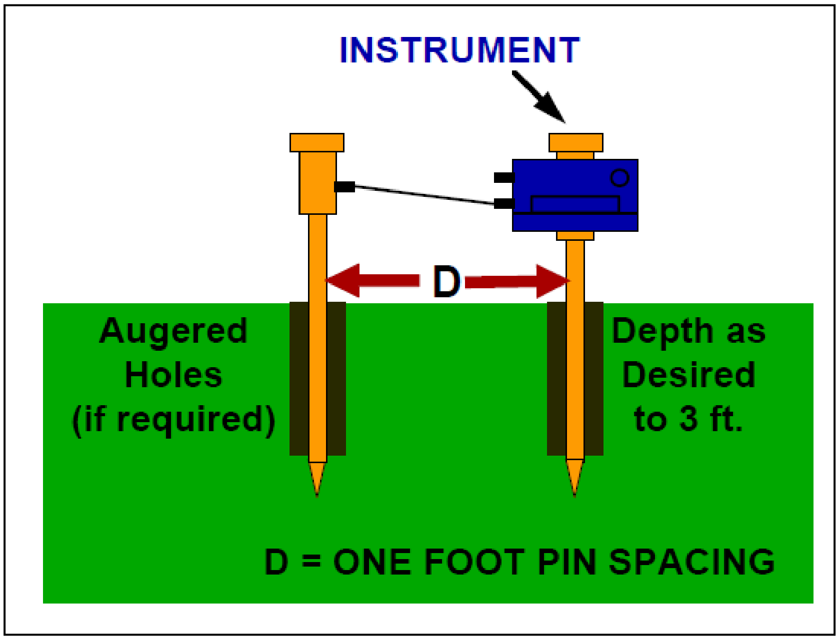


FIGURE 7-4: TWO-PIN METHOD OF SOIL RESISTIVITY MEASUREMENT

1) Other Methods (Soil Rod, Soil Box)

   A soil rod is essentially a two-pin resistivity-measuring device where the electrodes are both mounted on a single rod, as shown in Figure 7-5. As in the other two-pin method, the resistivity of the soil to a very shallow depth is measured. Also, the soil must be soft enough to allow penetration of the rod. Measurements using the soil rod, however, can be taken quickly when measuring in soft soil.

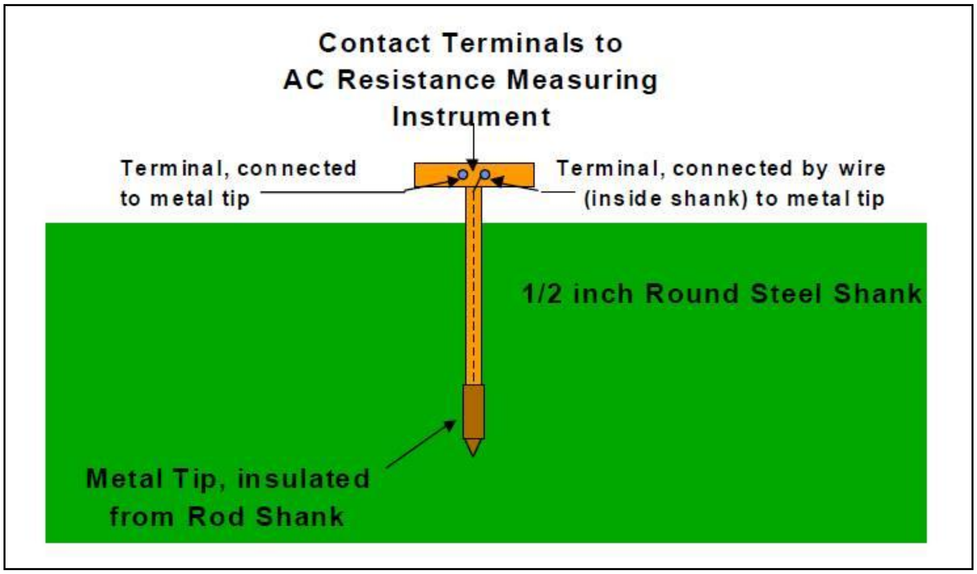


FIGURE 7-5: SOIL RESISTIVITY MEASUREMENT USING A SOIL ROD

7.9.1.2.1 When it is impractical to make field measurements of soil resistivity, soil samples can be taken and the resistivity of the sample can be determined by using a soil box. As shown in Figure 7-6, the method of measurement is essentially the four-pin method. Metal contacts in each end of the box pass current through the sample.

Potential drop is measured across probes inserted into the soil. The resistivity is calculated using constants furnished with the particular size of soil box being used. Due to the disturbance of the soil during sampling and possible drying out of the soil during shipment, this method of soil resistivity measurement is less likely to represent true, in-place soil resistivity than an actual field test. To minimize drying out of samples, they should be placed in plastic bags and sealed prior to shipment.

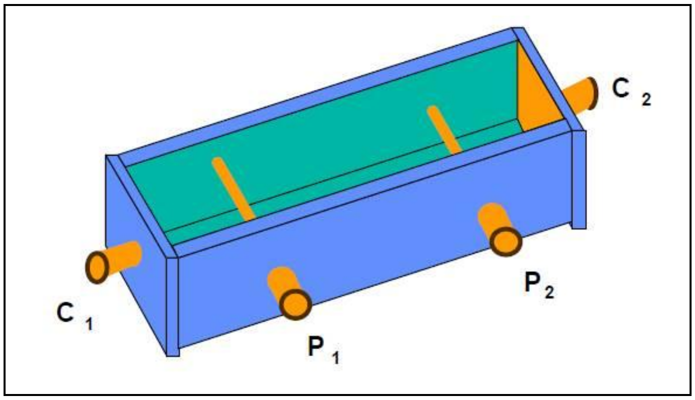


FIGURE 7-6: SOIL RESISTIVITY MEASUREMENT USING A SOIL BOX

APPENDIXES

8 REFERENCES

8.1 NACE STANDARDS FOR CATHODIC PROTECTION SYSTEMS

1. NACE 1 (SSPC - SP5) White Metal Blast Cleaning
2. NACE 2 (SSPC - SP10) Near White Metal Blast Cleaning
3. NACE 3 (SSPC - SP6) Commercial Blast Cleaning
4. NACE 4 (SSPC - SP7) Brush Off Cleaning
5. NACE 5 (SSPC – SP-12) Surface Preparation of Steel and Other Hard Materials by Water Blasting Prior to Coating or Recoating
6. NACE 10 (SSPC - PA6)Fiberglass-Reinforced Plastic (FRP) Linings Applied to Bottoms of Carbon Steel Aboveground Storage Tanks
7. RP0184-91Repair of Lining Systems
8. RP0193-2001 External Cathodic Protection of On-Grade Metallic Storage Tank Bottoms
9. RP0275 Application of Organic Coatings to the External Surface of Steel Pipe for Underground Service
10. SP0100-2014 (formerly RP0100) Cathodic Protection to Control External Corrosion of Concrete Pressure Pipeline and Mortar-Coated Steel Pipelines for Water or Waste Water Service
11. SP0104-2014 (Formerly RP0104-2004) The Use of Coupons for Cathodic Protection Monitoring Applications
12. SP0169-2013 (formerly RP0169) Control of External Corrosion on Underground or Submerged Metallic Piping Systems
13. SP0177-2014 (formerly RP0177) Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems
14. SP0178-2007 (Formerly RP0178-2003) Design, Fabrication, and Surface Finish of Metal Tanks and Vessels to be Lined for Immersion Service
15. SP0186-2007 (formerly RP0186) Application of Cathodic Protection for External Surfaces of Steel Well Casings
16. SP0187-2017 (Formerly RP0187) Design Considerations for Corrosion Control of Reinforcing Steel in Concrete
17. SP0188 Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
18. SP0196-2011 (formerly RP0196) Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks
19. SP0207-2007 Performing Close-Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines
20. SP0285-2011 (formerly RP0285) Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
21. SP0286-2007 (formerly RP0286) Electrical Isolation of Cathodically Protected Pipelines
22. SP0313-2013 Guided Wave Technology for Piping Applications
23. SP0387-2006 (formerly RP0387) Metallurgical and Inspection Requirements for Cast Sacrificial Anodes for Offshore Applications
24. SP0388-2014 (formerly RP0388) Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks
25. SP0492-2006 (formerly RP0492) Metallurgical and Inspection Requirements for Offshore Pipeline Bracelet Anodes

26. SP0572-2007 (formerly RP0572) Design, Installation, Operation, and Maintenance of Impressed Current Deep Goundbeds
27. SP0575-2007 (formerly RP0575) Internal Cathodic Protection Systems in Oil-Treating Vessels
28. SP0607-2007 (ISO 15589-2 (Modified)) Petroleum and natural gas industries Cathodic protection of pipeline transportation systems
29. TM0101-2012 Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Tank Systems
30. TM0105-2012 Test Procedures for Organic-Based Conductive Coating Anodes for Use on Concrete Structures
31. TM0108-2012 Testing of Catalyzed Titanium Anodes for Use in Soils or Natural Waters
32. TM0172-2001 Determining Corrosive Properties of Cargoes in Petroleum Product Pipelines
33. TM0190-2012 Impressed Current Test Method for Laboratory Testing of Aluminum Anodes
34. TM0211-2011 Durability Test for Copper/Copper Sulfate Permanent Reference Electrodes for Direct Burial Applications
35. TM0497-2012 Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems

8.2 ASTM STANDARDS FOR CATHODIC PROTECTION SYSTEMS

1. B843-07Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
2. G8 – 96 Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
3. G42 – 96Standard Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures
4. G95 – 07 Standard Test Method for Cathodic Disbondment Test of Pipeline Coatings (Attached Cell Method)
5. G193-12dStandard Terminology and Acronyms Relating to Corrosion

9 SPECIFICATIONS SECTION 13110 FOR NEW INSTALLATION OF CP SYSTEMS. GENERAL REQUIREMENTS FOR CATHODIC PROTECTION SYSTEMS FOR PIPELINE.

9.1 DESCRIPTION

This section addresses the materials, installation and testing for basic corrosion control and monitoring facilities on buried metallic piping. Materials include herein are: test and bond stations, simple sacrificial anode installations, wire and cable, alumino-thermic welds, casing insulators and end seals, insulating flange kits, supplemental linings at insulators and marker posts. Specifications for large sacrificial anode installations and impressed current cathodic protection systems shall be specifically designed for the particular application.

9.2 RELATED WORK SPECIFIED ELSEWHERE (WMWD Technical Specifications)

1. Standard Drawings
2. Record Drawings and Submittals: STD SPEC 01300.
3. Trenching, Backfilling, and Compacting: STD SPEC 02223.
4. General Concrete Construction: STD SPEC 03000.
5. Cold Applied Wax Tape Coating: STD SPEC 09952.
6. Polyethylene Sheet or Tube Encasement: STD SPEC 09954
7. Painting and Coating: STD SPEC 09900.

9.3 SUBMITTALS

9.3.1 Submit submittal packages in accordance with Standard Specifications Section 01300.

9.3.2 Submit manufacturer’s catalog data on precast concrete manholes, frames, and covers. Show dimensions and materials of construction by ASTM reference and grade.

9.4 GENERAL REQUIREMENTS FOR EQUIPMENT AND MATERIALS

9.4.1 TEST STATION

9.4.1.1 Post Mounted Test Boxes:

9.4.1.1.1 Enclosure: Post-mounted enclosures shall be constructed of one piece molded fiberglass and conform to NEMA 4X. The fiberglass-reinforced resins shall be chemically resistant to a wide range of corrosive atmospheres. It shall have a hinged cover with quick-release lockable latches and a seamless foam gasket. All hardware shall be stainless steel. Hinges shall be corrosion resistance polyester or stainless steel piano hinge. Size as follows unless specified differently in the project drawings:

No. of Wires	Size (inside)	Acceptable Product
2 or 3 wires	5.5x4.0x5.0”	Hoffman A-645JFGQRR
4 or 5 wires	7.5x6.0x5.28”	Hoffman A-865JFGQRR

9.4.1.1.2 Panel: The mounting panel shall be fiberglass, micarta or laminated phenolic sheet cross-laminated for resistance to warping and weathering. Minimum panel thickness shall be 3/16-inch. Panel shall be mounted off of the back of the enclosure to allow sufficient access to make up wire terminals.

9.4.1.1.3 Components: All terminal lugs shall be solid brass. Provide a properly sized terminal lug for all wires. See Standard Drawings or Drawings for wiring configuration and wire labels.

9.4.1.1.4 Post: Post shall be seasoned, construction heart garden grade redwood, 4 inches by4inches by 5 feet long, and surfaced on four sides. Cut a ¾-inch chamfer in all 4 top edges and paint per Standard Specification Section 09900 using System No. 60. Color shall be white and green as approved by the District.

9.4.1.1.5 Conduit: 2-inch diameter galvanized rigid steel conduit per UL 6 approximately 4-feetlong with long radius sweeps. Fittings shall be galvanized rigid steel per UL 514.

9.4.1.1.6 Brass Tags: Wire identification tags shall be 1½-inch diameter, 18 Ga. brass discs with a 3/16-inch diameter hole and die stamped with ¼-inch characters. Tags shall be attached to test wires with un-insulated AWG No. 14 solid copper wire. Tag legend shall be as indicated in the Drawings or Standard Drawings.

9.4.1.1.7 Concrete Pad: ASTM C-94 ready mix concrete.

9.4.1.2 At-Grade Test Box:

9.4.1.2.1 Concrete Box: At-grade test boxes shall be round, pre-cast concrete with dimensions of 13-1/2-inch O.D. by 8-inch I.D. by 12-inches high, similar to Christy G5 Utility Box with a cast iron supporting ring and lid, and shall have sufficient strength to support occasional H-20 vehicular traffic. The lid shall be 10 inches O.D. and cast with thelegend "CP Test" using letters not less than 1-1/2-inch high.

9.4.1.2.2 Concrete Pad: Test boxes mounted in un-paved areas shall be mounted in a reinforced 26 inches square by 4 inches thick concrete pad constructed of ASTM C94 Ready-Mix concrete. Rebar shall be No. 4. A concrete pad is not required where the test box isplaced in pavement.

9.4.1.2.3 Brass Tags: Wire identification tags shall be 1½-inch diameter, 18 Ga. brass discs with a 3/16-inch diameter hole and die stamped with ¼-inch characters. Tags shall be attached to test wires with un-insulated AWG No. 14 solid copper wire. Tag legendshall be as indicated in the Drawings or Standard Drawings.

9.4.2 PREPACKAGED MAGNESIUM ANODES

9.4.2.1 Magnesium Anode (High Potential): unless otherwise specified anodes shall be high potential prepackaged magnesium alloy ingot of the following chemical composition:

1.	Aluminum	0.010%
2.	Manganese	0.50 to 1.30%
3.	Copper	0.02% MAX
4.	Nickel	0.001% MAX
5.	Iron	0.03% MAX
6.	Other	0.05% Each or 0.3% MAX Total
7.	Magnesium	Remainder

9.4.2.2 Magnesium Anode (Standard Potential): If the Drawings call out standard potential magnesium anodes, the ingot shall have the following chemical composition:

1.	Aluminum	5.3 to 6.7%
2.	Manganese	0.15 to 0.30%
3.	Zinc	2.5 to 3.5%
4.	Copper	0.02% MAX
5.	Nickel	0.002% MAX
6.	Iron	0.003% MAX
7.	Silicon	0.10% MAX
8.	Other	0.05% Each or 0.3% MAX Total
9.	Magnesium	Remainder

9.4.2.3 Anode Weight: Unless otherwise specified the ingot weight of prepackaged magnesium anodes shall be 48 pounds. The anode ingot shall have a trapezoidal cross section and be approximately 32 inches long. Other anode ingot weights (with different cross sections and dimensions) may be specified in the Drawings.

9.4.2.4 Anode Backfill: Each magnesium anode shall be prepackaged in a permeable cloth bag with a backfill of the following composition:

1.	Gypsum	75%
2.	Powdered Bentonite	20%
3.	Anhydrous Sodium Sulfate	5%

9.4.2.5 Backfill grains shall be capable of 100% passing through a 100-mesh screen. The backfill shall be firmly packed around the anode by mechanical vibration to a density, which will maintain the magnesium ingot in the center of the cloth bag and surrounded by at least one inch of backfill.

9.4.2.6 Prepackage Weight: The total packaged weight of 48-pound (ingot weight) magnesium anodes and backfill shall be approximately 105 pounds. The cloth bag diameter is 8inches. The packaged weight and diameter of other anode sizes shall be as indicated in the Drawings.

9.4.2.7 Anode Lead Wire: Anode lead wire shall be AWG No. 12 stranded copper wire with THWN insulation conforming to UL Standard 83. Wire shall be connected to the strap core with silver solder. The connection shall be mechanically secured before soldering and shall have at least one and one-half turns of wire at the connection. The connection shall then be insulated by filling the remainder of the recess with electrical potting compound. Anode lead wire shall be of sufficient length to extend from the anode to the designated termination point without a splice. Wires with cut or damaged insulation will not be accepted and replacement of the entire lead will be required at the Contractor's expense.

9.4.3 PREPACKAGED ZINC ANODES

9.4.3.1 Zinc Alloy: The anode alloy shall conform to ASTM B 418, Type II and shall be prepackaged with the following chemical composition unless otherwise specified:

1.	Aluminum	0.005% Max
2.	Cadmium	0.003% Max
3.	Iron	0.0014% Max
4.	Zinc	Remainder

9.4.3.2 Anode Weight: Unless otherwise specified the Ingot weight of the prepackaged zinc anode shall be 30 pounds.

9.4.3.3 Anode Backfill: Each zinc anode shall be prepackaged in a permeable cloth bag with a backfill of the following composition:

1.	Gypsum	75%
2.	Powdered Bentonite	20%
3.	Anhydrous Sodium Sulfate	5%

9.4.3.4 Backfill grains shall be capable of 100% passing through a 100-mesh screen. The backfill shall be firmly packed around the anode by mechanical vibration to a density, which will maintain the zinc ingot in the center of the cloth bag and surrounded by at least one inch of backfill. The packaged weight of the 30-pound (ingot weight) zinc anode and backfill shall be approximately 70 pounds. Prepackaged weights for other size zinc anodes shall be as indicated in the Drawings.

9.4.3.5 Anode Lead Wire: Anode lead wire shall be AWG No. 12 stranded copper wire with THWN insulation conforming to UL Standard 83. Wire shall be connected to the steel rod core with silver solder. The connection shall be mechanically secured before brazing or silver soldering and shall have at least one and one-half turns of wire at the connection. The connection shall then be insulated with a heat-shrinkable sleeve and coated with bituminous compound. The Anode lead wire shall be of sufficient length to extend from the anode to the designated termination point without a splice. Wires with cut or damaged insulation will not be accepted and replacement of the entire lead will be required at the Contractor's expense.

9.4.4 SHUNTS

Shunts used in the anode test boxes shall be 0.01 ohms - resistance and rated at 6amperes capacity and accurate to plus or minus 1%. Use Holloway Type RS shunt unless otherwise specified.

9.4.5 WIRE AND CABLE

9.4.5.1 General: All DC wires shall be stranded copper with high molecular weight polyethylene (HMWPE) or thermal plastic (THWN) insulation suitable for direct burial in corrosive soil and water conforming to UL 83 and ASTM Standards B3 or B8. HMWPE insulation shall conform to the requirements of ASTM D1248 Type 1, Class C. THWN insulation shall conform to the requirements of ASTM D-2220. Wires with cut or damaged insulation will not be accepted and replacement of the entire length of wire will be required at the Contractor’s expense.

9.4.5.2 Test Leads: Unless otherwise indicated, test wires shall be AWG No. 8 HMWPE wire. THWN wire shall be used only where specifically called out. Each test lead shall be of sufficient length to extend from the attachment to the pipe or structure to the test box without a splice.

9.4.5.3 Bond Wires: Bond wires shall be AWG No. 2, No. 4, or No. 6 HMWPE depending on the pipe diameter and as indicated in the detail drawings or directed by the District. Bond wires shall be as short as possible.

9.4.6 LEAD WIRE CONNECTORS

9.4.6.1 Terminal Lugs: Terminal lugs shall be solderless, UL 486 copper or brass and sized to accommodate the wire.

9.4.6.2 Split-bolt Connectors: Split bolt connectors shall be UL 486 copper or brass and sized to accommodate the lead wire and shunt being used.

9.4.7 INSULATING FLANGE KITS

9.4.7.1 General: Insulating flange kits shall consist of Type E, full-face gaskets, insulating sleeves and double washers (steel and dielectric) on each end. All insulating material shall be of the type designated by the manufacturer as suitable for the operating temperature and pressure of the service. If the Insulating flange kit is not compatible with planned tapping valve, an additional flanged spool or a prefabricated insulating joint will be required.

9.4.7.2 Gaskets: Insulating gaskets shall be dielectric neoprene-faced phenolic.

9.4.7.2.1 Sleeves: Use full-length sleeves except for installation on threaded studs where half-length sleeves are required. For installation on threaded bolts, i.e., at butterfly valve flange bonnets and bases, the sleeves shall be half-length.

9.4.7.2.2 Flanges 12-inches or less: 1/32-inch thick phenolic tube.

9.4.7.3 Flanges greater than 12-inches: s 1/32-inch thick G10 epoxy glass tube material as per NEMA LI-1.

9.4.7.4 Washers: Insulating washers shall be 1/8-inch thick G10 epoxy glass sheet material.

9.4.7.5 Flanges 12-inches or less: Phenolic

9.4.7.6 Flanges greater than 12-inches: G10 epoxy glass

9.4.7.7 Steel Washers: Steel washers shall be 1/8-inch thick cadmium plated or zinc plated carbon steel.

9.4.8 WAX TAPE WRAP

9.4.8.1 Surfaces Requiring Wax Tape: All buried piping system surfaces not coated with the primary pipe coating such as flanges, valves, couplings, insulating flanges, adapters, uncoated pipe spools or specialty fittings.

9.4.8.2 Material and Application Standard: per Standard Specification Section 09952.

9.4.9 INTERNAL SUPPLEMENTAL LINING AT INSULATING FLANGES

9.4.9.1 Flanges Requiring Supplemental Lining: Supplemental lining is only required on insulating flanges greater than 20-inches and where specifically designated as requiring a supplemental lining in the Project Design Documents.

9.4.9.2 Lining: Supplemental lining shall be Aquatapoxy as manufactured by Raven Linings Corporation (Tulsa, OK), Hydro-Pox by Con-Tech of California (Stockton, CA), or District approved equal. All internal lining materials must be NSF approved for use in potable water.

9.4.10 PIPELINE CASING INSULATORS

9.4.10.1 Body: The casing insulator body shall be constructed of a 12-inch wide steel band with a heat-fused plastic (PVC) coating with a minimum thickness of 10 mils. The steel band shall be flanged with stainless steel tightening bolts and nuts. The body shall be provided with a ribbed PVC liner to protect the pipe coating and prevent slippage.

9.4.10.2 Runners: 2-inch wide reinforced plastic (18,000 psi compressive strength). Runners are attached with stainless steel nuts on 3/8-inch threaded studs that are welded to the steel band before coating. The bolt holes counter bored and filled with epoxy.

9.4.10.3 Acceptable Products: Use PSI Model A12G-2 or District's approved equal. Wooden skids or high-density polyethylene casing insulators are not acceptable.

9.4.11 CASING END SEALS

9.4.11.1 Type: End seals shall be either a heat shrinkable sleeve type or the mechanical link type. End seals shall provide full dielectric isolation and a watertight seal between the casing and the carrier pipes. Pre-molded casing seals held in place by an external band of metal or other material are not acceptable.

9.4.11.2 Heat Shrinkable Seal: Heat shrinkable sleeve shall have a minimum tensile strength of 2,500 psi and be resistant to abrasion, corrosive gases and be able to tolerate typical expansion and contraction of the casing and carrier pipes. Provide a separate nonconductive support skirt or transition padding that will allow a smooth transition of the heat shrink material from casing to carrier diameter. Watertight seals on both the casing and the carrier pipes are required. Use Raychem Caseal or Canusa CSK Casing Seal Kit.

9.4.11.3 Mechanical Link Seal: Articulated mechanical annular seal shall include EPDM rubber seal elements, non-metallic pressure plates and Type 316 stainless steel nuts and bolts for tightening. When compressed a full watertight seal is required. Use link-Seal Model "C" or District approved equivalent.

9.4.12 ALUMINO-THERMIC WELD KITS AND WELD COATING

9.4.12.1 Weld Kits: Wire-to-pipe connections shall be made by the alumino-thermic welding process. Weld charges and mold size shall be as specified by the manufacturer for various pipe sizes and surface configurations. Weld charges for use on cast and ductile iron are different from those used on steel. Care should be taken during installation to be sure correct charges are used. Welding charges and molds shall be the product of a manufacturer regularly engaged in the production of such materials. Weld charges for steel pipelines have green caps. Weld charges for cast or ductile iron have orange caps.

9.4.12.2 Weld Cap Primer: Weld cap primer shall be an elastomer-resin based corrosion resistant primer for underground services such as Royston Roybond Primer 747 or District approved equal.

9.4.12.3 Weld Caps: Alumino-thermic welds shall be sealed with a pre-fabricated plastic cap filled with formable mastic compound on a base of elastomeric tape. Weld caps shall be Royston Handy Cap 2 or District approved.

9.4.12.4 Weld Cap Overcoating: Weld caps and the surrounding area shall be overcoated with a cold-applied, black, thixotropic material containing plasticized coal tar pitch, solvents, and special fillers per MIL-C-18480A such as Protecto Wrap 160/160H, Carboline 330M, Tape-Coat TC Mastic or 3M Scotch Clad 244. Apply to at least 20 mils thickness.

9.4.13 PIPE ENCASEMENT

Unless otherwise specified all ductile iron pipe shall be fully encased in 8 mil (0.008 inches)polyethylene sheet material in accordance with AWWA C105 Method A and STD SPEC09954. The plastic encasement shall be installed without pinholes or tears and shall be fully protected from damage during backfilling. All pipe sections shall be fully inspected byte District's Inspector before the pipe is backfilled.

9.4.14 PLASTIC WARNING TAPE

Plastic warning tape shall be run in the wire trench at a depth of 12-inches and above each buried wire. The warning tape shall be 3 inches wide and shall have a printed warning -“Caution - Cathodic Protection Cable Buried Below” or similar.

9.4.15 MORTAR

Mortar used to repair concrete coated pipe after attachment of bond or pipe test lead wires shall be the fast drying, non-shrinkable type.

9.4.16 BARRIER POSTS

Where indicated protective barrier post shall be 6-inch Sch 40 steel pipe concrete filled. Pipe height, 4 feet, embedded depth 24-inches in a concrete footing. Paint OSHA safety orange epoxy or as indicated.

9.5 INSTALLATION REQUIREMENTS AND EXECUTION

9.5.1 GENERAL

Except as directed differently below, the installation of corrosion control and monitoring facilities shall conform to NACE Publication RP-0169 (Revised 1996) – Recommended Practice, Control of External Corrosion on Underground and Submerged Metallic Piping Systems and NACE RP0286 Electrical Isolation of Cathodically Protected Pipelines. The installation of impressed current cathodic protection facilities and large sacrificial anode systems is addressed in the Project Design Documents.

9.5.1.1 TEST BOXES

9.5.1.2 Post Mounted Test Boxes:

9.5.1.2.1 Location: locate redwood post directly above the pipeline, if possible, but not in a roadway or in a location that clearly obstructs existing access or is particularly susceptible to damage. The district shall approve test station locations.

9.5.1.2.2 Post: Use white paint for the finish coats and green paint for the top 4 inches of the chamfered end. Excavate a 16-inch diameter by 2-foot deep hole. Center the post and test box in the hole and fill the hole with concrete. The concrete shall be class C per Standard Spec Section 03000.

9.5.1.2.3 Test box and Conduit: Connect 2-inch galvanized conduit to the anode test box with a threaded flange and collar connection. Attach test box to the redwood post using mounting brackets and threaded fasteners or wood screws through the back of the test box. Attach conduit to the post with conduit clamps and wood screws if necessary. Insert all test leads in the galvanized conduit and run into test box prior to setting the post in concrete.

9.5.1.2.4 Wire Identification: Brass identification tags shall be securely attached to each of the wires in the test box. Tags shall be stamped with the size-material-service of the pipe to which the test leads are attached. For example 18”-STL-DW. Brass tags on wires in insulating flange test boxes shall be stamped with the additional identification of “N”, “S”, “E”, or “W” for North, South, East or West to indicate on which side of the insulating flange the wires are attached. Attach tags with bare No. 14 copper wire.

9.5.1.2.5 Concrete Footing: Footing shall be 16-inch diameter by 24-inches deep. Dome concrete slightly to prevent ponding water next to wood post.

9.5.1.3 At-Grade Test Boxes:

9.5.1.3.1 Location: The at-grade test boxes shall be installed over the pipeline or immediately adjacent to paved roadways behind the curb and out of traffic lanes if the pipeline is in the roadway. Test boxes can be embedded in the sidewalk just beyond the curb or placed in a concrete pad in the planter strip or just beyond the sidewalk. The District Representative shall approve test station location.

9.5.1.3.2 Installation: The test box shall be centered in a gravel leach field that extends 24 inches below the bottom of the test box. A 2-½ inch PVC reference cell tube shall extend into the test box 3 inches from the bottom and shall extend into the native soil below the test box by at least 3 inches. The reference cell tube shall be filled with native soil and not gravel. All wires shall be properly identified and cut off such that there is approximately 18 inches of slack wire above finish grade and coiled inside the test box. Keep the inside of the test box clear of all debris and other foreign material. Top of box shall be flush with finish grade in paved areas. In unpaved areas, the top of the box shall be 1 inch above grade with the concrete pad domed to make a smooth transition to grade at the perimeter of the pad.

9.5.1.3.3 Wire Identification: Brass identification tags shall be installed and marked per paragraph 9.4.1.1.6.

9.5.1.3.4 Concrete Pad: In unpaved areas the test box shall be mounted in a reinforced concrete pad 26-inches square by 4 inches deep constructed of ASTM C94 Ready-Mix concrete. Rebar shall be No. 4 steel placed as shown in the drawings.

9.5.1.3.5 Marker Posts: Redwood marker posts are required wherever at-grade anode test boxes are utilized in a remote area. Paint topside of test box cover per Standard Specification Section 09900, System No. 20. Color of finish coat shall be green and white. Locate marker post as directed by the District Representative. Cut, paint, and install the redwood post as described in 3.02 A.2. On the side facing the at-grade test box, stencil on the post in 2-inch high green letters the words "CP TEST" and the distance in feet from the marker post to the test box.

9.5.2 INSTALLING MAGNESIUM ANODES

9.5.2.1 General: Anodes shall be installed at locations as shown on the Drawings or as directed byte District. Care shall be taken to ensure that the cloth bag is not damaged and no backfill material lost during installation. Each magnesium anode shall be centered in the cloth bag. It may be necessary to re-center the anode in the cloth bag by rolling it on the ground prior to installation. Each magnesium anode shall be lowered into the hole using a sling or rope and placed vertically at the bottom of the hole. Do not lower, transport, handle or lift the anode by the lead wire.

9.5.2.2 Primary Excavation Method: Prepackaged magnesium anodes shall be installed in a vertical augured hole of 12-inches in diameter. The depth of the hole shall be 12 feet admeasured from the finish surface to the bottom of the anode unless otherwise specified.

9.5.2.3 Alternate Excavation Method: If the 12-foot depth cannot be obtained or if vertical auguring cannot be accomplished due to heavy rock, the District's Representative shall be notified for possible adjustment to the designed depth, position, and orientation of the anodes. Backhoe excavations must be approved by the District.

9.5.2.4 Relative Position: Anode beds shall be offset from the steel pipe a minimum of 10 feet unless otherwise indicated on the Corrosion Protection Detail Drawings or directed by the District. At no time shall an anode be installed outside of the pipeline right-of-way or District's easement.

9.5.2.5 Anode Soaking (Augured Holes): Once the prepackaged anode is in the hole, water shall be poured into the hole so that the anode is completely covered with water. Allow to soak for at least 15 minutes. Stone-free native soil shall then be used to backfill the anode hole. Do not use imported sand for backfilling. The anode hole shall be backfilled in stages and carefully tamped to ensure that no voids exist around the bag and that the bag and anode lead wire is not damaged. After backfill is level with the top of the anode, a minimum of 15gallons of water shall be poured into the hole to completely saturate the soil backfill. More water shall be added if it is suspected that the backfill is not completely saturated. Care must be taken to avoid damage to the anode and anode lead wire.

9.5.2.6 Anode Soaking (Backhoe Installations): Prepackaged must be pre-soaked in water for at least 15 minutes before installing in the trench. After covering the anode with native, rock free soil (approximately 3 inches over the anode) the anode and initial backfill shall be further soaked with 15 to 20 gallons of water and allowed to soak for 15 minutes. The remainder of the trench is backfilled with native soil.

9.5.2.7 Lead Wire: Anode lead wire shall be long enough to reach from the anode to the anode test box without a splice. Anode lead wires shall be trenched a minimum of 36-inches deep and terminate individually in the appropriate anode test box. Care shall be taken not to damage the lead wire thought the installation process.

9.5.2.8 Wire Tags: Anode wires are not tagged.

9.5.3 INSTALLING ANODE LEAD WIRES

9.5.3.1 Wire Trenching: All buried anode and test wires shall be installed at a minimum depth of36 inches. The bottom of the finished trench shall be sand or stone-free earth. The first three inches of sand backfill material shall be placed directly on the wires. The remainder of the trench shall be backfilled with stone-free earth. Care shall be taken when installing wire and backfilling trench so that insulation is not broken, cut, nicked, or bruised. If wire insulation is damaged during installation, the wire and anode shall be replaced unless wire splices or insulation repairs are approved by the District. Anode replacement shall be at the Contractor's expense. Plastic warning tape shall be installed approximately 12 inches below finished grade.

9.5.3.2 Wire Splicing and Insulation Repairs: Neither splices nor insulation repairs are allowed unless specifically approved by the District Representative.

9.5.4 INSTALLING ZINC ANODES

9.5.4.1 Facilities Requiring Zinc Anodes: Zinc anodes are required on all copper air-vacs, water sampling assemblies and water services. Zinc anodes may be required on other facilities as indicted on the Project or Corrosion Protection Detail Drawings.

9.5.4.2 Installation: Zinc anodes are typically installed in trench excavations below the buried copper tubing. Depths and locations with respect to the assembly shall be as shown in the Standard Drawings or as specified or shown in the Project Design Documents.

9.5.5 WIRE AND CABLE

9.5.5.1 General: No less than two test wires shall be attached to the pipe at each designated test site. All test wires shall terminate in a test box without a splice. A minimum of 18 inches of slack wire shall be coiled at the wire-to-pipe connection and in at-grade test boxes for each test wire. At post-mounted test stations slack wire shall be provided inside the box to the extent possible and with one 8-inch diameter loop at the below-grade entrance to the conduit.

9.5.5.2 Connection to Pipe: Connections of copper wire to the pipeline shall be made withalumino-thermic weld charges or by brazing. Welding charges shall be the product of a manufacturer regularly engaged in the manufacture of the material. Manufacturer's recommend cartridge size and type shall be used. Each weld shall be installed, tested and coated as described below.

9.5.5.2.1 Preparation of Wire: Use a cutter to prevent deforming wire ends. Remove only enough insulation from the wire to allow the weld connection to be made. Do not use a hacksaw for cutting.

9.5.5.2.2 Preparation of Metal: Remove all coating, dirt, grime and grease from the metal pipe at weld location by wire brushing and/or use of suitable safe solvents. Clean the pipe to a bright, shiny surface free of all serious pits and flaws by use of mechanical grinder or a file. The area of the pipe where the attachment is to be made must be absolutely dry. Failure to provide a dry surface for welding will result in a poor quality weld and could result in serious injury to the workman. Do not cut reinforcing rods when preparing metal surface for wire attachment.

9.5.5.2.3 Attachment of Wire to Pipe: The attachment of copper wire shall be made using an alumino-thermic weld as shown on the Standard Drawings. The wire is to be held at 30° to 45° angle to the surface when welding. Only one wire shall be attached with each weld.

9.5.5.2.4 Testing of All Completed Welds: As soon as the weld has cooled, the weldment shall be tested for strength by striking a sharp blow with a two-pound hammer while pulling firmly on the wire. All unsound welds are to be re-welded and re-tested. All weld slag shall be removed from the weldment.

9.5.5.2.5 Coating of All Completed Welds: Thoroughly clean by wire brushing the area to be coated. The area must be completely dry. Apply the weld cap primer and the weld cap. Overcoat the weld cap with a bituminous mastic coating material in accordance with the manufacturer's recommendations. Completely coat the weld, all bare pipe surfaces around the weld and any exposed copper wire. Allow sufficient time to dry prior to repair of the mortar coating on steel pipe.

9.5.5.2.6 Mortar Repair: On mortar coated pipe, the mortar coating shall be repaired after the bituminous weld coating has dried, using fast-setting, non-shrinkable mortar to restore the original outside diameter of the pipe at each weld location.

9.5.5.3 Plastic Lined Pipe: Do not weld test or bond wires directly to plastic lined pipe (sewer or reclaimed water). Wires must be attached to factory installed bonding pads per OMWD Standard Drawings.

9.5.5.4 Wire Trenching and Backfill:

9.5.5.4.1 Depth: All buried horizontal test lead runs shall be installed at a minimum depth of 36 inches.

9.5.5.4.2 Backfill: The bottom 2 inches of the finished trench shall be sand or stone-free earth. The first three inches of the backfill shall be sand or stone-free earth placed directly on the wires. The remainder of the trench shall be backfilled with native earth with a maximum stone size of 2 inches and compacted as specified in Standard Specification 02223.

9.5.5.4.3 Damaged Wire: Care shall be taken when installing wire and backfilling trench so that insulation is not broken, cut, nicked, or bruised. If wire insulation is damaged during installation, it shall be replaced completely at the Contractor's expense.

9.5.5.4.4 Warning Tape: Plastic warning tape shall be installed over all wire runs 12 inches below grade.

9.5.5.5 Installing Identification Tags

9.5.5.5.1 Characters: Tags shall be stamped with OMWD, size, material and service. For example a 24-inch CML&C steel water line shall be stamped "OMWD, 24"CML&C, W". An 8-inch ductile iron reclaimed water line would be tagged "OMWD, 8"DIP, RW". Anode lead wires are not tagged. Tags on wires on insulating flanges shall be stamped with "N, E, S or W" indicating which side of the insulating joint to which the wires are attached. The character size shall be 1/4-inch high.

9.5.5.5.2 Attachment to Wire: Identification tags shall be securely attached to each test wire in the test box with a bare No. 14 copper wire. Do not use plastic or nylon ties.

9.5.5.6 Wire Splices or Repairs

9.5.5.6.1 Approval: No wire splices or insulation repairs shall be made unless approved by the District Representative.

9.5.5.6.2 Splices: The minimum amount of insulation shall be removed from each wire end. Brass crimp or split-bolt connectors shall be used. The splice shall be encased in a plastic mold filled with insulating resin such as 3M Scotch cast splice kits.

9.5.5.6.3 Insulating Repairs: Depending on the severity of the insulation damage repairs shall be made with electrical tape or with a splice kit as determined by the District Representative.

9.5.5.6.4 Inspection: All splices and insulation repairs shall be inspected by the District Representative before they are buried.

9.5.6 CONTINUITY BONDING:

9.5.6.1 General: All joints on buried metallic pipe shall be metallically continuous by welding or bonding. Joints to be bonded include all unwelded pipe joints and mechanical joints including flanges (except insulating flanges), valves, couplings, adapters and special fittings. All bonding shall be done with single conductor, stranded copper jumper wires with HMWPE insulation. Bond wires shall be as short as possible with only minimal slack. All pipe reaches with one or more unwelded joints (or one or more bonds) will be tested for continuity.

9.5.6.2 Pipe Joints: At least two wires are required for each steel or ductile iron pipe bond. Two wires shall be installed unless otherwise specified. Three wires may be required at valves, couplings, special fittings and across unwelded joints on pipe larger than 24-inches. Bond wire sizes may be No. 2, 4 or 6. Use No. 4 bond wires unless indicated otherwise in the project drawings.

9.5.6.3 Mechanical Joints and Fittings: All flanges and in-line fittings (valves, couplings, etc.) shall be completely bridged by at least two bond wires. Three wires may be required on fittings larger than 24-inches. One additional No. 6 HMWPE wire is required from the pipe (on either side) to the fitting. Bond wire sizes may be No. 2, 4 or 6. Use No. 4 bond wires unless indicated otherwise in the project drawings.

9.5.6.4 Wire Attachment Method: Bond wire attachment, testing and subsequent coating of the welds shall be as specified in 9.5.5.6.

9.5.6.5 Wire Attachment Location: Bond wires can either be attached to the pipe or pipe cylinder directly off to the outside edges of flanges that are welded to the pipe. Bond wires shall not be attached to valve bodies, but instead to the flange of the valve.

9.5.7 INSULATING FLANGE KITS

9.5.7.1 Flange Kits: Insulating kits shall be installed as shown on drawings and as recommended by the manufacturer. Moisture, soil, or other foreign matter must be carefully prevented from contacting any portion of the mating surfaces prior to installing insulator gasket. If moisture, soil, or other foreign matter contacts any portion of these surfaces, the entire joint shall be disassembled, cleaned with a suitable solvent and dried prior to reassembly.

9.5.7.2 Spool Assembly: All direct buried insulating kits, greater than 20-inches in diameter, shall be pre-installed and tested on the pipe spool prior to installing the spool in the ditch. If possible, all smaller size direct buried insulating kits shall be similarly pre-installed and tested.

9.5.7.3 Handling of Gasket: Care shall be taken to prevent any excessive bending or flexing of the gasket. Creased or damaged gaskets shall be rejected and removed from the job site.

9.5.7.4 Alignment: Alignment pins shall be used to properly align the flange and gasket.

9.5.7.5 Bolt Tightening: The manufacturer's recommended bolt-tightening sequence shall be followed. Bolt insulating sleeves shall be centered within the insulation washers so that the insulating sleeve is not compressed and damaged.

9.5.7.6 Testing: All insulating flanges must be tested by a qualified Corrosion Technician or Engineer and accepted by the District Representative. All buried insulating flanges must be tested prior to wax tape wrap coating and backfilling. The assembled flange shall be tested as described below.

9.5.7.7 Wax Tape Coating: After testing and the District's acceptance, the insulating flange shall be fully wrapped with petrolatum wax tape, including individual wrapping of all bolts, nuts, and washers, and irregular surfaces, per Standard Specification Section 09952.

9.5.8 SUPPLEMENTARY INTERIOR LINING AT INSULATING FLANGES

9.5.8.1 General: Supplementary linings are required only where called out in the drawings or Project Design Documents. It is the contractor's responsibility to determine and verify which insulating flanges require supplementary internal lining.

9.5.8.2 Extent of lining: the interior of the pipeline shall be lined with a supplementary epoxy lining for a distance of two pipe diameters in each direction away from an insulating flange. At an insulated flange on a valve, the supplementary lining shall be applied (for a distance of two pipe diameters) only to the pipe directly adjacent to the insulating flange.

9.5.8.3 Surface Preparation: The surface preparation of the mortar lining shall consist of wire brushing (hand or power) or water blasting to remove the latence and all loose mortar to provide a clean abraded surface for adhesion of the lining. The surface shall be clean and free of dust and standing water but not necessarily dry.

9.5.8.4 Mixing: The two-part epoxy paint shall be thoroughly mixed per the manufacturer's recommendations but at a minimum of two minutes by hand or with a mechanical mixer before being applied by brush.

9.5.8.5 Pot Life: A typical pot life is 30 minutes. The lining material shall not be applied after its useful pot life.

9.5.8.6 Application: Application of undiluted lining material shall be by spray, roller or brush until a maximum coating thickness of 20 mils is achieved. Each ensuing coat shall be applied before the previous coat fully cures, usually within 3 to 6 hours. Typically, this material is applied at the rate of 140 square feet per gallon. This would ordinarily produce the required coating with a total of two coats. However, the 20-mil minimum thickness shall be satisfied regardless of the number of applications necessary to achieve it.

9.5.8.7 Inspection: Each pipe spool to which the supplementary lining is applied must be inspected and accepted by the District Representative prior to assembly.

9.5.9 CASING INSTALLATIONS

9.5.9.1 Casing Insulators: The number and orientation of runners on each casing insulator shall be as recommended by the manufacturer depending on pipe size. The spacing between insulators shall be determined by the civil or structural engineer.

9.5.9.2 End Seals: Heat shrinkable or mechanical link seals shall be installed in accordance with the manufacturer's recommendations. Remove all contaminants and debris from the annulus. Seals must be watertight.

9.5.9.3 Casing Test Stations: Test stations (4-wire) shall be installed on all casings. Use 2 each No. 10 HMWPE wires on the casing and 2 each No. 8 HMWPE wires on the carrier pipe unless otherwise directed. Use post-mounted or at-grade test stations as indicted in the project drawings or as directed by the District Representative.

9.6 TESTING REQUIREMENTS

9.6.1 TEST LEADS AND BOND WIRES

9.6.1.1 Responsibility: The Contractor shall be responsible for testing all test leads and bond wire welds.

9.6.1.2 Test Method: All completed wire connection welds shall be tested for strength by striking the weld with a sharp blow with a 2-pound hammer while pulling firmly on the wire. Welds failing this test shall be re-welded and re-tested. Wire welds shall be spot tested by the District Representative. After backfilling pipe, all test lead pairs shall be tested using a standard ohmmeter or resistance meter for broken welds. Bond wires shall be tested through continuity testing described below.

9.6.1.3 Acceptance: The resistance between each pair of test leads shall not exceed 150% of the total wire resistance as determined from calculations based on published wire resistance data and an estimate of test wire length.

9.6.2 ANODE INSTALLATION

9.6.2.1 Responsibility: The contractor must provide the proper rated potential anode, sufficient anode lead wire length and the proper anode hole depth. The District shall test each installed anode for wire connection integrity and for open-circuit potential.

9.6.2.2 Notification: The Contractor shall notify the District at least 5 days in advance of the start and completion of the anode installations, including anodes and test stations.

9.6.2.3 Cathodic Protection Performance Test Method: The performance of the cathodic protection system shall be tested by the District Representative. The testing shall include: measurement of all open-circuit anode potentials; pipe-to-soil potentials at each test station and other locations as necessary before the anodes are connected; initial anode currents after connecting anode leads to the pipe leads; and the pipe-to-soil potential at each previously tested site with all anodes connected. Pre and post cathodic protection potentials at midpoints between anode beds are required as necessary to verify that the pipeline is fully protected. Adequate protection shall be as defined in NACE RP0169.

9.6.2.4 Field Report: All system deficiencies shall be listed and described in one or more field test reports and presented to the Contractor for repairs.

9.6.2.5 Acceptance: The system will be accepted if all anodes, test stations, and supporting facilities are installed properly. Cathodic protection performance, with the exception of materials and installation deficiencies, is not the Contractor’s responsibility.

9.6.3 WIRE TRENCHING

9.6.3.1 Responsibility: The District Representative, at his or her discretion, shall inspect wire trenches and backfill material and methods.

9.6.3.2 Test Method: The depth, trench bottom padding and backfill material shall be visually inspected prior to backfilling.

9.6.3.3 Acceptance: Conformance with project specifications.

9.6.4 INSULATOR TESTING

9.6.4.1 Responsibility: Insulating flanges shall be inspected and tested by the District Corrosion Engineer or Corrosion Technician. Buried insulators must be tested and approved prior to application of wax tape and backfilling. Large diameter insulators shall be tested on the spool prior to installation in the ditch.

9.6.4.2 Test Method: The assembled flange shall be tested with an insulator testing device (i.e., Gas Electronics Model 601 Insulation Checker) specifically designed for this purpose. Additionally, the pipe-to-soil potential, using a high impedance voltmeter and suitable reference cell, shall be measured on each side of the insulator after installation in the trench but before backfilling. Potential testing can only be done on piping that has been installed in the ditch.

9.6.4.3 Acceptance: The installation shall be considered complete when the insulator testing device indicates that no shorts or partial shorts are present and when the potential tests indicate greater than 20-millivolt pipe-to-soil potential difference across the flange. (Note that this test may not be valid if the pipe on each side of the insulator is in contract through interconnection piping or through contacts to the electrical grounding system.) If shorts are detected the Contractor shall assist the District in finding partial shorts or shorted bolts. All disassembly and re-assembly necessary to gain the acceptance of the District shall be done at the Contractor's expense.

9.6.5 PIPELINE CONTINUITY

9.6.5.1 Responsibility: The District’s Corrosion Engineer shall test the continuity of all sections of buried pipe that contains non-welded pipe joints or mechanical joints or fittings. All such joints are required to be bonded per this specification.

9.6.5.2 Test Method: Resistance shall be measured by the linear resistance method. A direct current shall be impressed from one end of the test section to the other (test station to test station) using DC power supply (battery). A voltage drop is measured for several current levels. The resistance (R) is calculated using the equation $R = dV/I$, where dV is the voltage drop and I is the current. The resistance shall be calculated for three or four different current levels.

9.6.5.3 Acceptance: Acceptance is reasonable comparison of the measured resistance with the calculated or theoretical resistance. The measured resistance shall not exceed the theoretical resistance by more than 130%. The Contractor shall submit calculations of the theoretical resistance and the measured resistance for each section of pipe tested.

9.6.5.4 Deficiencies: If discontinuity or high resistance is found between sections of pipe tested, it is the Contractor's responsibility to locate, excavate, and repair all bonds that are found to be discontinuous. Continuity tests shall be repeated after repairs are made. Note: Discontinuities may be difficult and expensive to locate and may require several excavations to expose pipe joints and attach temporary test leads for progressive continuity testing. Accordingly, the Contractor shall exercise due care in installing continuity bond sand should schedule continuity testing as early as possible so that discontinuity location and repairs, if necessary, do not conflict with road paving operations.

9.6.6 TEST STATIONS

9.6.6.1 Responsibility: The District Representative will inspect all test station installations for compliance with this specification. The District Representative or Corrosion Engineer will test all wires for continuity and proper connection.

9.6.6.2 Test Method: Test stations will be visually inspected. Wire continuity will be tested by potential and resistance measurements.

9.6.6.3 Acceptance: Installation in accordance with this specification and good workmanship and verification that all wires are properly connected.

9.6.7 COATING AND SUPPLEMENTARY LINING

9.6.7.1 Responsibility: The District Representative shall inspect all completed wax tape wrapping and supplementary linings at insulators for compliance with these specifications prior to backfilling.

9.6.7.2 Test Method: Inspection shall be visual.

9.6.7.3 Wax Tape Acceptance: Wax tape applications shall be accepted if: the application conforms with this specification; there are no voids or gaps under the wax tape; stud-ends, nuts, couplings rods and all irregular surfaces are individually wrapped such that there is complete coverage with the petrolatum material; the outer wrap is complete and tightly adhering to the wax tape; and the application is done in a good workman-like manner.

9.6.7.4 Supplementary Lining Acceptance: Internal supplementary linings must cover the specified length of pipe and must be well bonded to the substrate and free of voids or damage.

9.6.8 DEFICIENCIES

Deficiencies: Any deficiencies or omissions in materials or workmanship found by these tests shall be rectified by the Contractor at his expense. Deficiencies shall include but are not limited to: broken or missing test leads; improper or unclean wire trench backfill;

inadequate pipeline continuity; shorted or partially shorted insulators; lack of 18-inch slack wire in at-grade test boxes; improperly mounted or located test boxes; improper wire identification; poorly applied wax tape or supplementary lining; and other deficiencies associated with the workmanship, installation and non-functioning equipment.

10 STANDARD DRAWINGS AND DETAILS FOR NEW CP INSTALLATION

10.1 WMWD STANDARD DRAWING W-0490 – CATHODIC PROTECTION TEST STATION FLANGE INSULATION GASKET KIT

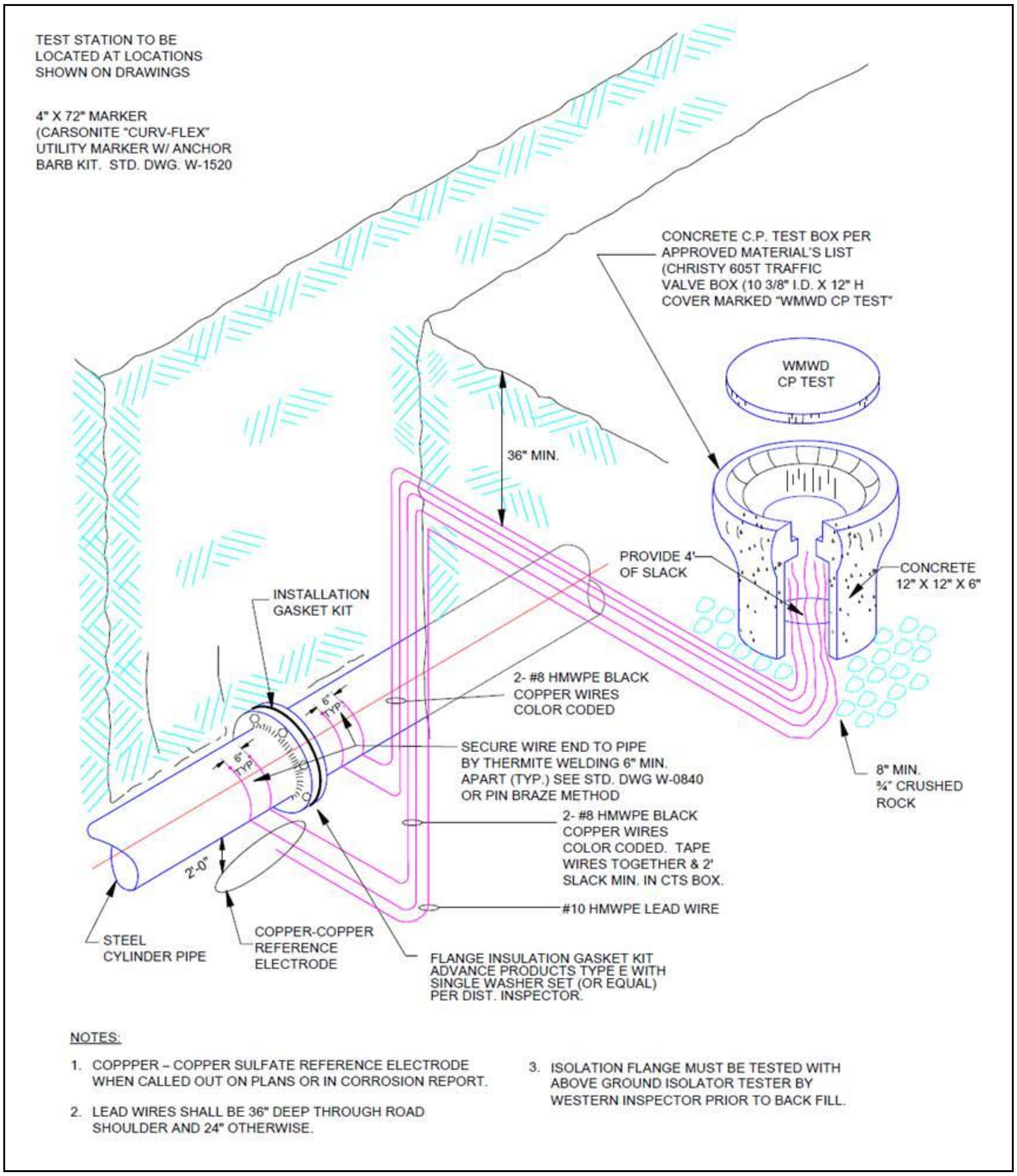
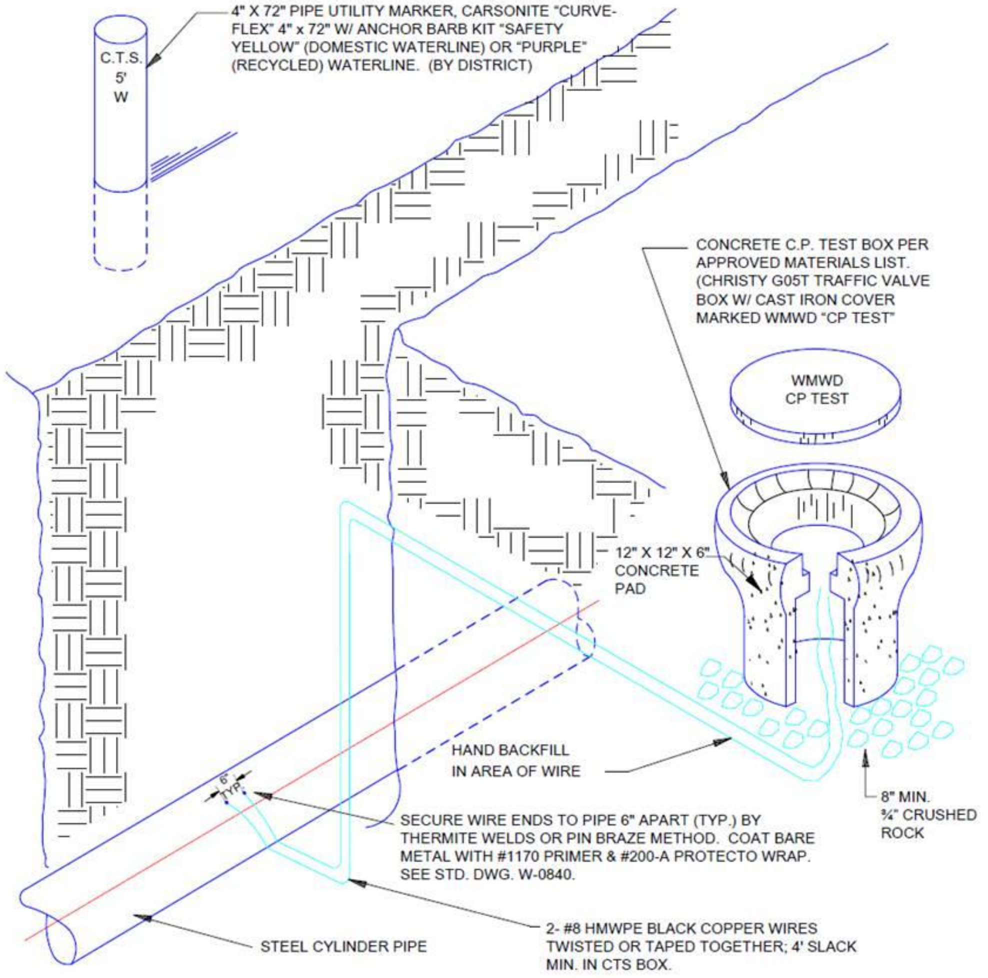


FIGURE 10-1: CATHODIC PROTECTION TEST STATION FLANGE INSULATION GASKET KIT

10.2 WMWD STANDARD DRAWING W-0500 – CATHODIC PROTECTION UNDERGROUND TEST STATION STEEL CYLINDER PIPE

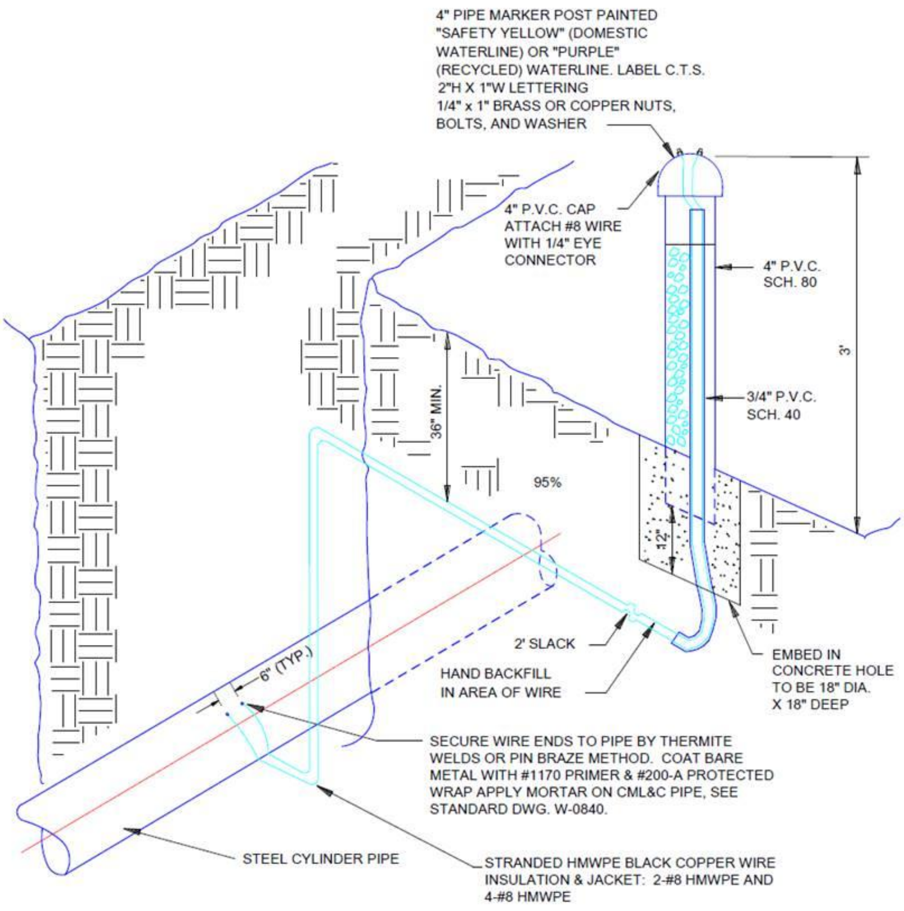


GENERAL NOTES:

1. TEST STATIONS TO BE INSTALLED AT LOCATIONS SHOWN ON JOB DRAWINGS.
2. BOX TO BE FIELD LOCATED PER WMWD INSPECTOR.

FIGURE 10-2: CATHODIC PROTECTION UNDERGROUND TEST STATION STEEL CYLINDER PIPE

10.3 WMWD STANDARD DRAWING W-0510 – CATHODIC PROTECTION ABOVE GROUND TEST STATION STEEL CYLINDER PIPE



GENERAL NOTES:

1. TEST STATIONS TO BE INSTALLED AT LOCATIONS SHOWN ON JOB DRAWINGS.
2. TO BE FIELD LOCATED PER WMWD INSPECTOR.

FIGURE 10-3: CATHODIC PROTECTION ABOVE GROUND TEST STATION STEEL CYLINDER PIPE

10.4 WMWD STANDARD DRAWING W-0540 – CASING INSTALLATION DETAIL

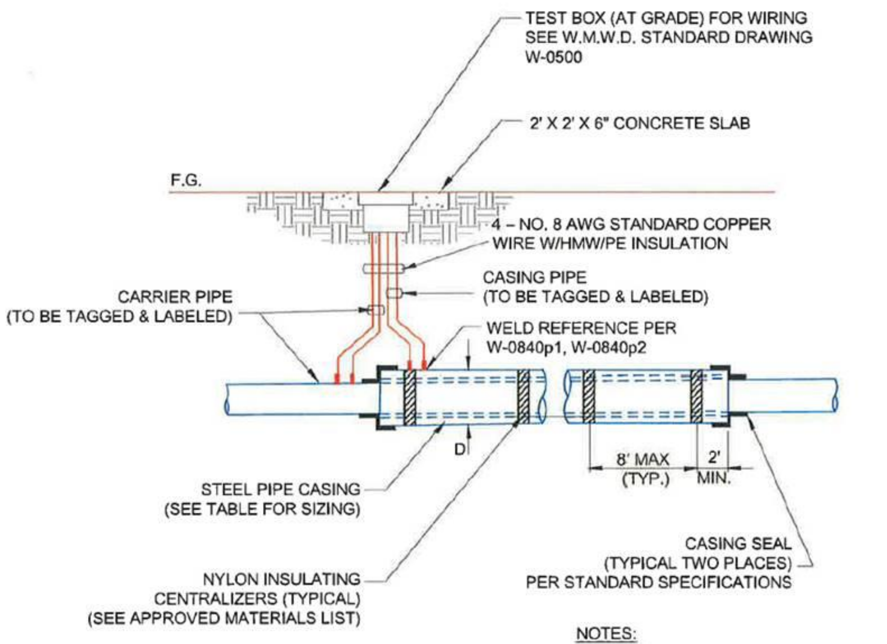


TABLE "A"

CASING DIAMETER "D" (INCHES)	STREETS & HWYS THICKNESS "T" MINIMUM UP TO 150' LENGTH	STREETS & HWYS THICKNESS "T" MINIMUM OVER 150' LENGTH	RAILROADS THICKNESS "T" (MINIMUM)
4" - 10" OD	1/4"	1/4"	4" - 12", 1/4"
12" - 16" OD	1/4"	1/4"	14" - 16", 9/32"
18" - 20" OD	1/4"	1/4"	18", 5/16" 20", 11/32"
22" OD	1/4"	1/4"	3/8"
24" OD	1/4"	1/4"	13/32"
26" OD	1/4"	1/4"	7/16"
28" OD	1/4"	1/4"	15/32"
30" OD	3/8"	1/2"	15/32"
32" OD	3/8"	1/2"	1/2"
34" - 36" OD	3/8"	1/2"	17/32"
38" OD	3/8"	1/2"	9/16"
40" OD	1/2"	3/4"	9/16"
42" OD	1/2"	3/4"	9/16"
48" - 60" OD	1/2"	3/4"	AS REQUIRED
62" - 72" OD	3/4"	3/4"	AS REQUIRED

NOTES:

1. THE ANNULAR SPACE BETWEEN THE CARRIER PIPE AND CASING SHALL NOT BE FILLED UNLESS OTHERWISE SPECIFIED ON THE PLANS
2. RESTRAIN OR WELD ALL JOINTS FOR CARRIER PIPE WITHIN CASING
3. MINIMUM CASING WALL THICKNESS 'T' SPECIFIED IN "TABLE A" IS REQUIRED FOR CASING IN PLACE, AND DOES NOT ACCOUNT FOR CONSTRUCTION LOADS. THE CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR THE STRUCTURAL SUFFICIENCY OF THE CASING DURING CONSTRUCTION, AND ALSO THE METHOD OF INSTALLATION
4. IF CARRIER PIPE IS NON-METALLIC DELETE CATHODIC TEST LEADS TO CARRIER PIPE

FIGURE 10-4: CASING INSTALLATION DETAIL

10.5 WMWD STANDARD DRAWING W-0800 – ANODE TEST STATION INSTALLATION DETAIL

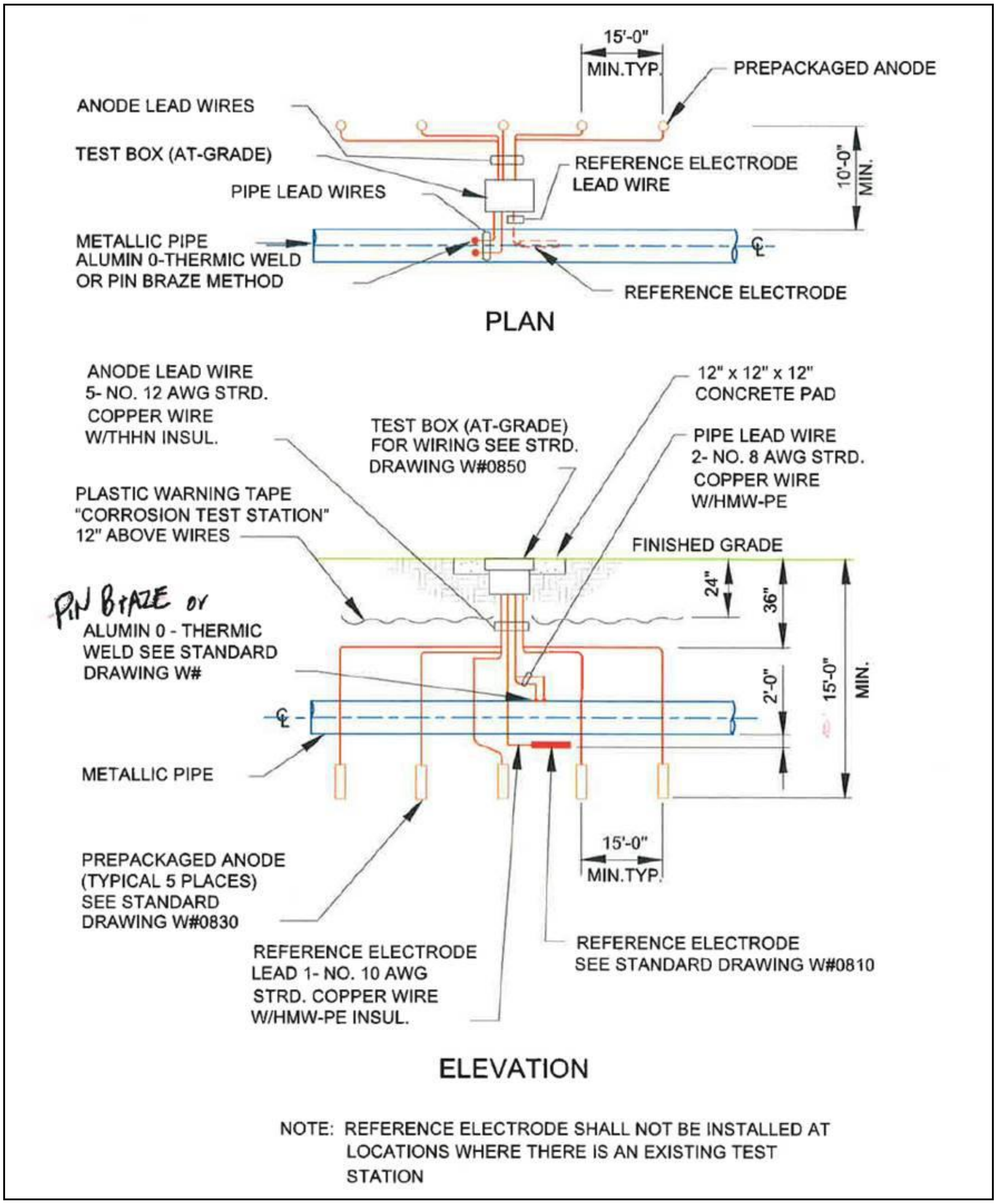


FIGURE 10-5: ANODE TEST STATION INSTALLATION DETAIL

10.6 WMWD STANDARD DRAWING W-0810 - COPPER COPPER SULFATE REFERENCE ELECTRODE

GENERAL NOTES:

1. PLACE REFERENCE ELECTRODE IN TRENCH. ADJACENT AND PERPENDICULAR TO PIPE. EVEN WITH OR BELOW PIPE SPRING LINE.
2. AFTER REFERENCE ELECTRODE IS PLACED IN TRENCH, OR HOLE, SOAK WITH A MINIMUM TEN GALLONS OF FRESH WATER. DO NOT PRESOAK BEFORE INSTALLATION.
3. IMMEDIATELY AFTER SOAKING REFERENCED ELECTRODE IN TRENCH OR HOLE, BACK FILL WITH NATIVE SOIL ONLY. NO SAND. TAP BACKFIELD TO INSURE GOOD COMPACTION.
4. CONNECT REFERENCED ELECTRODE LEAD WIRE AND PIPE TEST LEAD WIRE TO SEPARATE TERMINALS IN TEST BOX. (DO NOT CONNECT TOGETHER). SEE STD. DWG. W-0850.

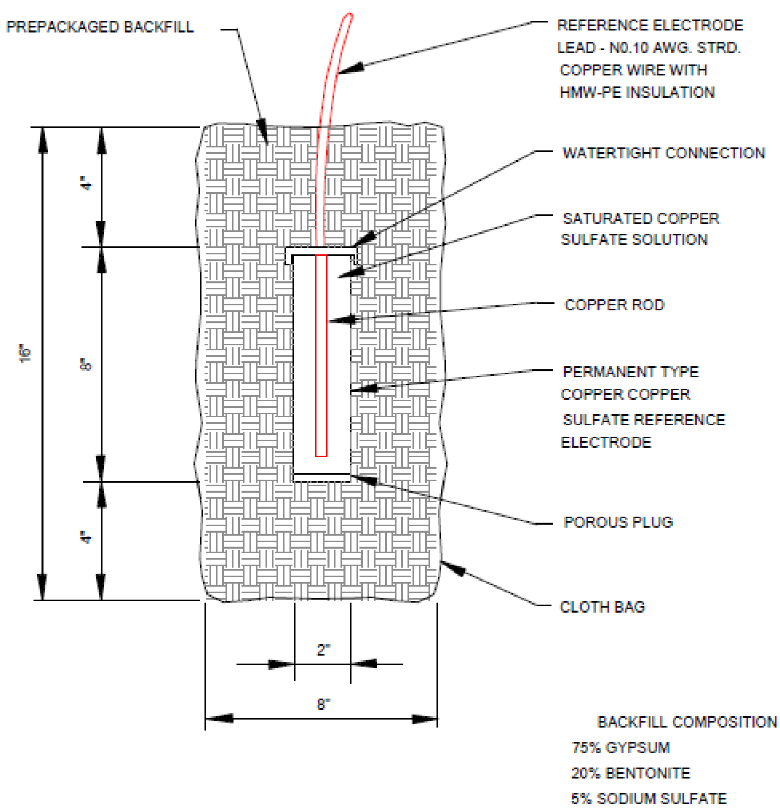
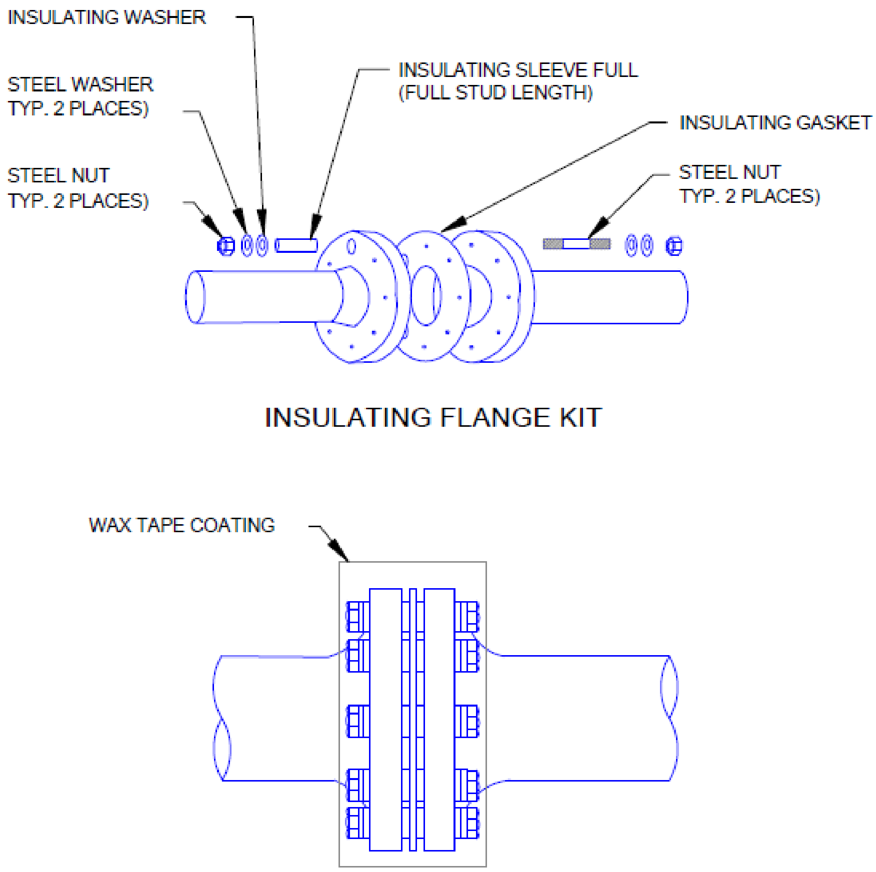


FIGURE 10-6: COPPER COPPER SULFATE REFERENCE ELECTRODE

10.7 WMWD STANDARD DRAWING W-0820 – INSULATING FLANGE DETAIL



NOTE:
1. HARDWARE QUANTITIES IN INSULATING FLANGE KIT WILL VARY BASED ON GASKET PATTERN AND PIPE SIZE.
2. ISOLATION FLANGE MUST BE TESTED WITH ABOVE GROUND ISOLATER TESTER BY WESTERN INSPECTOR PRIOR TO BACKFILL.

FIGURE 10-6: INSULATING FLANGE DETAIL

10.8 WMWD STANDARD DRAWING W-0830 – MAGNESIUM ANODE DETAIL

GENERAL NOTES:

1. PLACE PREPACKAGED ANODE IN 12" DIA HOLE 15 FOOT MIN. BELOW PIPE SPRING LINE.
2. AFTER PREPACKAGED ANODE IS PLACED IN HOLE, SOAK ANODE WITH A MIN. 25 GALLONS OF FRESH WATER. DO NOT PRESOAK BEFORE INSTALLATION.
3. IMMEDIATELY AFTER SOAKING ANODE IN HOLE, BACKFILL WITH THE NATIVE MATERIAL ONLY. NO SAND. TAP BACKFILL TO INSURE GOOD COMPACTION.
4. CONNECT ANODE LEAD WIRE AND PIPE TEST LEAD WIRE IN TEST BOX AS SHOWN IN STD. DWG. W-0850.
5. SEE STANDARD DRAWING W—0800 FOR INSTALLATION DETAILS.

HIGH POTENTIAL ALLOY SPECIFICATIONS CHEMICAL COMPOSITION	
ELEMENT	AMOUNT
Al	0.010% Max.
Mn	0.50 to 1.30%
Cu	0.02% Max.
Ni	0.001% Max.
Fe	0.03% Max.
Other	0.05% Max.
	0.3% Max. Total
Mg	Remainder

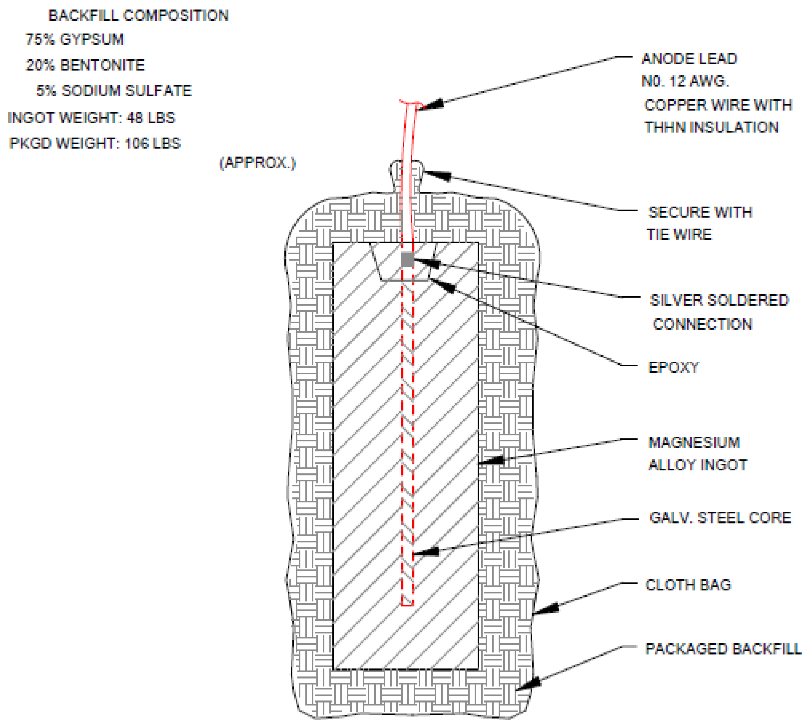


FIGURE 10-8: MAGNESIUM ANODE DETAIL

11 CTS General Information

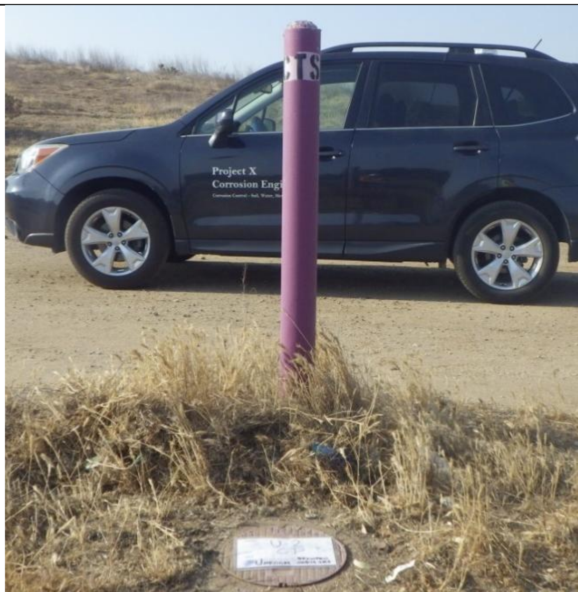
11.1 Bollards Pics

11.2 **CTS Box Pics**

11.3 CTS at Grade Pics

11.4 CTS at Grade with Bollard/Marker Pics



11.5 CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility ID	CTS Types	Longitude (Lat)	Latitude (Long)
Alberian	0989	40033755	Could Not Locate	-117.3818122	33.88590833
Basilone	Unk 1		CTS At Grade	-117.33199	33.92624
Basilone	Unk 2		CTS At Grade	-117.33489	33.92586
Basilone	Unk 3		CTS At Grade	-117.33456	33.92585
Basilone	Unk 4		CTS At Grade	-117.33454	33.92583
Bergamont	0344	40039750	CTS At Grade	-117.3256506	33.8864069
Bergamont	0345	40039751	CTS At Grade	-117.3279397	33.88597574
Bergamont	0346	46034756	CTS At Grade	-117.32957	33.88567
Berylwood	0930	32039751	CTS At Grade	-117.3301308	33.928874
Berylwood	0931	32039752	CTS At Grade	-117.3301261	33.92832231
Blackwood	0926	32039756	CTS At Grade	-117.3230609	33.92705553
Blackwood	0927	32039755	CTS At Grade	-117.3232255	33.92835552
Blackwood	0928	32039754	Could Not Locate	-117.3230698	33.92937743
Blackwood	0929	32039753	CTS At Grade	-117.3235076	33.93093581
Blackwood	0932	31039750	Could Not Locate	-117.3247475	33.93172936
Blackwood	0933	32039757	Could Not Locate	-117.3232281	33.92580956
Blackwood	0934	33039750	CTS At Grade	-117.3229738	33.92444194
Cannon	Unk 10		CTS At Grade	-117.33459	33.92406
Cannon	Unk 1		CTS At Grade	-117.32539	33.91966
Cannon	Unk 2		CTS At Grade	-117.32815	33.92085
Cannon	Unk 4		CTS At Grade	-117.32902	33.92155
Cannon	Unk 5		CTS At Grade	-117.32944	33.92187
Cannon	Unk 6		CTS At Grade	-117.3296	33.92196
Cannon	Unk 7		CTS At Grade	-117.3305	33.9226
Cannon	Unk 3		CTS At Grade	-117.3284	33.92106
Cannon	Unk 8		CTS At Grade	-117.3334	33.92382
Cannon	Unk 9		CTS At Grade	-117.33376	33.92394
Canyon Ridge Rd	0171	41030751	At Grade with Bollard	-117.4139321	33.88034908
Canyon Ridge Rd	0172	41030750	At Grade with Bollard	-117.4141642	33.88047076
Canyon Ridge Rd	0973	41030757	Could Not Locate	-117.4138892	33.87931795
Canyon Ridge Rd	0981	41030756	CTS At Grade	-117.4161423	33.88054853
Canyon Ridge Rd	0982	41030755	Could Not Locate	-117.4140277	33.87613243
Constable Rd.	0569	40032750	Could Not Locate	-117.3978891	33.88479539
Constable Rd.	0974	40032751	CTS At Grade	-117.397921	33.88414805
Dauchy Wood	0294	40035755	CTS At Grade	-117.3613524	33.8824555
Dauchy Wood	0350	40037750	CTS At Grade	-117.348455	33.88625609
Dauchy Wood	0352	40036750	At Grade with Bollard	-117.3524651	33.88382118
Dauchy Wood	0353	40036751	CTS At Grade	-117.3570898	33.88251032
Dauchy Wood	0484		At Grade with Bollard	-117.3381808	33.88729008
Dauchy Wood	0493	39038766	CTS At Grade	-117.3353471	33.88730332
Dauchy Wood	0495	39038763	CTS At Grade	-117.3393609	33.88728462
Dauchy Wood	0497	39038760	At Grade with Bollard	-117.3402256	33.88739466
Dauchy Wood	0498	39038767	CTS At Grade	-117.3334097	33.88731922

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
Dauchy Wood	0499	39038765	CTS At Grade	-117.3370874	33.88729512
Dauchy Wood	0502	39037750	At Grade with Bollard	-117.3440314	33.88726895
Dauchy Wood	0655	40038753	CTS At Grade	-117.3367948	33.88701659
Dauchy Wood	V&A 1		CTS At Grade	-117.3385783	33.8870385
Descanso	0975	54030750	CTS At Grade	-117.4109105	33.80437376
Descanso	0976	55030750	CTS At Grade	-117.4122071	33.8038747
Descanso	0977	54030754	Could Not Locate	-117.4086161	33.80898167
Descanso	0978	54030753	CTS At Grade	-117.4097594	33.8076616
Descanso	0979	54030752	CTS At Grade	-117.4092667	33.80640532
Descanso	0980	54030751	CTS At Grade	-117.4091932	33.80504425
Fort Kent	0945	34039759	CTS At Grade	-117.3265264	33.91885303
Four Winds	0170	41030752	Could Not Locate	-117.41268	33.87878
Fox Glen Rd	0185	47034750	CTS At Grade	-117.3713811	33.84815508
Fox Glen Rd	0233	47034753	CTS At Grade	-117.3712159	33.84724007
Fox Glen Rd	0234	47034756	CTS At Grade	-117.369827	33.84539249
Fox Glen Rd	0242	46035753	CTS At Grade	-117.3682721	33.84901483
Fox Glen Rd	0243	46035750	CTS At Grade	-117.3693746	33.84955299
Fox Glen Rd	0246		CTS At Grade	-117.3738454	33.84942721
Fox Glen Rd	0247	46034757	CTS At Grade	-117.3722432	33.84937995
Fox Glen Rd	0248	46034755	CTS At Grade	-117.3713187	33.849455
Fox Glen Rd	0249	46034754	CTS At Grade	-117.3700388	33.84955104
Fox Glen Rd	0574	47035750	CTS At Grade	-117.368273	33.84815309
Fox Glen Rd	0575	47035751	CTS At Grade	-117.3679052	33.84680157
Fox Glen Rd	0576	47035752	CTS At Grade	-117.3692436	33.84641807
Fox Glen Rd	0577	47035753	CTS At Grade	-117.3683126	33.8460569
Fox Glen Rd	0578	47035754	CTS At Grade	-117.3680514	33.8454351
Fox Glen Rd	0941	46034762	CTS At Grade	-117.3713698	33.84864197
Fox Glen Rd	Near 0248, 0249		CTS At Grade	-117.37131	33.84945
Gardner	0943	40035757	CTS At Grade	-117.3618563	33.88512845
Gardner	0944	40035756	CTS At Grade	-117.3617087	33.88643397
Gardner	0949	40035758	CTS At Grade	-117.3618671	33.88394327
Gold Valley	0950	54038750	CTS At Grade	-117.3352312	33.80923666
Gold Valley	0951	54038751	CTS At Grade	-117.3350429	33.80762531
Harley	0244	46035752	Could Not Locate	-117.3624203	33.84948323
Harley	0245	46035751	Could Not Locate	-117.36235	33.8496
Harley	0446	49034751	Could Not Locate	-117.3730449	33.83658454
Harley	0447	49034750	Could Not Locate	-117.3732513	33.83681759
Harley	0448	49034752	Could Not Locate	-117.3731466	33.83643254
Harley	0451	48034762	Bollard	-117.371137	33.84011019
Harley	0452	48034757	At Grade with Bollard	-117.3726171	33.83938251
Harley	0453	48034756	At Grade with Bollard	-117.37233	33.83941
Harley	0454		Could Not Locate	-117.3719516	33.83963431
Harley	0455	48034758	Could Not Locate	-117.3726868	33.83915771

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
Harley	0456	48034759	At Grade with Bollard	-117.3730565	33.83859574
Harley	0458	48034754	Bollard	-117.3712639	33.8401053
Harley	0461	48034761	Could Not Locate	-117.3729407	33.83766894
Harley	0463	48034753	Could Not Locate	-117.3708475	33.84038094
Harley	0947	49034753	At Grade with Bollard	-117.3731939	33.83719161
Harley	0954	47035755	At Grade with Bollard	-117.3645033	33.84371285
Harley	0447-1		At Grade with Bollard	-117.3732513	33.83681759
Idaleona Rd	0149	55038750	At Grade with Bollard	-117.338351	33.80013428
Idaleona Rd	0163	55038751	Could Not Locate	-117.3353253	33.80006123
Kaison Circle	0319	43040750	CTS At Grade	-117.3172661	33.86819694
Kaison Circle	0320	43040752	CTS At Grade	-117.3172621	33.86705028
Kaison Circle	V&A 3		CTS At Grade	-117.31722	33.86625
Krameria Ave	0056	41035753	CTS At Grade	-117.3613048	33.8799462
Krameria Ave	0057	41035752	CTS At Grade	-117.3624011	33.8799429
Krameria Ave	0058	41035751	CTS At Grade	-117.3640752	33.87993759
Krameria Ave	0059	41035750	CTS At Grade	-117.3670045	33.8799338
Krameria Ave	0060	41035754	CTS At Grade	-117.3699625	33.87979501
Krameria Ave	0068	41036751	CTS At Grade	-117.3580076	33.87995115
Krameria Ave	0069	41036750	CTS At Grade	-117.3596556	33.87994841
Krameria Ave	0274	41035755	Could Not Locate	-117.3691852	33.87979456
Krameria Ave	0585	41036753	CTS At Grade	-117.3547878	33.8799474
Krameria Ave	0586	41036752	CTS At Grade	-117.3567095	33.87995473
Krameria Ave	Unkown		CTS At Grade		
Krameria Ave	V&A 7		Could Not Locate	-117.36563	33.87987
Lake Pointe Dr-Sun Summit Dr	0555	41023750	CTS At Grade	-117.4832602	33.88018546
Lake Pointe Dr-Sun Summit Dr	0556	41023751	CTS At Grade	-117.48253	33.87944
Lake Pointe Dr-Sun Summit Dr	0556.1		CTS At Grade	-117.48348	33.88301
Lake Pointe Dr-Sun Summit Dr	0557	41023752	CTS At Grade	-117.48141	33.8778
Lake Pointe Dr-Sun Summit Dr	0558	41023755	CTS At Grade	-117.48142	33.87701
Lake Pointe Dr-Sun Summit Dr	0564	40023750	CTS At Grade	-117.48348	33.88301
Lake Pointe Dr-Sun Summit Dr	0565	40023751	CTS At Grade	-117.48198	33.88241
Lake Pointe Dr-Sun Summit Dr	0566	40023752	CTS At Grade	-117.48191	33.8811
Lake Pointe Dr-Sun Summit Dr	V&A 10		CTS At Grade	-117.48648	33.88081
Lake Pointe Dr-Sun Summit Dr	V&A 11		CTS At Grade	-117.48765	33.88088
Lake Pointe Dr-Sun Summit Dr	V&A 12		CTS At Grade	-117.48844	33.88216
Lake Pointe Dr-Sun Summit Dr	V&A 13		CTS At Grade	-117.48916	33.88343
Lake Pointe Dr-Sun Summit Dr	V&A 14		CTS At Grade	-117.49081	33.88397
Lake Pointe Dr-Sun Summit Dr	V&A 15		CTS At Grade	-117.49227	33.88441
Lake Pointe Dr-Sun Summit Dr	V&A 8		CTS At Grade	-117.48445	33.87995
Lake Pointe Dr-Sun Summit Dr	V&A 9		CTS At Grade	-117.48592	33.88082
Lake Pointe Dr-Sun Summit Dr	V&A2		CTS At Grade		
Lambeth Ct	0341	40039755	CTS At Grade	-117.3236922	33.88396091
Lambeth Ct	0342	40039756	CTS At Grade	-117.3245652	33.8839444

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
Limecrest	0961	40040753	CTS At Grade	-117.3194138	33.88636581
Limecrest	0962	40040752	CTS At Grade	-117.3194193	33.88589293
Limecrest	0964	39040754	CTS At Grade	-117.319447	33.88744997
Mandarin	0343	40039753	CTS At Grade	-117.3227882	33.88573534
Mission Grove	0408		CTS At Grade	-117.3226324	33.92595969
Mission Grove	0963	33039751	CTS At Grade	-117.3244566	33.92498997
Mission Grove	0965	33039752	CTS At Grade	-117.3247595	33.92335378
Mission Grove	Unk 1		CTS At Grade	-117.33233	33.92897
Mission Grove	Unk 2		CTS At Grade	-117.33383	33.92986
Mission Grove	Unk 4		CTS At Grade	-117.32989	33.92901
Mission Grove	Unk 6		CTS At Grade	-117.32664	33.92902
Mission Grove	Unk 7		CTS At Grade	-117.32464	33.92947
Mission Grove	Unk 3		CTS At Grade	-117.33072	33.92894
Mission Grove	Unk 5		CTS At Grade	-117.32784	33.929
Mission Grove Parkway	0112		Could Not Locate	-117.3250185	33.91607963
Mission Grove Parkway	0186	36039760	CTS At Grade	-117.3287017	33.9091597
Mission Grove Parkway	0204	34039757	CTS At Grade	-117.3248089	33.91578971
Mission Grove Parkway	0515	36039750	CTS At Grade	-117.3266579	33.90423638
Mission Grove Parkway	0516	36039752	CTS At Grade	-117.328183	33.908216
Mission Grove Parkway	0517	36039751	CTS At Grade	-117.3253165	33.90898996
Mission Grove Parkway	0518	36039757	CTS At Grade	-117.3276606	33.90630451
Mission Grove Parkway	0519	36039756	Could Not Locate	-117.3277276	33.90648852
Mission Grove Parkway	0520	36039758	CTS At Grade	-117.327651	33.90627822
Mission Grove Parkway	0521	36039759	Could Not Locate	-117.3273881	33.90555796
Mission Grove Parkway	0522	36039754	CTS At Grade	-117.3278836	33.90691707
Mission Grove Parkway	0523	36039753	CTS At Grade	-117.3255121	33.90721372
Mission Grove Parkway	0524	36039755	CTS At Grade	-117.3257845	33.90668367
Mission Grove Parkway	0526	35039755	CTS At Grade	-117.3245861	33.90942666
Mission Grove Parkway	0526.1		CTS At Grade	-117.3245861	33.90942666
Mission Grove Parkway	0527	35039756	CTS At Grade	-117.328763	33.90933296
Mission Grove Parkway	0528	35039754	CTS At Grade	-117.3289917	33.90996021
Mission Grove Parkway	0532	35039753	CTS At Grade	-117.3295007	33.91136005
Mission Grove Parkway	0632	36039762	CTS At Grade	-117.3274724	33.90579317
Mission Grove Parkway	0633	36039763	Could Not Locate	-117.3271229	33.90483588
Mission Grove Parkway	0529 & 0531	35039751	CTS At Grade	-117.3303065	33.91351105
Mission Grove Parkway	V&A 2		CTS At Grade	-117.3237973	33.9127099
Mountain Ct	0023	43025751	CTS At Grade	-117.46056	33.86525
Mountain Ct	0935	43025752	CTS At Grade	-117.46069	33.86481
Mountain Ct	V&A 1		CTS At Grade	-117.46048	33.86547
Mountain Ct	V&A 3		Could Not Locate	-117.46092	33.86478

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
New Ridge - Basilone	0379	33038750	CTS At Grade	-117.3330814	33.92551791
New Ridge - Basilone	0409	32038750	CTS At Grade	-117.3336611	33.92669836
New Ridge - Basilone	Unk #3		CTS At Grade		
New Ridge - Basilone	Unk 1		CTS At Grade	-117.33256	33.93034
New Ridge - Basilone	Unk 2		CTS At Grade	-117.33359	33.92955
New Ridge - Basilone	V&A 2		CTS At Grade	-117.33314	33.92587
New Ridge - Basilone	V&A 4		CTS At Grade	-117.3333	33.92549
New Ridge - Basilone	V&A 5	3.5	CTS At Grade	-117.3328	33.9249
Owari	0936	40039758	CTS At Grade	-117.3271378	33.8854612
Owari	0937	40039760	CTS At Grade	-117.3243753	33.88473081
Owari	0938	40039759	CTS At Grade	-117.3257632	33.88499599
Owari	0938.1		CTS At Grade	-117.3258	33.885
Owari	0939	40039761	CTS At Grade	-117.324726	33.88472408
Owl Tree Ct	0005	45035752	CTS At Grade	-117.365788	33.85520963
Owl Tree Ct	0006	45035753	CTS At Grade	-117.3646332	33.85508657
Owl Tree Ct	0007	45035754	CTS At Grade	-117.3631699	33.85504552
Owl Tree Ct	0008	45035750	CTS At Grade	-117.3599317	33.85554257
Owl Tree Ct	0009	45035751	CTS At Grade	-117.3613605	33.85526482
Owl Tree Ct	0307	45036754	CTS At Grade	-117.3578716	33.8560155
Owl Tree Ct	0308	45036753	CTS At Grade	-117.3567406	33.85627541
Owl Tree Ct	0309	45036752	CTS At Grade	-117.3555726	33.85654321
Owl Tree Ct	0310	45036751	CTS At Grade	-117.354248	33.85684707
Owl Tree Ct	0311	45036750	CTS At Grade	-117.3531638	33.85751028
Owl Tree Ct	Unk CTS		CTS At Grade		
Owl Tree Ct	V&A 9		CTS At Grade	-117.35534	33.85666
Piedras	0140	59037753	CTS At Grade	-117.3472407	33.78158086
Piedras	0141	59037754	CTS At Grade	-117.3468735	33.7806891
Piedras	0473	58037750	Could Not Locate	-117.3452731	33.78707387
Piedras	0474	58037751	CTS At Grade	-117.3453287	33.78592518
Piedras	0475	58037752	CTS At Grade	-117.3458114	33.78498968
Piedras	0476	58037754	CTS At Grade	-117.3468645	33.7839031
Piedras	0477	58037755	CTS At Grade	-117.3472756	33.7831538
Piedras	V&A 5		CTS At Grade	-117.3470092	33.783606
Prairie Way	0078	38038751	CTS At Grade	-117.3345695	33.89433322
Prairie Way	0079	38038752	CTS At Grade	-117.3345665	33.89388487
Prairie Way	0080	38038754	CTS At Grade	-117.3345621	33.89308093
Prairie Way	0485	39038756	CTS At Grade	-117.3345575	33.89001881
Prairie Way	0486	39038755	CTS At Grade	-117.3348649	33.89078817
Prairie Way	0487	39038752	CTS At Grade	-117.3345605	33.89182115
Prairie Way	0488	39038750	CTS At Grade	-117.3360325	33.89260652
Prairie Way	0489	39038754	CTS At Grade	-117.3368347	33.89144262
Prairie Way	0490	39038757	CTS At Grade	-117.3366717	33.88998431
Prairie Way	0491	39038758	CTS At Grade	-117.3366081	33.88894699

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
Prairie Way	0492	39038759	CTS At Grade	-117.3348688	33.88895528
Prairie Way	0494	39038751	Could Not Locate	-117.3341005	33.8919789
Prairie Way	V&A 10		CTS At Grade	-117.33677	33.89094
Prairie Way	V&A 3		CTS At Grade	-117.33449	33.89371
Roberts	0083	38037750	CTS At Grade	-117.349998	33.89749517
Roberts	0363	37037755	Could Not Locate	-117.3420269	33.90005114
Roberts	0364	37037750	CTS At Grade	-117.3493217	33.9000346
Roberts	0365	37037751	Could Not Locate	-117.3478891	33.90004432
Roberts	0366	40041751	Could Not Locate	-117.34654	33.90004
Roberts	0367	37037753	CTS At Grade	-117.3450016	33.90004776
Roberts	0368	37036751	CTS At Grade	-117.350529	33.90002467
Roberts	0369	37036750	CTS At Grade	-117.3520593	33.90001187
Roberts	0370	37036752	CTS At Grade	-117.3530449	33.89975584
Roberts	0371	37036753	Could Not Locate	-117.353	33.89845
Roberts	0514	37037754	Could Not Locate	-117.3435628	33.90004915
Roberts	0579	38036750	CTS At Grade	-117.3515249	33.8970031
Roberts	V&A 10		CTS At Grade	-117.35297	33.89755
Rocky Bluff Rd	0147	58034751	PVC Pipeline	-117.3713482	33.78588229
Rocky Bluff Rd	V&A 2		PVC Pipeline	-117.37191	33.78606
Santa Rosa	0142	59037755	Could Not Locate	-117.3468063	33.77984227
Santa Rosa	0143	58036751	CTS At Grade	-117.3491821	33.78472625
Santa Rosa	0144	58036754	CTS At Grade	-117.3518577	33.78291499
Santa Rosa	0145	58036752	CTS At Grade	-117.352513	33.78427808
Santa Rosa	0146	58036750	CTS At Grade	-117.351844	33.78540602
Santa Rosa	0464	59037756	CTS At Grade	-117.3474495	33.7795254
Santa Rosa	0465	59037752	CTS At Grade	-117.3487553	33.78210878
Santa Rosa	0469	59036752	CTS At Grade	-117.3503837	33.7797537
Santa Rosa	0470	59036753	CTS At Grade	-117.3522888	33.77945655
Santa Rosa	0471	59036751	CTS At Grade	-117.3528266	33.78073528
Santa Rosa	0472	59036750	CTS At Grade	-117.3525868	33.78175099
Santa Rosa	0478	58037753	CTS At Grade	-117.347567	33.78468853
Santa Rosa	0479	58036753	CTS At Grade	-117.3499019	33.78401222
Santa Rosa	0480	58036755	Could Not Locate	-117.3501806	33.78287377
Santa Rosa	V&A 2.5		Could Not Locate		
Scenic View	0550	52030752	CTS At Grade	-117.4125594	33.81906905
Scenic View	0551	52030750	CTS At Grade	-117.4138023	33.81906673
Scenic View	0552	52030751	Could Not Locate	-117.413212	33.81906783
Sky Ridge	0024		Could Not Locate	-117.4588025	33.86847393
Sky Ridge	CTS#1		CTS At Grade	-117.45807	33.86784
Spring View Lane	0020	44026751	CTS At Grade	-117.4550893	33.85875966
Stanhope	Unk 1		CTS At Grade	-117.32558	33.92061

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
Stone Ridge	0043	42033754	CTS At Grade	-117.3851719	33.87423226
Stone Ridge	0044	42033756	CTS At Grade	-117.3853092	33.87342565
Stone Ridge	0271	42033750	CTS At Grade	-117.3865914	33.87515915
Stone Ridge	0272	42033751	CTS At Grade	-117.3872126	33.87468196
Stone Ridge	0273	42033753	CTS At Grade	-117.3860098	33.87455345
Stone Ridge	0275	41033752	Could Not Locate	-117.3845089	33.87838156
Stone Ridge	0276	41033750	CTS At Grade	-117.3854381	33.87891084
Stone Ridge	0277	41033751	CTS At Grade	-117.3872698	33.87865427
Stone Ridge	0278	41033756	CTS At Grade	-117.3847531	33.87609556
Stone Ridge	0279	41033754	CTS At Grade	-117.385611	33.87742335
Stone Ridge	0280	41033753	CTS At Grade	-117.3870694	33.87742184
Stone Ridge	0281	41033755	CTS At Grade	-117.3885138	33.87647699
Stone Ridge	0282	41032757	CTS At Grade	-117.3901425	33.87594687
Stone Ridge	0283	41032751	CTS At Grade	-117.3902437	33.87734963
Stone Ridge	0284	41032758	Could Not Locate	-117.3908914	33.87588194
Stone Ridge	0285	41032752	CTS At Grade	-117.3910582	33.87708348
Stone Ridge	0286	41032754	Could Not Locate	-117.3910564	33.87677177
Stone Ridge	0287	41032755	CTS At Grade	-117.3921118	33.87651646
Stone Ridge	Unk		CTS At Grade		
Stone Ridge	Unkown		CTS At Grade		
Stone Ridge	V&A 3		CTS At Grade	-117.38422	33.8781
U2	0301	45039750	At Grade with Bollard	-117.3224915	33.85943849
U2	0302	45038750	Could Not Locate	-117.331427	33.85834732
U2	0303	45037751	At Grade with Bollard	-117.3401243	33.85812525
U2	0304	45037750	Bollard	-117.3452606	33.85808462
U2	0305	45037753	Bollard	-117.34932	33.85691
U2	0306	45037752	Bollard	-117.34932	33.85697
U2	0312	44040750	Could Not Locate	-117.3201885	33.8652334
U2	0313	44039750	Could Not Locate	-117.3210547	33.8645743
U2	0314	44039752	CTS At Grade	-117.32273	33.86321858
U2	0315	44039754	Bollard	-117.322535	33.86077811
U2	0316	44039751	At Grade with Bollard	-117.3226802	33.86330329
U2	0317	44039753	At Grade with Bollard	-117.32253	33.86242
U2	0321	43040758	Could Not Locate	-117.3171349	33.86555797
U2	0322	43040756	Could Not Locate	-117.3160318	33.8657503
U2	0323	43040753	Could Not Locate	-117.3152543	33.86580353
U2	0324	43040754	Could Not Locate	-117.31731	33.86577
U2	0325	43040757	CTS At Grade	-117.3162519	33.86574689
U2	0326	43040755	CTS At Grade	-117.3139769	33.8657888
U2	0580	46037750	CTS At Grade	-117.3493827	33.85212867
U2	0582	45039753	Could Not Locate	-117.3290807	33.85807118
U2	0583	45039752	CTS At Grade	-117.3266381	33.8581042

CP - CTS Types and Lat/Long

Pipeline Name	UNITID WCPD00	Facility Id	CTS Types	Longitude	Latitude
U2	0584	45039751	Bollard	-117.3225645	33.85841818
U2	0748	47036R751	CTS At Grade	-117.355239	33.84720233
U2	0749	47036R750	Could Not Locate	-117.3580534	33.84721386
U2	0750	45038R751	Could Not Locate	-117.3335447	33.85803098
U2	0751	45038R750	box	-117.3335447	33.85803098
U2	0752	45037R750	Could Not Locate	-117.3455149	33.85798373
U2	0753	45037R751	CTS At Grade	-117.3455852	33.85798309
U2	0764	43040R751	CTS At Grade	-117.3169	33.86576
U2	0765	43040R753	At Grade with Bollard	-117.318248	33.86573282
U2	0766	44039R750	Could Not Locate	-117.3226963	33.86304064
U2	0767	45037R753	Could Not Locate	-117.3479622	33.85730982
U2	0768	43040R750	CTS At Grade	-117.3145759	33.86579909
U2	0917	51034750	At Grade with Bollard	-117.3710241	33.82213776
U2	0303.1		At Grade with Bollard	-117.3401243	33.85812525
U2	Unk		At Grade with Bollard		
Van Buren II	0159	40034750	Could Not Locate	-117.3706089	33.88256357
Van Buren II	0160	40034751	At Grade with Bollard	-117.3739851	33.88247413
Van Buren II	0161	40033753	CTS At Grade	-117.3836584	33.88210592
Van Buren II	0162	40033752	CTS At Grade	-117.3852047	33.8820925
Van Buren II	0164	40033754	CTS At Grade	-117.3869505	33.88204161
Van Buren II	0165	40033750	Could Not Locate	-117.3803671	33.88219678
Van Buren II	0187	40033751	Could Not Locate	-117.3820557	33.88214916
Van Buren II	0295	40035754	Could Not Locate	-117.3682754	33.88250092
Van Buren II	0296	40034756	CTS At Grade	-117.3721275	33.88222896
Van Buren II	0297	40034755	CTS At Grade	-117.3737747	33.88222883
Van Buren II	0298	40034754	CTS At Grade	-117.3754247	33.88222797
Van Buren II	0299	40034753	CTS At Grade	-117.376969	33.8822275
Van Buren II	0300	40034752	Could Not Locate	-117.3787169	33.88222365
Woodcrest	0290	40035750	CTS At Grade	-117.3657871	33.88342866
Woodcrest	0291	40035752	Could Not Locate	-117.3653443	33.88311861
Woodcrest	0292		Could Not Locate	-117.3638689	33.88268487
Woodcrest	0293	40035751	Could Not Locate	-117.3640798	33.88313662
Woodcrest	Unk		Could Not Locate		

11.6 Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Alessandro	0098	34042759	Could Not Locate	-117.2923004	33.91641769
Alessandro	0101	34042756	CTS At Grade	-117.2950409	33.91650969
Alessandro	0102	34042757	Could Not Locate	-117.2978521	33.91647151
Alessandro	0103	34042758	CTS At Grade	-117.3010816	33.91641717
Alessandro	0104	34041750	CTS At Grade	-117.3032139	33.91658925
Alessandro	0105	34041751	Could Not Locate	-117.3053941	33.91640602
Alessandro	0106	34041752	Could Not Locate	-117.3084852	33.91637828
Alessandro	0107	34040754	Could Not Locate	-117.3138395	33.91627284
Alessandro	0108	34040753	CTS At Grade	-117.3195258	33.91627383
Alessandro	0109	34040752	CTS At Grade	-117.3168893	33.91630242
Alessandro	0110		Could Not Locate	-117.3141373	33.91633224
Alessandro	0111	34040751	CTS At Grade	-117.3114499	33.91635258
Alessandro	0113	34039756	Could Not Locate	-117.3221396	33.9162777
Alessandro	0222	34042760	CTS At Grade	-117.2922134	33.91518349
Alessandro	0392	34039753	CTS At Grade	-117.3216775	33.91665853
Alta Cresta	0595	40037754	CTS At Grade	-117.3486664	33.88633409
Alta Cresta	0596	40037753	CTS At Grade	-117.348775	33.88463644
Alta Cresta	0597	40037752	CTS At Grade	-117.3481553	33.88193492
Alta Cresta	0598	40037751	CTS At Grade	-117.348487	33.88327799
Alta Cresta	0599	41037755	Could Not Locate	-117.3481251	33.88056956
Alta Cresta	0600	41037754	CTS At Grade	-117.3482646	33.87923717
Alta Cresta	0601	41037753	CTS At Grade	-117.3488443	33.87655133
Alta Cresta	0602	41037752	CTS At Grade	-117.3488349	33.87792965
Arlington	0116	36022750	Could Not Locate	-117.4978577	33.90300875
Arlington	0117	37020750	Could Not Locate	-117.5090818	33.89770158
Arlington	0118	37019750	CTS At Grade	-117.5277831	33.89706355
Arlington	0119	37018751	Could Not Locate	-117.5382034	33.8981521
Arlington	0120	37018750	CTS At Grade	-117.5348058	33.89847246
Arlington	0121	37018752	CTS At Grade	-117.5298803	33.89810034
Arlington	0122	37017756	CTS At Grade	-117.5395318	33.89768769
Arlington	0123	37017757	Could Not Locate	-117.5418377	33.89732561
Arlington	0124	37017755	CTS At Grade	-117.5431503	33.89794218
Arlington	0125	37017753	CTS At Grade	-117.54298	33.89877737
Arlington	0126	37017754	Could Not Locate	-117.5433962	33.89845669
Arlington	0127	37017752	Could Not Locate	-117.5434984	33.89938954
Arlington	0128	37017750	CTS At Grade	-117.545473	33.90144632
Arlington	0129	37017751	CTS At Grade	-117.545107	33.89989479
Arlington	0130	36017750	CTS At Grade	-117.5439758	33.90668986
Arlington	0131	36017751	Could Not Locate	-117.5441392	33.9047178
Arlington	0413	38023752	CTS At Grade	-117.4862526	33.89506631
Arlington	0414	38023753	CTS At Grade	-117.4878351	33.89467317
Arlington	0415	38022751	CTS At Grade	-117.489879	33.89576852
Arlington	0416	38022752	CTS At Grade	-117.4890375	33.89472221

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Arlington	0417	38022750	CTS At Grade	-117.4916514	33.89594133
Arlington	0418	38020750	CTS At Grade	-117.512464	33.89631939
Arlington	0419	38020751	CTS At Grade	-117.5171218	33.89395489
Arlington	0420	38019750	CTS At Grade	-117.5247353	33.89495109
Arlington	0421	38019752	CTS At Grade	-117.5206394	33.89177147
Arlington	0422	38019751	CTS At Grade	-117.5228578	33.89275753
Arlington	0424	37022751	CTS At Grade	-117.4948482	33.89963214
Arlington	0425	37022750	CTS At Grade	-117.4964595	33.90138896
Arlington	0426	37021752	CTS At Grade	-117.5067731	33.89984956
Arlington	0427	37021751	CTS At Grade	-117.503881	33.90110014
Arlington	0428	37021750	Could Not Locate	-117.5003972	33.90124153
Arlington	0429	36017752	CTS At Grade	-117.5449021	33.90365499
Arlington	0430	36017753	CTS At Grade	-117.5457058	33.90318518
Arlington	0431	35017750	Could Not Locate	-117.544232	33.91257808
Arlington	0432	35017752	CTS At Grade	-117.5435049	33.90891652
Arlington	0433	35017751	Could Not Locate	-117.5440604	33.91062079
Arlington	0434	34017753	CTS At Grade	-117.5442883	33.91463638
Arlington	0435	34017752	CTS At Grade	-117.543826	33.91669842
Arlington	0436	34017751	CTS At Grade	-117.5462982	33.91671044
Arlington	0437	34017750	Could Not Locate	-117.5476747	33.91722851
Arlington	0438	33017752	CTS At Grade	-117.5460128	33.9187804
Arlington	0439	33017751	Could Not Locate	-117.5442891	33.92061598
Arlington	0440	33017750	CTS At Grade	-117.5439969	33.92237671
Arlington	0441	32017752	CTS At Grade	-117.5434026	33.92409559
Arlington	0442	32017751	CTS At Grade	-117.5453391	33.92436737
Arlington	0443	32017750	CTS At Grade	-117.5477948	33.92436178
Arlington	0444	32016750	Could Not Locate	-117.5541063	33.9289891
Arlington	0537	32016751	CTS At Grade	-117.5540978	33.92642358
Arlington	0538	32016752	Could Not Locate	-117.5540931	33.92477773
Arlington	0539	32016753	CTS At Grade	-117.5539106	33.92434793
Arlington	0540	32016754	CTS At Grade	-117.5502445	33.92435626
Arlington	0541	31016750	CTS At Grade	-117.5540875	33.93342212
Arlington	0542	31016751	Could Not Locate	-117.5540804	33.93128431
Arlington	0543	30016751	Could Not Locate	-117.5540802	33.93511242
Arlington	0544	30016750	Could Not Locate	-117.5541349	33.93781899
Arlington	0545	29016752	Could Not Locate	-117.5543448	33.9415215
Arlington	0546	29016753	CTS At Grade	-117.5541422	33.9403333
Arlington	0547	29016751	Could Not Locate	-117.5565921	33.94221136
Arlington	0548	29016750	Could Not Locate	-117.5566464	33.94421137
Arlington	0567		Could Not Locate	-117.48328	33.89621497
Arlington	0568	38023751	CTS At Grade	-117.4848508	33.89580152
Arlington	0118-1		CTS At Grade	-117.5277831	33.89706355

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Barton	0063	41040750	CTS At Grade	-117.3137526	33.8794569
Barton	0064	41040751	At Grade with Bollard	-117.3137553	33.87654405
Barton	0326	43040755	CTS At Grade	-117.3139769	33.8657888
Barton	0327	43040751	Could Not Locate	-117.3137434	33.86800282
Barton	0329	42040751	At Grade with Bollard	-117.3137535	33.87121289
Barton	0330		Could Not Locate	-117.3137569	33.87396129
Barton	0339	40040751	CTS At Grade	-117.3137512	33.88227457
Barton	0340	40040750	CTS At Grade	-117.3137514	33.88476477
Barton	0354	39040752	Could Not Locate	-117.3136942	33.88796933
Barton	0356	39040751	At Grade with Bollard	-117.3141528	33.8880418
Barton	V&A #4		Could Not Locate	-117.3137514	33.87258
Bountiful St	0359	39039753	Could Not Locate	-117.3279281	33.8897341
Bountiful St	0360	39039752	Could Not Locate	-117.3271892	33.89070874
Bountiful St	0482	39039751	Could Not Locate	-117.3258272	33.8913488
Bountiful St	0483	39039755	Could Not Locate	-117.3279971	33.88840778
Carpinus St	0135	49039750	Could Not Locate	-117.3206796	33.83696897
Carpinus St	0208	48039751	CTS At Grade	-117.3253898	33.84045844
Carpinus St	0209	48039750	CTS At Grade	-117.3236449	33.84061496
Carpinus St	0210	48039752	CTS At Grade	-117.3220781	33.84051309
Carpinus St	0211	48039753	CTS At Grade	-117.3209587	33.8395865
Carpinus St	0212	48039754	CTS At Grade	-117.3207343	33.83823678
Carpinus St	0845	48039R752	Could Not Locate	-117.3216201	33.84050909
Carpinus St	0846	48039R753	CTS At Grade	-117.3205915	33.83914428
Carpinus St	0847	49039R750	Could Not Locate	-117.3205299	33.83774092
Carpinus St	V&A1		CTS At Grade	-117.3269	33.84073
Cole - Lurin - Nandina	0621	43039750	At Grade with Bollard	-117.3226788	33.86658827
Cole - Lurin - Nandina	0622	43039751	At Grade with Bollard	-117.3204538	33.86554528
Cole - Lurin - Nandina	0623	43039752	Could Not Locate	-117.3221006	33.86552033
Cole - Lurin - Nandina	0624	43039753	At Grade with Bollard	-117.322726	33.86796225
Cole - Lurin - Nandina	0625	43039754	At Grade with Bollard	-117.3226943	33.86933544
Cole - Lurin - Nandina	0626	43039755	At Grade with Bollard	-117.3227197	33.87071733
Cole - Lurin - Nandina	0627	42039750	At Grade with Bollard	-117.3226791	33.87212796
Cole - Lurin - Nandina	0628	42039751	At Grade with Bollard	-117.3227403	33.87349111
Cole - Lurin - Nandina	0629	42039752	At Grade with Bollard	-117.3227405	33.87487032
Cole - Lurin - Nandina	0630	42039753	At Grade with Bollard	-117.3227407	33.8762018
Cole Ave	0842	47039R750	CTS At Grade	-117.3224116	33.84374073
Cole Ave	0843	48039R750	CTS At Grade	-117.3224003	33.84252377
Cole Ave	0844	48039R751	CTS At Grade	-117.3226315	33.84120102
Cole Ave	0842-1		CTS At Grade	-117.3224116	33.84374073
Cole Ave-North Krameria	MP 0051		Could Not Locate	-117.32284	33.88397
Cole Ave-North Krameria	MP 0052		Could Not Locate	-117.32298	33.88462
Cole Ave-North Krameria	MP 0054		Could Not Locate	-117.32334	33.88574

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Cottonwood	0373		Could Not Locate	-117.2955946	33.92388882
Cottonwood	0399		CTS At Grade	-117.2893874	33.92477562
Cottonwood	0400		CTS At Grade	-117.2875933	33.9241704
Cottonwood	0401		Could Not Locate	-117.2881993	33.92460483
Cottonwood	0402		CTS At Grade	-117.2893914	33.92459727
Cottonwood	0404		CTS At Grade	-117.2924564	33.92404276
Dan Kipper	0861	30042751	CTS At Grade	-117.2992921	33.9420537
Dan Kipper	0862	30042752	CTS At Grade	-117.3002092	33.94131691
Dan Kipper	0863	30042750	Could Not Locate	-117.2990656	33.94213246
Dan Kipper	0864	30041752	CTS At Grade	-117.3050602	33.94127018
Dan Kipper	0865	30041751	CTS At Grade	-117.3035059	33.94128518
Dan Kipper	0866	30041750	CTS At Grade	-117.3018575	33.94130106
Eagle Valley	0012	47025751	CTS Box	-117.4636509	33.84514683
Eagle Valley	0013	46026750	CTS Box	-117.4565171	33.85208165
Eagle Valley	0019	45026752	CTS Box	-117.4536157	33.85833448
Eagle Valley	0011-FH		Could Not Locate	-117.4624939	33.84669453
East Ridge	0385		Could Not Locate	-117.3009371	33.93113163
El Sobrante	0014	45027750	Bollard	-117.447801	33.85843216
El Sobrante	0015	45027752	Bollard	-117.4400989	33.85831452
El Sobrante	0016	45027751	Bollard	-117.4438491	33.85836951
El Sobrante	0018	45026751	Bollard	-117.451137	33.85848038
Gamble	0942	40036752	Could Not Locate	-117.3530149	33.88155426
Gravity	0017		Could Not Locate	-117.4542385	33.8584955
Gravity	0021	44026750	CTS Box	-117.4507677	33.85948961
Gravity	0022	43027750	Could Not Locate	-117.4401734	33.86966831
Gravity	0025	42029750	CTS Box	-117.42576	33.87331
Gravity	0026	42028750	CTS At Grade	-117.4376219	33.87108037
Gravity	0084	35036751	Could Not Locate	-117.3553142	33.91220176
Gravity	0085	35036750	Bollard	-117.35196	33.91244
Gravity	0115	34039755	CTS At Grade	-117.3298506	33.91634969
Gravity	0132	48023750	CTS Box	-117.4807434	33.83983356
Gravity	0133	48022750	CTS Box	-117.4887711	33.8379907
Gravity	0134	47024750	CTS Box	-117.4730475	33.84255319
Gravity	0150	40031756	At Grade with Bollard	-117.4042876	33.88297873
Gravity	0151	40031755	At Grade with Bollard	-117.4044297	33.88303996
Gravity	0152	40030752	CTS At Grade	-117.4126217	33.88162291
Gravity	0153	40030753	At Grade with Bollard	-117.4130945	33.88144035
Gravity	0154	40030751	At Grade with Bollard	-117.4117183	33.88232641
Gravity	0155	40030750	At Grade with Bollard	-117.4107085	33.8823706
Gravity	0171	41030751	At Grade with Bollard	-117.4139321	33.88034908
Gravity	0174	40031758	Could Not Locate	-117.4076061	33.88266295
Gravity	0180	40031754	No Access	-117.4046493	33.88336506
Gravity	0181	40031759	At Grade with Bollard	-117.4090084	33.88259987

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Gravity	0182	40031757	Could Not Locate	-117.4061249	33.88269965
Gravity	0189	42028751	CTS At Grade	-117.4385961	33.87115331
Gravity	0206	36036751	Bollard	-117.3599273	33.90670177
Gravity	0207	37035750	Bollard	-117.3642801	33.90117759
Gravity	0372	37035751	Bollard	-117.368595	33.89843434
Gravity	0390	34039754	Could Not Locate	-117.3307238	33.9164504
Gravity	0393	34038750	Bollard	-117.3403934	33.91635591
Gravity	0394	34038752	Bollard	-117.3385339	33.91636111
Gravity	0395	34038751	Bollard	-117.3368929	33.9163813
Gravity	0396	34038753	Could Not Locate	-117.3312656	33.9160136
Gravity	0397	34037751	Could Not Locate	-117.3456167	33.91462622
Gravity	0398	34037750	Could Not Locate	-117.3444148	33.91512537
Gravity	0445	50020750	box	-117.5125306	33.82994931
Gravity	0449	49022750	box	-117.4969266	33.83470385
Gravity	0450	49021750	box	-117.5049874	33.83113115
Gravity	0525	36036750	Bollard	-117.3586796	33.90842297
Gravity	0533	35037750	Bollard	-117.3476276	33.91383327
Gravity	0534	35037751	Bollard	-117.3504906	33.91272441
Gravity	0535	35036753	Bollard	-117.3571431	33.91047512
Gravity	0536	35036752	Could Not Locate	-117.3563546	33.91136656
Gravity	0570	39034750	Bollard	-117.375421	33.89198024
Gravity	0571	39033750	box	-117.3815414	33.88825689
Gravity	0572	39032750	box	-117.3899612	33.88720974
Gravity	0573	38034750	box	-117.3701959	33.89752813
Gravity	0774	42028R753	Could Not Locate	-117.4372923	33.87093554
Gravity	unknown-A		Bollard	-117.445045	33.863995
Gravity	V&A 32		box	-117.41899	33.87748
Hawkhill	0205	46039751	CTS At Grade	-117.3275116	33.85099313
Hawkhill	0213	46039750	CTS At Grade	-117.3286563	33.84949545
Hawkhill	0214	47039750	CTS At Grade	-117.3277144	33.84813166
Hawkhill	0215	47039751	CTS At Grade	-117.3269279	33.8461326
Hawkhill	0589	46039752	CTS At Grade	-117.3247176	33.8510702
Jansen	0631	53034750	At Grade with Bollard	-117.3710896	33.81513862
Jansen	0910	53034752	At Grade with Bollard	-117.3711344	33.81333384
Jansen	0911	54034752	At Grade with Bollard	-117.3712208	33.80657441
Jansen	0912	52034752	CTS At Grade	-117.3711359	33.81787693
Jansen	0913	53034754	At Grade with Bollard	-117.3711697	33.81108091
Jansen	0914	53034753	At Grade with Bollard	-117.3711519	33.81195992
Jansen	0915	54034751	At Grade with Bollard	-117.3712113	33.80805741
Jansen	0916	54034750	At Grade with Bollard	-117.3711904	33.80945969
Jansen	0917	51034750	At Grade with Bollard	-117.3710241	33.82213776
Jansen	0918	52034751	At Grade with Bollard	-117.3711964	33.81937208
Jansen	0919	55034752	At Grade with Bollard	-117.3712444	33.80245248

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Jansen	0920	55034751	At Grade with Bollard	-117.3712364	33.80389515
Jansen	0921	54034753	At Grade with Bollard	-117.3712288	33.80520043
Jansen	0922	55034754	At Grade with Bollard	-117.3712519	33.8010785
Jansen	0923	55034753	At Grade with Bollard	-117.3712574	33.80005823
Jansen	0924	53034751	At Grade with Bollard	-117.3710902	33.81433756
Jansen	0925	52034750	At Grade with Bollard	-117.3711667	33.81660335
Jansen	Unk		At Grade with Bollard	-117.3712717	33.82071833
Krameria-Taft	0856	41039750	CTS At Grade	-117.322582	33.88164176
Krameria-Taft	0857	41039751	CTS At Grade	-117.3225669	33.88037305
Krameria-Taft	0860	40039757	CTS At Grade	-117.3226402	33.88313437
Krameria-Taft	0952	41038752	CTS At Grade	-117.3399213	33.87987683
Krameria-Taft	0953	41038753	CTS At Grade	-117.3384952	33.87988946
Krameria-Taft	0957	41038757	CTS At Grade	-117.3316266	33.88007621
Krameria-Taft	0958	41038756	CTS At Grade	-117.3333274	33.88006987
Krameria-Taft	0959	41038755	CTS At Grade	-117.3349753	33.87991222
Krameria-Taft	0960	41038754	CTS At Grade	-117.3369912	33.87989856
Krameria-Taft	MP 0044		Could Not Locate	-117.32948	33.88
Krameria-Taft	MP 0045		Could Not Locate	-117.3274	33.88004
Krameria-Taft	MP 0047		CTS At Grade	-117.32619	33.88006
Krameria-Taft	MP 0048		CTS At Grade	-117.32454	33.88004
Krameria-Taft	MP 0050		CTS At Grade	-117.32292	33.88001
La Sierra	38024750	38024750	Could Not Locate	-117.4723997	33.89567526
La Sierra	38025750	38025750	CTS At Grade	-117.4685853	33.89385892
La Sierra	38025751	38025751	CTS At Grade	-117.4669468	33.89188204
La Sierra	39025750	39025750	CTS At Grade	-117.4639928	33.88827455
La Sierra	39025751	39025751	Could Not Locate	-117.4625034	33.88643913
La Sierra	39025752	39025752	CTS At Grade	-117.466429	33.89125794
La Sierra	39025753	39025753	CTS At Grade	-117.4654362	33.89003341
La Sierra	40025750	40025750	Could Not Locate	-117.4609573	33.88466701
La Sierra	40025751	40025751	Could Not Locate	-117.4590787	33.88327729
La Sierra	40026750	40026750	CTS At Grade	-117.4570926	33.88189984
La Sierra	41026750	41026750	CTS At Grade	-117.4561137	33.87570458
La Sierra	41026751	41026751	CTS At Grade	-117.4559291	33.87999426
La Sierra	41026752	41026752	CTS At Grade	-117.4556556	33.87866906
La Sierra	41026753	41026753	CTS At Grade	-117.4556862	33.8778665
La Sierra	42026750	42026750	CTS At Grade	-117.4562173	33.87122761
La Sierra	42026751	42026751	CTS At Grade	-117.4565345	33.87354494
La Sierra	43026750	43026750	Could Not Locate	-117.4553457	33.86915049
La Sierra	43026751	43026751	CTS At Grade	-117.4543151	33.86712411
La Sierra	43026752	43026752	CTS At Grade	-117.4538868	33.86515131
La Sierra	44026752	44026752	CTS At Grade	-117.4539612	33.862959
La Sierra	44026753	44026753	CTS At Grade	-117.454034	33.86074722
La Sierra	44026754	44026754	Could Not Locate	-117.453631	33.85864192

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Lake Hills-Summer Springs	0412	41024752	Bollard	-117.4777905	33.87810538
Lake Hills-Summer Springs	0423	40024751	Bollard	-117.4716178	33.8815329
Lake Hills-Summer Springs	0553	41024751	Bollard	-117.476906	33.87916188
Lake Hills-Summer Springs	0554	41024750	Bollard	-117.4754373	33.88009307
Lake Hills-Summer Springs	0559	41023753	Bollard	-117.4801965	33.87750201
Lake Hills-Summer Springs	0560	41023754	Bollard	-117.4786917	33.8771435
Lake Hills-Summer Springs	0562	40024752	Bollard	-117.4748128	33.88126753
Lake Hills-Summer Springs	0563	40024750	Bollard	-117.4732064	33.88153471
Lance Dr	0406		Could Not Locate	-117.3037707	33.93092045
Lance Dr	0407		CTS At Grade	-117.3037556	33.92975099
Lockewood Ave	0032	45033752	Could Not Locate	-117.3830729	33.85802727
Lockewood Ave	0033	45033751	Bollard	-117.387148	33.85808344
Lockewood Ave	0034	45033750	Bollard	-117.3849731	33.85812221
Lockewood Ave	0035	45033753	At Grade with Bollard	-117.3809983	33.85802615
Lockewood Ave	0036	45032752	Bollard	-117.3943828	33.8579775
Lockewood Ave	0037	45032750	Bollard	-117.3909737	33.85803163
Lockewood Ave	0038	45032754	Bollard	-117.3895738	33.8579765
Lockewood Ave	0039	45032753	Bollard	-117.3926535	33.85797684
Lockewood Ave	0040	45032751	Bollard	-117.396531	33.85797744
Lockewood Ave	0188	44032751	Bollard	-117.3966329	33.85992513
Lockewood Ave	0254	44032750	Could Not Locate	-117.3965807	33.86196632
Lurin Ave-DW	41037758	41037758	Could Not Locate	-117.3470904	33.87633829
Lurin Ave-DW	0850-DW		Could Not Locate	-117.3449	33.87635905
Lurin Ave-DW	41037756-DW		Could Not Locate	-117.3457726	33.87634922
Lurin Ave-DW	41037759-DW		Could Not Locate	-117.3485932	33.87632582
Lurin Ave-RW	0850	41037R750	CTS At Grade	-117.3449	33.87635905
Lurin Ave-RW	0851	41037R751	CTS At Grade	-117.3465485	33.87634852
Lurin Ave-RW	0852-RW		CTS At Grade	-117.348145	33.87633831
Lurin Ave-RW	41037759-RW		CTS At Grade	-117.3485932	33.87632582
Mariposa	0045	42033759	Could Not Locate	-117.3830605	33.87258184
Mariposa	0050	42033761	Could Not Locate	-117.3828847	33.8719148
Mariposa	0203	43033759	CTS At Grade	-117.3819156	33.86496012
Mariposa	0264	43033756	Could Not Locate	-117.3807462	33.86595801
Mariposa	0265	43033758	Could Not Locate	-117.3799383	33.8671139
Mariposa	0266	43034750	Could Not Locate	-117.379407	33.86841465
Mariposa	0635	43034751	Could Not Locate	-117.3788931	33.86972038
Mariposa	0636	42034750	Could Not Locate	-117.378302	33.87096155
Mariposa	0637	42034751	Could Not Locate	-117.377149	33.8718671

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
McAllister	0807	35030R753	At Grade with Bollard	-117.4179024	33.90919526
McAllister	0808	35030R752	At Grade with Bollard	-117.415575	33.91052615
McAllister	0809	35030R751	At Grade with Bollard	-117.4135341	33.91169129
McAllister	0810	35030R750	At Grade with Bollard	-117.4116508	33.91276674
McAllister	0811	34031R750	At Grade with Bollard	-117.4097858	33.91543394
McAllister	0812	34031R751	At Grade with Bollard	-117.4093436	33.91408398
McAllister	0813	34030R750	At Grade with Bollard	-117.4125396	33.91880829
McAllister	0814	34030R751	At Grade with Bollard	-117.4111084	33.9170436
McAllister	0815	33031R750	CTS At Grade	-117.4069507	33.92489348
McAllister	0816	33031R751	CTS At Grade	-117.4086826	33.92351409
McAllister	0817	33030R750	CTS At Grade	-117.4111667	33.92210276
McAllister	0818	33030R752	CTS At Grade	-117.4137336	33.92032223
McAllister	0819	33030R751	CTS At Grade	-117.4128801	33.9211295
McAllister	0820	32031R750	CTS At Grade	-117.4085625	33.92687413
McAllister	0903	39028R753	At Grade with Bollard	-117.4379438	33.88699878
McAllister	0904	39028R754	CTS At Grade	-117.4389027	33.88654394
McAllister	0905	41028750	At Grade with Bollard	-117.4348821	33.87812111
McAllister	0906	41028751	Could Not Locate	-117.4359077	33.87707759
McAllister	0907	41028752	At Grade with Bollard	-117.4342914	33.87885094
McAllister	0908	41028753	Could Not Locate	-117.4363928	33.87567587
McAllister	0909	42028753	Could Not Locate	-117.4361408	33.87431884
McAllister	0904-Casing		CTS At Grade	-117.4389027	33.88654394
Meridian Business Center	0216	38043750	Could Not Locate	-117.2831798	33.89773267
Meridian Business Center	0217	37043757	CTS At Grade	-117.2839731	33.89884624
Meridian Business Center	0218	37043756	CTS At Grade	-117.2848057	33.90001591
Meridian Business Center	0219	37043755	CTS At Grade	-117.2856047	33.90113832
Meridian Business Center	0220	37043754	CTS At Grade	-117.2835843	33.90185504
Meridian Business Center	0221	36043752	Could Not Locate	-117.2854584	33.90833819
Meridian Business Center	0223	35042750	CTS At Grade	-117.2916717	33.91382675
Meridian Business Center	0224	35043750	Could Not Locate	-117.2907291	33.9126534
Meridian Business Center	0225	35043751	CTS At Grade	-117.2897106	33.9115766
Meridian Business Center	0226	35043752	CTS At Grade	-117.2886897	33.91049677
Meridian Business Center	0227	36043750	Could Not Locate	-117.287743	33.90919494
Meridian Business Center	0228	36043751	CTS At Grade	-117.2875607	33.90865482
Meridian Business Center	0229	36043754	CTS At Grade	-117.284998	33.907348
Meridian Business Center	0230	37043753	CTS At Grade	-117.2864643	33.90237574
Meridian Business Center	0231	37043751	Could Not Locate	-117.2871473	33.90356977
Meridian Business Center	0232	36043753	Could Not Locate	-117.2874921	33.90759873
Meridian Business Center	0588	36043755	Could Not Locate	-117.2877977	33.90625206
Meridian Business Center	0590	36043758	CTS At Grade	-117.2877272	33.9048653
Meridian Business Center	0591	37043752	Could Not Locate	-117.2820844	33.90260539
Meridian Business Center	0592	36043756	CTS At Grade	-117.2840607	33.90614526
Meridian Business Center	0593	37043750	Could Not Locate	-117.2827137	33.90365793

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Meridian Business Center	0603	38044750	CTS At Grade	-117.2806566	33.89368511
Meridian Business Center	0604	38043751	Could Not Locate	-117.2812432	33.89362537
Meridian Business Center	0605	38043752	CTS At Grade	-117.2812964	33.89502922
Meridian Business Center	0606	38043753	CTS At Grade	-117.2821222	33.89626118
Meridian Business Center	0607	39043750	Could Not Locate	-117.2827119	33.89300155
Meridian Business Center	0608	39043751	CTS At Grade	-117.284177	33.89237927
Meridian Business Center	0609	39043752	CTS At Grade	-117.2854889	33.89180916
Meridian Business Center	0638	36043759	CTS At Grade	-117.2852255	33.90894154
Meridian Business Center	0855	36043757	Could Not Locate	-117.2835136	33.9049174
Mockingbird Canyon Rd	0001	46034750	Bollard	-117.3743549	33.85279187
Mockingbird Canyon Rd	0002	46034751	Bollard	-117.374327	33.85140503
Mockingbird Canyon Rd	0003	46034752	Could Not Locate	-117.3742139	33.85007883
Mockingbird Canyon Rd	0004	46034758	Could Not Locate	-117.3746796	33.84873917
Mockingbird Canyon Rd	0010	45034755	Could Not Locate	-117.3747126	33.85419909
Mockingbird Canyon Rd	0027	45034754	Bollard	-117.3759313	33.85506239
Mockingbird Canyon Rd	0028	45034750	Bollard	-117.3786234	33.85854579
Mockingbird Canyon Rd	0028.1		CTS At Grade	-117.3786234	33.85854579
Mockingbird Canyon Rd	0029	45034756	Bollard	-117.3745973	33.8539744
Mockingbird Canyon Rd	0030	45034753	Bollard	-117.3765784	33.85573285
Mockingbird Canyon Rd	0031	45034752	Bollard	-117.3777353	33.85702428
Mockingbird Canyon Rd	0041		Could Not Locate		
Mockingbird Canyon Rd	0042	44033750	Bollard	-117.3814286	33.86380464
Mockingbird Canyon Rd	0051	42032754	Bollard	-117.3899066	33.87205617
Mockingbird Canyon Rd	0052	42032753	Could Not Locate	-117.391192	33.87293116
Mockingbird Canyon Rd	0053	42032752	Could Not Locate	-117.3927415	33.87338189
Mockingbird Canyon Rd	0054	42032751	Bollard	-117.3939678	33.87444682
Mockingbird Canyon Rd	0055	42032750	Could Not Locate	-117.3953845	33.87525422
Mockingbird Canyon Rd	0150	40031756	Bollard	-117.4042876	33.88297873
Mockingbird Canyon Rd	0151	40031755	Bollard	-117.4044297	33.88303996
Mockingbird Canyon Rd	0156	39031750	At Grade with Bollard	-117.4091635	33.88674613
Mockingbird Canyon Rd	0157	39030753	At Grade with Bollard	-117.4103952	33.88721313
Mockingbird Canyon Rd	0158	39030752	At Grade with Bollard	-117.4115202	33.88763586
Mockingbird Canyon Rd	0166		Could Not Locate	-117.3994914	33.87765719
Mockingbird Canyon Rd	0167	41031751	Bollard	-117.4014883	33.87975351
Mockingbird Canyon Rd	0168	41031750	Bollard	-117.4026491	33.88099396
Mockingbird Canyon Rd	0169	41031753	Bollard	-117.4005674	33.87880357
Mockingbird Canyon Rd	0173		Could Not Locate	-117.4039278	33.88260297
Mockingbird Canyon Rd	0175	40031762	Bollard	-117.4034345	33.88221229
Mockingbird Canyon Rd	0176	40031753	At Grade with Bollard	-117.4052208	33.88442121
Mockingbird Canyon Rd	0177	40031752	At Grade with Bollard	-117.4060991	33.88515828
Mockingbird Canyon Rd	0178	40031751	At Grade with Bollard	-117.4070624	33.88578972
Mockingbird Canyon Rd	0179	40031750	At Grade with Bollard	-117.4081524	33.88633571
Mockingbird Canyon Rd	0183	39030751	CTS At Grade	-117.4125601	33.88811985

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Mockingbird Canyon Rd	0184	39030750	Could Not Locate	-117.4135787	33.88873209
Mockingbird Canyon Rd	0235	47034751	Could Not Locate	-117.3746933	33.84792104
Mockingbird Canyon Rd	0236	47034758	Could Not Locate	-117.3739359	33.84375864
Mockingbird Canyon Rd	0237	47034754	Bollard	-117.3750012	33.84609543
Mockingbird Canyon Rd	0238	47034755	Could Not Locate	-117.3748	33.84591
Mockingbird Canyon Rd	0239	47034759	Could Not Locate	-117.3738242	33.84353036
Mockingbird Canyon Rd	0240	47034757	Bollard	-117.3744662	33.84484293
Mockingbird Canyon Rd	0241	47034752	Bollard	-117.3749609	33.8474888
Mockingbird Canyon Rd	0250	46034753	Bollard	-117.3743188	33.84961971
Mockingbird Canyon Rd	0251	45034751	Could Not Locate	-117.3786518	33.85848743
Mockingbird Canyon Rd	0252		Could Not Locate	-117.3801089	33.86101191
Mockingbird Canyon Rd	0253	44033751	Bollard	-117.3807433	33.86218488
Mockingbird Canyon Rd	0255	43033753	Could Not Locate	-117.3844146	33.86757706
Mockingbird Canyon Rd	0256		Could Not Locate	-117.385287	33.86824641
Mockingbird Canyon Rd	0257	43033757	Could Not Locate	-117.3824403	33.86493882
Mockingbird Canyon Rd	0258	43033755	Bollard	-117.3833611	33.86640054
Mockingbird Canyon Rd	0258.1		Bollard	-117.3833611	33.86640054
Mockingbird Canyon Rd	0259	43033754	Bollard	-117.3843143	33.86717967
Mockingbird Canyon Rd	0260	43033751	Bollard	-117.3863684	33.86915472
Mockingbird Canyon Rd	0261	43033750	Bollard	-117.387785	33.86999931
Mockingbird Canyon Rd	0262	42033766	Bollard	-117.3883854	33.8705171
Mockingbird Canyon Rd	0263	42033765	Bollard	-117.3886564	33.87086051
Mockingbird Canyon Rd	0267	42033762	Bollard	-117.3892742	33.87147694
Mockingbird Canyon Rd	0288		Could Not Locate	-117.3967988	33.87614405
Mockingbird Canyon Rd	0289	41032753	Bollard	-117.3983762	33.87679025
Mockingbird Canyon Rd	0457	48034760	At Grade with Bollard	-117.3734931	33.83814847
Mockingbird Canyon Rd	0459	48034751	Could Not Locate	-117.3726407	33.8417409
Mockingbird Canyon Rd	0460	48034750	Bollard	-117.3731525	33.84236178
Mockingbird Canyon Rd	0462	48034752	Bollard	-117.3721224	33.84126534
Mockingbird Canyon Rd	0253		Bollard	-117.3807433	33.86218488
Mockingbird Canyon Rd	41 unk		CTS At Grade	-117.3794028	33.85967993
Mockingbird Canyon Rd	42 unk		CTS At Grade	-117.3814286	33.86380464
Murrieta	0657	100050753	Could Not Locate	-117.2111031	33.55629163
Murrieta	0658	100050754	Could Not Locate	-117.2168321	33.55637406
Murrieta	0659	100050755	Could Not Locate	-117.2162309	33.5573062
Murrieta	0660	100050756	Could Not Locate	-117.2128278	33.55787822
Murrieta	0661		Could Not Locate	-117.2218992	33.54311174
Murrieta	0662	120049751	At Grade with Bollard	-117.2242206	33.54417326
Murrieta	0663	98050753	Could Not Locate	-117.2180304	33.56801764
Murrieta	0664	120049752	At Grade with Bollard	-117.2273394	33.54228881
Murrieta	0665	100048753	CTS At Grade	-117.2293327	33.55682586
Murrieta	0666	99051751	At Grade with Bollard	-117.2061285	33.56235989
Murrieta	0667	99051752	Could Not Locate	-117.2066003	33.55961764

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Murrieta	0668	130049750	Could Not Locate	-117.2249641	33.54058963
Murrieta	0669	130049751	At Grade with Bollard	-117.2242251	33.54137958
Murrieta	0670	120049753	At Grade with Bollard	-117.2231013	33.54290135
Murrieta	0671	99050754	At Grade with Bollard	-117.2093445	33.5621653
Murrieta	0673	98049752	Could Not Locate	-117.2216588	33.56630978
Murrieta	0674	100051751	CTS At Grade	-117.1984905	33.55537701
Murrieta	0675	100050757	CTS At Grade	-117.21791	33.55566284
Murrieta	0675.1		Could Not Locate	-117.21791	33.55566284
Murrieta	0677		Could Not Locate	-117.2207049	33.5437585
Murrieta	0678	120049755	Could Not Locate	-117.2187007	33.54528486
Murrieta	0679	99050755	CTS At Grade	-117.213855	33.55869635
Murrieta	0680	99050757	Could Not Locate	-117.2107526	33.56103136
Murrieta	0682	100050758	Could Not Locate	-117.2102384	33.55691319
Murrieta	0683		Could Not Locate	-117.2141577	33.54884101
Murrieta	0685	98048756	Could Not Locate	-117.2363229	33.56860856
Murrieta	0686	96048757	CTS At Grade	-117.2379057	33.57610553
Murrieta	0687	96048760	Could Not Locate	-117.2344699	33.57824199
Murrieta	0688	100049750	Could Not Locate	-117.2260746	33.55462074
Murrieta	0689	99048750	Could Not Locate	-117.2317151	33.55898976
Murrieta	0690	98048750	CTS At Grade	-117.2319646	33.56772448
Murrieta	0691	98048751	Could Not Locate	-117.2327385	33.56848424
Murrieta	0692	97048750	Could Not Locate	-117.2315481	33.56937638
Murrieta	0693	97048751	At Grade with Bollard	-117.232328	33.57059934
Murrieta	0694	97048752	CTS At Grade	-117.2346417	33.57265506
Murrieta	0695	96048750	CTS At Grade	-117.23497	33.57628057
Murrieta	0696	96048751	At Grade with Bollard	-117.233441	33.57677271
Murrieta	0697	96048752	CTS At Grade	-117.2367799	33.57715528
Murrieta	0698	96048753	Could Not Locate	-117.2360754	33.57836035
Murrieta	0699	96048754	Could Not Locate	-117.2359149	33.57858358
Murrieta	0700	96048755	Could Not Locate	-117.236696	33.57878495
Murrieta	0701	96048756	CTS At Grade	-117.2357463	33.57890833
Murrieta	0702	95048750	At Grade with Bollard	-117.2342018	33.5818826
Murrieta	0703	95048751	Could Not Locate	-117.2357744	33.58192681
Murrieta	0704	96047750	Could Not Locate	-117.2387312	33.57673797
Murrieta	0705	96047751	CTS At Grade	-117.2401719	33.57782824
Murrieta	0706	96047752	CTS At Grade	-117.2400537	33.57836901
Murrieta	0707	99048751	Could Not Locate	-117.2356425	33.56261554
Murrieta	0708	99048752	Could Not Locate	-117.2358619	33.56280034
Murrieta	0709	98048752	Could Not Locate	-117.2346222	33.56691993
Murrieta	0710	96048758	Could Not Locate	-117.2287248	33.57714441

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Murrieta	0711	96048759	Could Not Locate	-117.2351849	33.57957302
Murrieta	0712	95048752	Could Not Locate	-117.2380015	33.58085484
Murrieta	0713	96048761	Could Not Locate	-117.233845	33.57982218
Murrieta	0714	95048753	Could Not Locate	-117.2334449	33.5807057
Murrieta	0715	95048754	At Grade with Bollard	-117.2355308	33.58020194
Murrieta	0716	97049751	Could Not Locate	-117.2280027	33.57186464
Murrieta	0717	97048753	Could Not Locate	-117.2312525	33.56958434
Murrieta	0718	97049752	Could Not Locate	-117.2280593	33.57190663
Murrieta	0719	97048754	Could Not Locate	-117.2311128	33.56947633
Murrieta	0720	95048755	CTS At Grade	-117.2321102	33.58099381
Murrieta	0721	98048753	Could Not Locate	-117.2372811	33.56557144
Murrieta	0722	98047750	Could Not Locate	-117.2390184	33.56869663
Murrieta	0723	97048755	Could Not Locate	-117.2329465	33.57079803
Murrieta	0724	97048756	Could Not Locate	-117.2364803	33.57097214
Murrieta	0725	98048754	CTS At Grade	-117.2339951	33.56868155
Murrieta	0726	98048755	Could Not Locate	-117.2360966	33.56697816
Murrieta	0727	96049750	Could Not Locate	-117.2267964	33.57610974
Murrieta	0728	97049753	CTS At Grade	-117.227371	33.57156108
Murrieta	0729	97048757	CTS At Grade	-117.233895	33.57180991
Murrieta	0732	110052751	Could Not Locate	-117.1939327	33.5511579
Murrieta	0733	110052752	At Grade with Bollard	-117.1957275	33.55280674
Murrieta	0734	110052753	At Grade with Bollard	-117.1964372	33.55285794
Murrieta	0735	110052754	At Grade with Bollard	-117.191267	33.55291702
Murrieta	0736	100052750	At Grade with Bollard	-117.1955816	33.5530898
Murrieta	0737	100052751	At Grade with Bollard	-117.1947079	33.55348104
Murrieta	0738	100052752	At Grade with Bollard	-117.197085	33.55394067
Murrieta	0739	110052755	Could Not Locate	-117.1948352	33.5518708
Murrieta	0740		Could Not Locate	-117.1997699	33.55911978
Murrieta	0741	120049756	At Grade with Bollard	-117.2191617	33.54720258
Murrieta	0742	110049751	Could Not Locate	-117.222472	33.55025392
Murrieta	0743	110049752	At Grade with Bollard	-117.2202655	33.5482194
Murrieta	0744	110049753	Could Not Locate	-117.22357	33.55126
Murrieta	0745	120050750	At Grade with Bollard	-117.2178887	33.54603292
Murrieta	0746	110049750	Could Not Locate	-117.2213687	33.54923665
Murrieta	0747	110049754	At Grade with Bollard	-117.222662	33.5520988
Murrieta	0897	99050756	CTS At Grade	-117.2137582	33.5586919
Murrieta	0747 E		CTS At Grade	-117.22266	33.55566
Murrieta	0747 W		CTS At Grade	-117.22266	33.55566
Murrieta	Point 61 New CTS		CTS At Grade	-117.23743	33.57746

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
New Nandina	0653	43040759	Could Not Locate	-117.3137515	33.86554611
New Nandina	0762	43041R750	At Grade with Bollard	-117.3086395	33.86580425
New Nandina	0763	43041R751	At Grade with Bollard	-117.3066038	33.86581267
New Nandina	0769	43040R752	At Grade with Bollard	-117.3118611	33.8657927
New Nandina	0821	43045R750	CTS At Grade	-117.2680072	33.86622154
New Nandina	0822	43045R751	CTS At Grade	-117.2696541	33.86620451
New Nandina	0823	43044R750	At Grade with Bollard	-117.2713011	33.86618649
New Nandina	0824	43044R752	At Grade with Bollard	-117.2746871	33.86615022
New Nandina	0825	43044R751	At Grade with Bollard	-117.2730402	33.86616794
New Nandina	0826	43044R753	Could Not Locate	-117.276334	33.86613248
New Nandina	0827	43044R754	At Grade with Bollard	-117.2779546	33.866115
New Nandina	0828	43044R755	Could Not Locate	-117.2796278	33.86609843
New Nandina	0829	43043R755	At Grade with Bollard	-117.2901956	33.8659742
New Nandina	0830	43043R752	At Grade with Bollard	-117.2844968	33.86604717
New Nandina	0831	43043R751	CTS At Grade	-117.2829282	33.86606156
New Nandina	0832	43043R750	At Grade with Bollard	-117.2812747	33.86608313
New Nandina	0833	43043R753	At Grade with Bollard	-117.2875031	33.86600473
New Nandina	0834	43043R754	At Grade with Bollard	-117.2887465	33.86600186
New Nandina	0835	43042R754	At Grade with Bollard	-117.2960454	33.8658627
New Nandina	0836	43042R751	At Grade with Bollard	-117.3000959	33.86584033
New Nandina	0837	43042R750	At Grade with Bollard	-117.2935756	33.8659096
New Nandina	0838	43042R753	At Grade with Bollard	-117.2960125	33.86586333
New Nandina	0839	43042R752	At Grade with Bollard	-117.2985477	33.86584702
New Nandina	0840	43041R753	At Grade with Bollard	-117.30283	33.86582862
New Nandina	0841	43041R752	Could Not Locate	-117.3049172	33.86581948
New Nandina	Unk		At Grade with Bollard	-117.29174	33.865883
Orange Terrace	0072	38040751	CTS At Grade	-117.3129826	33.89479873
Orange Terrace	0073	38040750	CTS At Grade	-117.316245	33.89477223
Orange Terrace	0074	38040752	CTS At Grade	-117.3189179	33.89473052
Orange Terrace	0075	38039751	CTS At Grade	-117.325091	33.89471433
Orange Terrace	0077	38039752	CTS At Grade	-117.3222593	33.89468944
Orange Terrace	0503		Could Not Locate	-117.3101034	33.89448083
Pennington	0046	42033752	At Grade with Bollard	-117.3879897	33.87463179
Pennington	0047	42033755	At Grade with Bollard	-117.3879763	33.87390792
Pennington	0048	42033757	Could Not Locate	-117.3878339	33.87270725
Pennington	0049	42033763	Could Not Locate	-117.3885415	33.87128455
Pennington	0268	42033764	Could Not Locate	-117.3886588	33.87117766
Pennington	0269	42033758	CTS At Grade	-117.387962	33.87266714
Pennington	0270	42033760	Could Not Locate	-117.3879666	33.87231868
Plummer			Abandoned		

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Rolling Meadows	0147	58034751	Could Not Locate	-117.3713482	33.78588229
Rolling Meadows	0610	55034750	At Grade with Bollard	-117.3711507	33.79969117
Rolling Meadows	0611	56034753	At Grade with Bollard	-117.3713005	33.79424992
Rolling Meadows	0612	56034752	At Grade with Bollard	-117.3712871	33.7955823
Rolling Meadows	0613	56034751	At Grade with Bollard	-117.3713186	33.79699704
Rolling Meadows	0614	56034750	At Grade with Bollard	-117.3712841	33.79837181
Rolling Meadows	0615	57034754	At Grade with Bollard	-117.3711388	33.78902424
Rolling Meadows	0616	57034753	At Grade with Bollard	-117.3711626	33.79039538
Rolling Meadows	0617	57034752	At Grade with Bollard	-117.3711461	33.79172598
Rolling Meadows	0618	57034751	Could Not Locate	-117.3711427	33.79301078
Rolling Meadows	0619	58034753	At Grade with Bollard	-117.3712062	33.786344
Rolling Meadows	0620	58034752	At Grade with Bollard	-117.3712148	33.78764874
Rolling Meadows	0645	58034755	At Grade with Bollard	-117.3711328	33.78521979
Rolling Meadows	0646	58034756	At Grade with Bollard	-117.370874	33.78387037
Rolling Meadows	0647	58034757	At Grade with Bollard	-117.3704949	33.7825776
Rolling Meadows	0648	59034750	At Grade with Bollard	-117.3705905	33.78129576
Rolling Meadows	0649	60034750	At Grade with Bollard	-117.3711746	33.7759884
Rolling Meadows	0650	59034753	At Grade with Bollard	-117.3714428	33.77727091
Rolling Meadows	0651		At Grade with Bollard	-117.3714433	33.77876333
Rolling Meadows	0652	59034751	At Grade with Bollard	-117.3709237	33.77997242
Roosevelt - Chicago	0190	42037753	Could Not Locate	-117.3489003	33.87109122
Roosevelt - Chicago	0191	42037752	Could Not Locate	-117.3489097	33.87246285
Roosevelt - Chicago	0192	42037751	Could Not Locate	-117.3488514	33.87439426
Roosevelt - Chicago	0193	42037750	Could Not Locate	-117.3488509	33.87518136
Roosevelt - Chicago	0194	43037753	At Grade with Bollard	-117.3490424	33.86968439
Roosevelt - Chicago	0195	43037752	At Grade with Bollard	-117.3489634	33.86831247
Roosevelt - Chicago	0196	43037751	At Grade with Bollard	-117.3489638	33.866938
Roosevelt - Chicago	0197	43037750	At Grade with Bollard	-117.3489515	33.86554257
Roosevelt - Chicago	0198	44037753	CTS At Grade	-117.348925	33.86010797
Roosevelt - Chicago	0199	44037752	At Grade with Bollard	-117.3489028	33.86301011
Roosevelt - Chicago	0200	44037751	Could Not Locate	-117.3488979	33.86409549
Roosevelt - Chicago	0202	45037754	CTS At Grade	-117.3489349	33.85873401
Roosevelt - Chicago	0594	44037754	Could Not Locate	-117.3489143	33.8616362
Roosevelt - Chicago	V&A2		Could Not Locate	-117.3488	33.87379
Roosevelt - Chicago	V&A6		At Grade with Bollard	-117.34892	33.86745
Rose Quartz	0466	59037757	Could Not Locate	-117.3428724	33.77823217
Rose Quartz	Blow Off		Could Not Locate		
Sumac Lane	0858	61036752	CTS At Grade	-117.3577593	33.7684669
Sumac Lane	0867	61035753	CTS At Grade	-117.3593852	33.76822606
Sumac Lane	0868	61035752	Could Not Locate	-117.3610191	33.76862054
Sumac Lane	0869	61035751	Could Not Locate	-117.3621899	33.76958971
Sumac Lane	0870	61035750	Could Not Locate	-117.3626831	33.7709347
Sumac Lane	0871	61036753	Could Not Locate	-117.3532011	33.76824105

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Sumac Lane	0872	61036751	Could Not Locate	-117.3546129	33.76876958
Sumac Lane	0873	61036750	Could Not Locate	-117.356204	33.76881972
Sumac Lane	FH		Could Not Locate		
Sumac Lane	FH		Could Not Locate		
Sweet Line	41028754	41028754	CTS At Grade	-117.4326693	33.87823391
Sweet Line	41028755	41028755	CTS At Grade	-117.432195	33.87742471
Sweet Line	41028756	41028756	CTS At Grade	-117.4312258	33.87640258
Sweet Line	41029750	41029750	CTS At Grade	-117.4195306	33.87546973
Sweet Line	41030753	41030753	Could Not Locate	-117.41827	33.87696301
Sweet Line	41030754	41030754	CTS At Grade	-117.418591	33.87605621
Sweet Line	42028754	42028754	CTS At Grade	-117.430826	33.8752008
Sweet Line	42028755	42028755	CTS At Grade	-117.4298096	33.87301436
Sweet Line	42028756	42028756	CTS At Grade	-117.4308497	33.87384507
Sweet Line	42029751	42029751	CTS At Grade	-117.4225951	33.87473529
Sweet Line	42029752	42029752	CTS At Grade	-117.4210728	33.87513052
Sweet Line	42029753	42029753	CTS At Grade	-117.4281768	33.8730003
Sweet Line	42029754	42029754	CTS At Grade	-117.4265546	33.87317133
Sweet Line	42029755	42029755	CTS At Grade	-117.4249782	33.87274942
Sweet Line	42029756	42029756	CTS At Grade	-117.4234011	33.87308708
Sweet Line	42029757	42029757	CTS At Grade	-117.4235789	33.87422974
Sycamore Canyon	0094	34042753	Could Not Locate	-117.2922088	33.91710595
Sycamore Canyon	0095	34042750	CTS At Grade	-117.2923195	33.92016
Sycamore Canyon	0096	34042755	Could Not Locate	-117.2920755	33.91691708
Sycamore Canyon	0097	34042754	Could Not Locate	-117.2920079	33.91699501
Sycamore Canyon	0099	34042751	CTS At Grade	-117.2922107	33.91967171
Sycamore Canyon	0100	34042752	CTS At Grade	-117.2921785	33.9180842
Sycamore Canyon	0373	33042752	CTS At Grade	-117.2955946	33.92388882
Sycamore Canyon	0374	33042755	CTS At Grade	-117.2938492	33.92178994
Sycamore Canyon	0375	33042754	CTS At Grade	-117.2953249	33.92273239
Sycamore Canyon	0376	33042753	CTS At Grade	-117.2960724	33.92364307
Sycamore Canyon	0377	33042750	Could Not Locate	-117.2963894	33.92504495
Sycamore Canyon	0378		Could Not Locate	-117.2927478	33.92092639
Sycamore Canyon	0387	32042752	Could Not Locate	-117.296554	33.92865857
Sycamore Canyon	0388	32042753	Could Not Locate	-117.2965076	33.92781068
Sycamore Canyon	0405	32042754	Could Not Locate	-117.2964178	33.9263581
Sycamore Canyon	0376 FH		Could Not Locate	-117.2960724	33.92364307
Sycamore Meridian-Railrd	0086		Could Not Locate	-117.2903975	33.91707442
Sycamore Meridian-Railrd	0087		Could Not Locate	-117.2901576	33.91825889
Sycamore Meridian-Railrd	0088		Could Not Locate	-117.2898812	33.91944384
Sycamore Meridian-Railrd	0089		Could Not Locate	-117.2878991	33.91953896
Sycamore Meridian-Railrd	0090		At Grade with Bollard	-117.2861459	33.91955129
Sycamore Meridian-Railrd	0091		Could Not Locate	-117.286039	33.91802461
Sycamore Meridian-Railrd	0092		Could Not Locate	-117.2860363	33.91785975
Sycamore Meridian-Railrd	0093		Could Not Locate	-117.286105	33.91701412

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Taft	0303	45037751	Could Not Locate	-117.3401243	33.85812525
Taft	0318	44037750	Bollard	-117.3401181	33.86149009
Taft	0328	43038750	Bollard	-117.3400659	33.86534689
Taft	0331	42038750	Bollard	-117.3401452	33.87096934
Taft-Mariposa-Van Buren	0065	41038750	Could Not Locate	-117.340151	33.87905774
Taft-Mariposa-Van Buren	0066	41038751	Could Not Locate	-117.3401384	33.87650242
Taft-Mariposa-Van Buren	0067	41037751	Could Not Locate	-117.3404437	33.87639318
Taft-Mariposa-Van Buren	0347	40038752	Could Not Locate	-117.3401928	33.88177938
Taft-Mariposa-Van Buren	0348	40038751	Could Not Locate	-117.3401712	33.88393297
Taft-Mariposa-Van Buren	0349	40038750	Could Not Locate	-117.340175	33.88650192
Trautwein Rd	0076	38039750	CTS At Grade	-117.3250943	33.89598534
Trautwein Rd	0504	37039751	Could Not Locate	-117.326513	33.90214325
Trautwein Rd	0505	37039750	Could Not Locate	-117.3268322	33.90302046
Trautwein Rd	0506	37039755	CTS At Grade	-117.3254939	33.89951621
Trautwein Rd	0587	36039761	CTS At Grade	-117.3267778	33.90390305
Van Buren East	0071	40042753	Could Not Locate	-117.2919611	33.88437497
Van Buren East	0333	40042752	At Grade with Bollard	-117.2942751	33.8845669
Van Buren East	0334	40042751	At Grade with Bollard	-117.2968467	33.88543392
Van Buren East	0335		At Grade with Bollard	-117.2994822	33.8866357
Van Buren East	0336	40041751	Could Not Locate	-117.3048644	33.88742139
Van Buren East	0337	40041750	Could Not Locate	-117.307256	33.88741284
Van Buren East	0338	40041752	At Grade with Bollard	-117.3023486	33.88732886
Van Buren East	0355	39040750	At Grade with Bollard	-117.3186683	33.88892276
Van Buren East	0357	39040753	At Grade with Bollard	-117.3112238	33.88751586
Van Buren East	0361	39039757	Could Not Locate	-117.3294998	33.88756172
Van Buren East	0362	39039756	At Grade with Bollard	-117.3281571	33.88781893
Van Buren East	0500	39038762	Could Not Locate	-117.3310749	33.88737378
Van Buren East	0501	39038761	Could Not Locate	-117.3312516	33.8874598
Van Buren-Sysco	0879		Could Not Locate		
Van Buren-Sysco	0880	38044751	CTS At Grade	-117.2797393	33.89413095
Van Buren-Sysco	0881	38044752	Could Not Locate	-117.2781801	33.8942044
Van Buren-Sysco	0882	38044753	CTS At Grade	-117.2768822	33.89358419
Van Buren-Sysco	0883		CTS At Grade		
Van Buren-Sysco	0883		Could Not Locate	-117.27617	33.89242767
Van Buren-Sysco	0884	39044752	CTS At Grade	-117.2758862	33.89107396
Van Buren-Sysco	0885	39044753	Could Not Locate	-117.2761085	33.89096157
Van Buren-Sysco	0886	39044754	Could Not Locate	-117.2760856	33.88958613
Van Buren-Sysco	0887	39044755	Could Not Locate	-117.2761028	33.88824617
Van Buren-Sysco	0888	39044756	CTS At Grade	-117.275858	33.8896983
Van Buren-Sysco	0889	39044757	CTS At Grade	-117.2803908	33.89242253
Van Buren-Sysco	0890	39044758	Could Not Locate	-117.2803499	33.89107573
Van Buren-Sysco	0891	39044759	CTS At Grade	-117.2803102	33.8897352
Van Buren-Sysco	0892	39044760	CTS At Grade	-117.2802984	33.88904522

Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Van Buren-Sysco	0893	39044761	CTS At Grade	-117.2762419	33.88933473
Van Buren-Sysco	0894	39044762	CTS At Grade	-117.2778891	33.8893212
Van Buren-Sysco	0895	39044763	CTS At Grade	-117.2794719	33.88930818
Van Buren-Sysco	0896		CTS At Grade		
Van Buren-Sysco	0898	39043753	Could Not Locate	-117.2818605	33.88957813
Van Buren-Sysco	0899	39043754	Could Not Locate	-117.2832756	33.88885351
Van Buren-Sysco	0900	39043755	CTS At Grade	-117.2840706	33.88774031
Van Buren-Sysco	0901	40043750	Could Not Locate	-117.2847651	33.8869235
Van Buren-Sysco	0902	40043751	Could Not Locate	-117.2862356	33.88630547
Van Buren-Sysco	40043752	40043752	CTS At Grade	-117.2899337	33.88503626
Van Buren-Sysco	40043753	40043753	CTS At Grade	-117.2884551	33.88540981
Van Buren-Sysco	40043754	40043754	CTS At Grade	-117.2880103	33.88555678
Village Dr	0848	43043R757	Could Not Locate	-117.2874356	33.86735464
Village Dr	0849	43043R756	Could Not Locate	-117.2874507	33.86878233
Village Dr	0853	43043R758	At Grade with Bollard	-117.2875469	33.87002117
Village Dr	0854	42043R750	At Grade with Bollard	-117.287712	33.87125891
Village Dr	40043755	40043755	CTS At Grade	-117.2872549	33.88239452
Village Dr	40043756	40043756	CTS At Grade	-117.2872721	33.8837684
Village Dr	41043753	41043753	Could Not Locate	-117.2876353	33.87804909
Village Dr	41043754	41043754	CTS At Grade	-117.2872536	33.88113633
Village West	40041753	40041753	CTS At Grade	-117.307578	33.88312943
Village West	40041754	40041754	CTS At Grade	-117.3074154	33.88580012
Village West	40041755	40041755	CTS At Grade	-117.3074236	33.88700793
Village West	40041756	40041756	CTS At Grade	-117.3074676	33.88445899
Village West	41041754	41041754	CTS At Grade	-117.3076097	33.88175805
Village West-Krameria	41041751	41041751	CTS At Grade	-117.3065125	33.88126964
Village West-Krameria	41041752	41041752	CTS At Grade	-117.3048651	33.88126369
Village West-Krameria	41041753	41041753	CTS At Grade	-117.303212	33.88125771
Village West-Krameria	41041755	41041755	CTS At Grade	-117.3015705	33.88125174
Village West-Krameria	41042758	41042758	CTS At Grade	-117.2949812	33.88122756
Village West-Krameria	41042759	41042759	CTS At Grade	-117.29188	33.88182417
Village West-Krameria	41042760	41042760	CTS At Grade	-117.2999232	33.88124573
Village West-Krameria	41042761	41042761	CTS At Grade	-117.2982758	33.88123969
Village West-Krameria	41042762	41042762	CTS At Grade	-117.2966353	33.88123367
Village West-Krameria	41043750	41043750	CTS At Grade	-117.2902229	33.88183957
Village West-Krameria	41043751	41043751	CTS At Grade	-117.2886406	33.8814737
Village West-Krameria	41043752	41043752	CTS At Grade	-117.2876857	33.8814461
Wood Rd	0081	38038753	Could Not Locate	-117.3313807	33.89371715
Wood Rd	0082	38038750	Could Not Locate	-117.3313667	33.89632102
Wood Rd	0496	39038753	Could Not Locate	-117.3314699	33.89149414
Wood Rd	V&A 2		Could Not Locate	-117.33128	33.90088
Wood Rd	V&A 3		Could Not Locate	-117.33126	33.9014

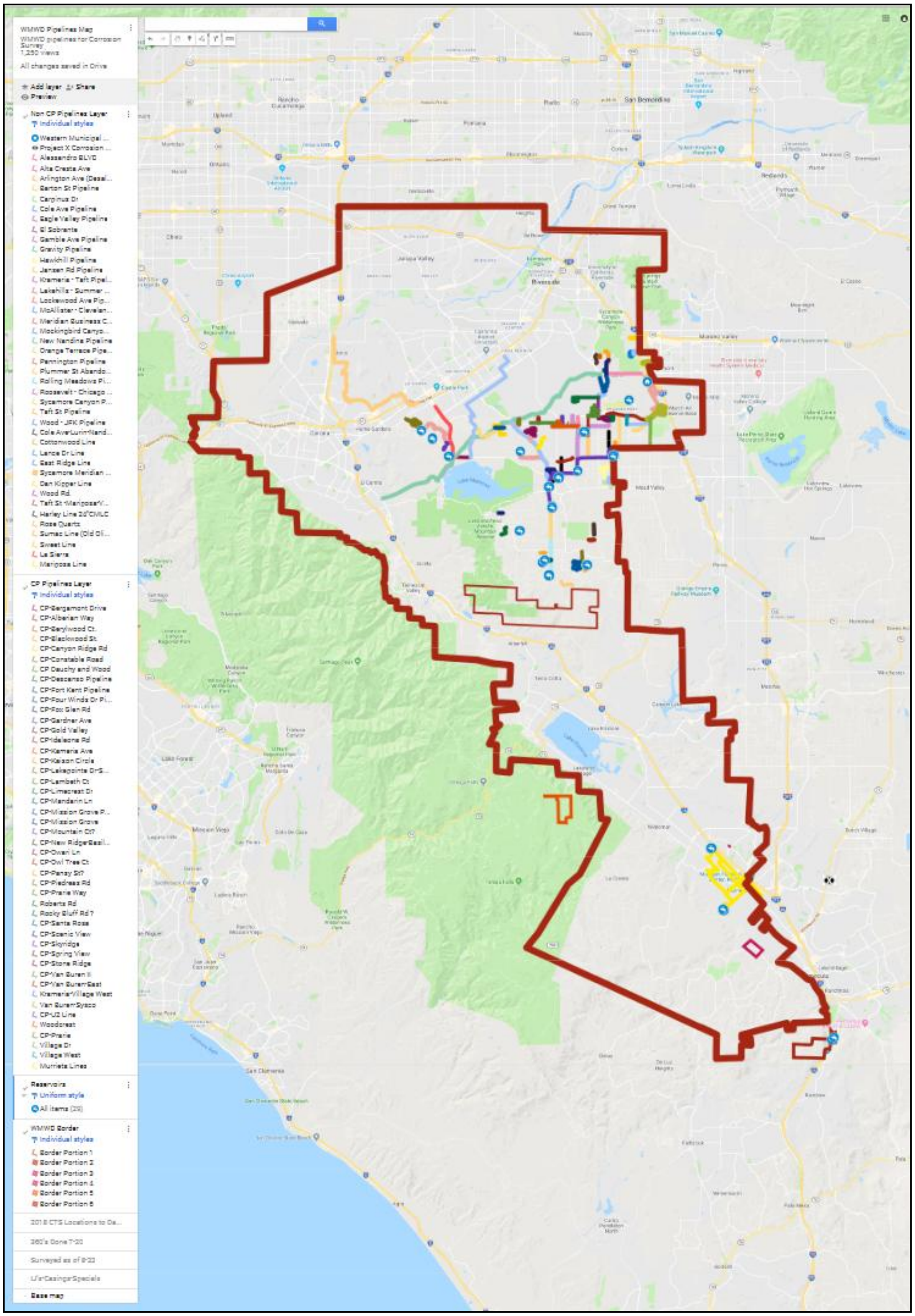
Non-CP - CTS Types and Lat/Long

Pipeline Name	UNIT ID # WCPD00	Facility ID	CTS Type	Longitude	Latitude
Wood-JFK	0507	37039754	CTS At Grade	-117.3267145	33.90173653
Wood-JFK	0508	37039753	CTS At Grade	-117.3284204	33.90174171
Wood-JFK	0509	37039752	CTS At Grade	-117.3299974	33.90181322
Wood-JFK	0510	37038752	Could Not Locate	-117.3311795	33.90035811
Wood-JFK	0511	37038750	Could Not Locate	-117.3311705	33.9016221
Wood-JFK	0513	37038753	Could Not Locate	-117.3314343	33.89960807

11.7 Tank CTS

Reservoir Name	WCPD00 UNIT ID #	Longitude	Latitude
Capello DW	Unk CTS#	-117.3977029	33.8069559
CITP P-1 DW	Unk Tank CTS 1	-117.3731983	33.8373955
CITP P-2 DW	947	-117.3737562	33.837401
El Nido DW	948	-117.3408079	33.782565
El Nido RW	Unk Tank CTS 2	-117.341406	33.7824669
Grizzly Ridge 1 DW	946	-117.2364888	33.5835945
Grizzly Ridge 2 DW	940	-117.2360516	33.583409
Harley John DW	954	-117.3647305	33.8439487
Hidden Valley DW	Unk Tank CTS 3	-117.3730497	33.7754676
Home Garden	Unk Tank CTS	-117.5174423	33.8707295
IDU-1 #1 RW Abandoned	Unk Tank CTS	-117.4795135	33.8412798
IDU-1 #2 RW	Unk Tank CTS	-117.4715136	33.8175365
IDU-1 #3 RW	Unk Tank CTS	-117.437308	33.8016624
Hillside, Lower 1 DW	956	-117.3708862	33.82347
Hillside, Lower 2 DW	955	-117.3706287	33.8233141
Hillside, Upper RW	985	-117.3708218	33.8230021
Jim Jack RW	990	-117.377069	33.786313
La Sierra DW	986	-117.4577308	33.8588163
Lake Hills DW	988	-117.480661	33.8770652
Lockwood DW	987	-117.3973811	33.8623399
Lurin East DW	984	-117.3434177	33.8759306
Lurin RW	Unk Tank CTS#	-117.343411	33.876076
Lurin West DW	983	-117.3442505	33.8761422
Markham 1 DW	581	-117.3185617	33.8597117
Markham 2 DW	966	-117.3189962	33.858901
Old Lake DW	967	-117.4715026	33.8712941
Olga Gordon #1 DW	969	-117.2257733	33.5403395
Olga Gordon #2 DW	968	-117.226299	33.5406167
Orange Crest DW	970	-117.3053706	33.8983826
Rainbow 1 DW	Unk Tank CTS#	-117.1341652	33.4486307
Rainbow 2 DW	Unk Tank CTS#	-117.1326792	33.4502152
Roosevelt RW	972	-117.3491442	33.8483316
Rocky Bluff Dw	Unk CTS#	-117.379138	33.784104
Unk WMWD Tank DW	Unk CTS#	-117.3708218	33.835535

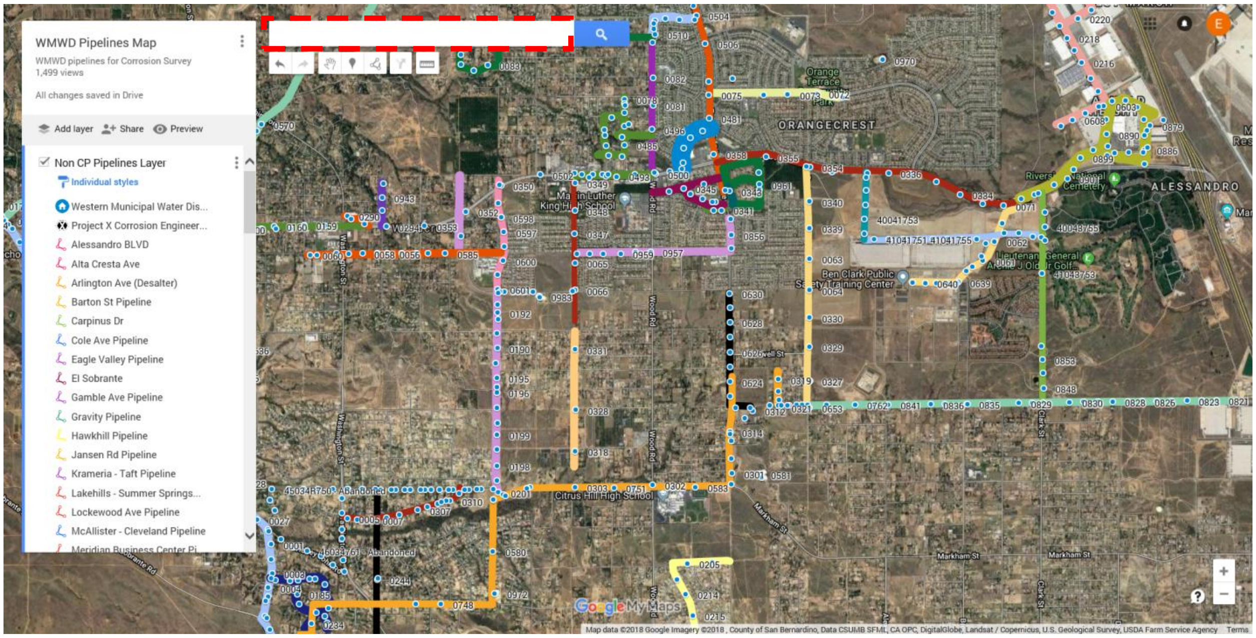
11.8 Map of WMWD Pipelines and Reservoirs



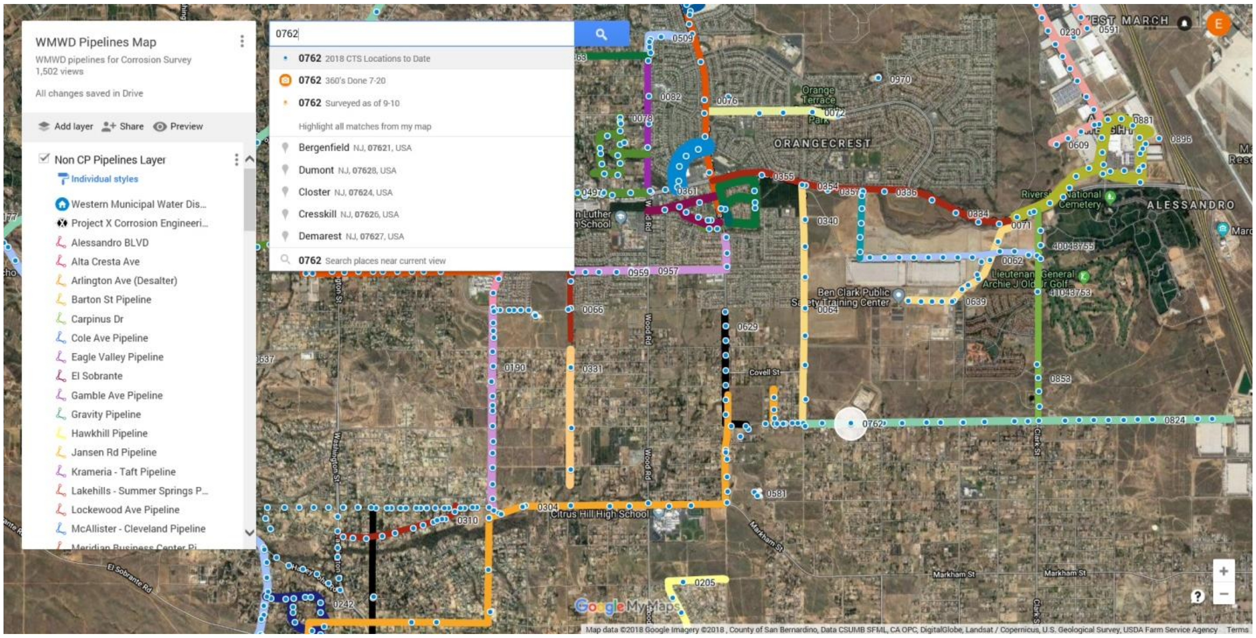
11.9 Instructions to locate a CTS with Google Maps

Two sources are used to locate CTSs: WMWD GeoViewer8 and Google Maps.

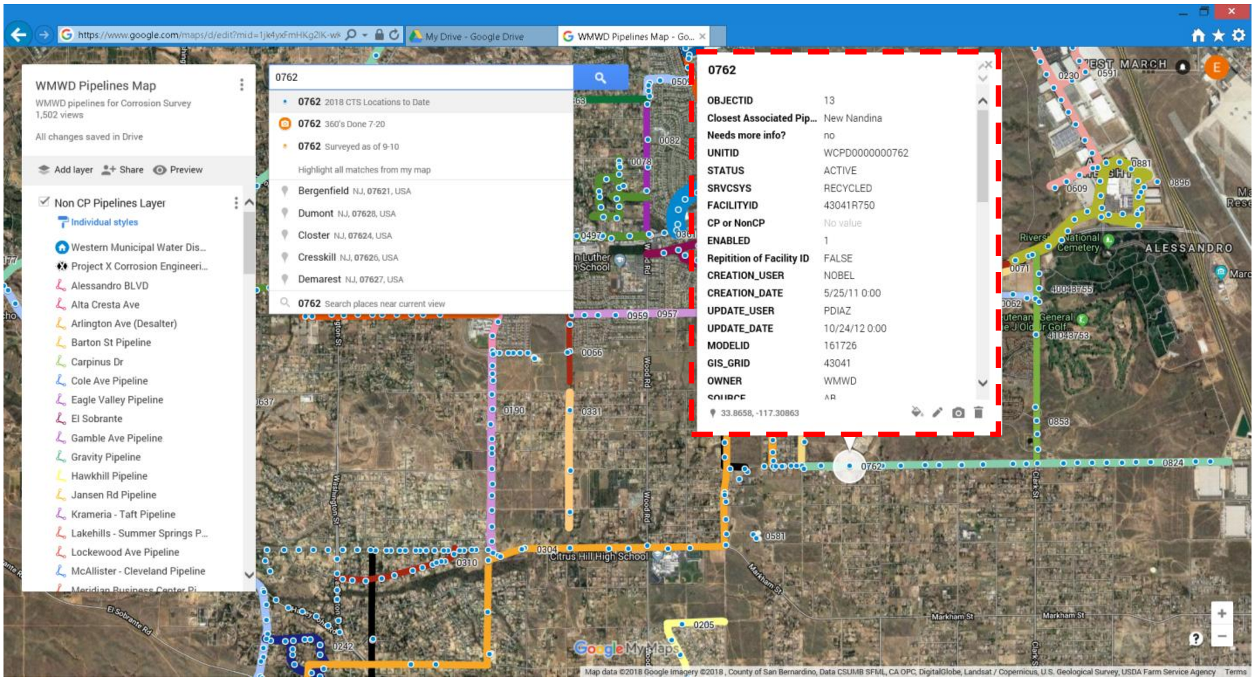
The below will guide the user on how to search for a specific CTS using Google Maps.
Link: https://www.google.com/maps/d/edit?mid=1jk4yxFmHKg2IK-wKVz7Reipi321rFbDn&ll



- Type in the CTS number you are interested in locating in the red dashed box.
- For example type in 0762



- Click on 0762, do not press enter



- The results in the red dashed box populate

12 WMWD preferred CTS Wire bonding method

CADwelding or arc welding has been the norm for field bonding of copper wires to pipes and fittings for many years. Pin brazing is a newer method which is gaining acceptance among users due to its ease of use, no need for thermite molds designed for specific pipe diameters, and for its consistent weld connection. Pin brazing is allowed on submarine piping and offshore oil infrastructure.

Exothermic thermite based Cadwelds of thin wall ductile iron or steel pipes can sometimes completely burn through the metal wall leaving a pinhole. Prior to cadwelding a pipe or structure, a sample pipe should be cadwelded to confirm that the thermite charge is not too strong resulting in a pin-hole.

Arc welding can also result in pinholes but is largely dependent on operator skill. A skilled operator will not create a pinhole.

Pin Brazing is performed using a tool similar to a nail gun with a trigger. The wire and connector is placed on the gun tip, held against the item to be bonded, trigger pulled and bonding is complete similar to copper pipe soldering. The other benefit of Pin Brazing is that gravity does not affect where bonding can be performed as is the case with Cadwelding. Pin brazing systems are portable systems as heavy as a car battery. As pin brazing does not exceed 650C, and is almost instantaneous (2 seconds), the metal heat affected zone is much more localized and focused on the surface not affecting internal epoxy coatings or liners. **Error! Reference ource not found.** shows the effect of brazing and thermite welding on internal pipe temperatures.

Project X Corrosion Engineering examined cross sections of Pin Brazed wire connection, Cadwelded connection, and an Arc welded connection. We found the fusing of substrate to copper cable to be equal in strength and quality between cadweld and pin brazing as reported in other papers[1]. Fusing between bolts and ductile iron pipe using arc welding was found to be extremely poor due to the fusing of metals only occurring on the outskirts of the bolt.

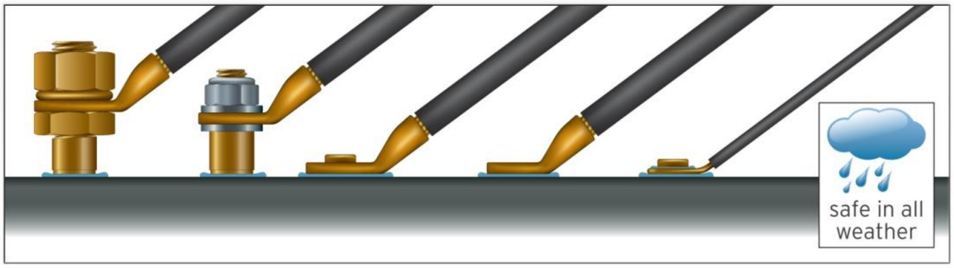
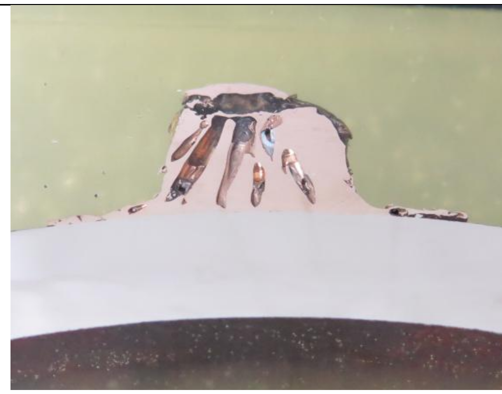


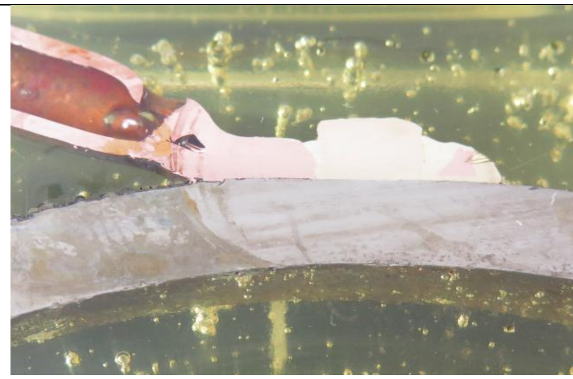
Figure 12.1 Typical Brazing Pins

[1] http://anticorr.com/DOWNLOADS/Integrity_of_Pipe_to_CP_System_Connections_2008.pdf

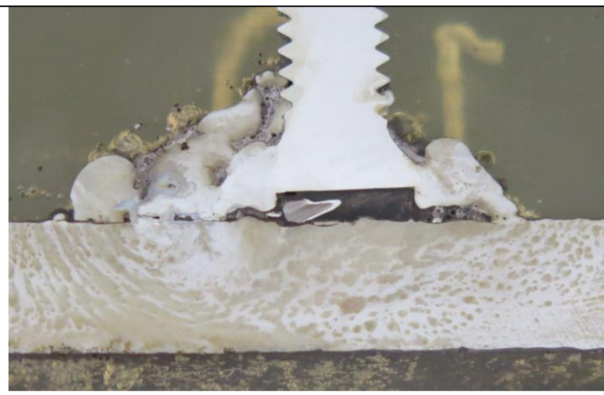
CADWELD


CADWELD


PIN BRAZE


PIN BRAZE


Arc Weld


Bolt Arc Welded


Pin Braze, internet image

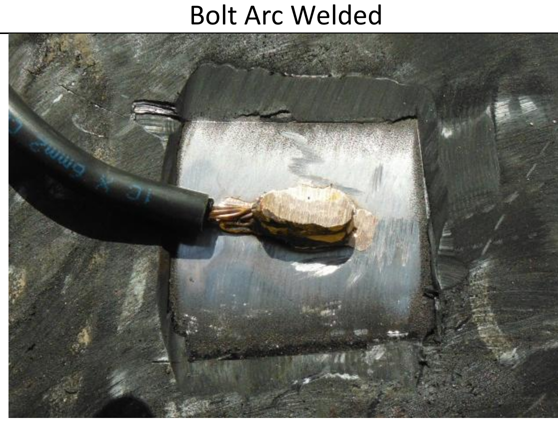

CADWELD, internet image

Figure 1 Wire Bond Comparisons

12.1 Pin Brazing Instructions per BAC

Instructions in accordance with BAC CORROSION CONTROL (https://www.corrosionservice.com/wp-content/uploads/2015/08/Pin-Brazing-procedure-PB001.pdf)

BAC® CORROSION CONTROL	PIN BRAZING PROCEDURE PB001	RCSL® CORROSION MONITORING

Rev.	Date.	Issue Type.	Prepared by:	Checked by:	Approved by:
1	28/08/2013	Issued	LG	SJ	SFG

OPERATION OF EASYBOND PIN BRAZING UNIT

1 PREPARATION OF THE SURFACE

It is crucial that to achieve a successful pin braze, the area of connection onto the pipeline (or other metal substrate) has a clean bright metal finish. In order to achieve this some degree of surface preparation will be required.

Pipeline and plant owners often have their own procedures for surface preparation and you should fully familiarise yourself with these procedures prior to any surface preparation works.

STEP ONE

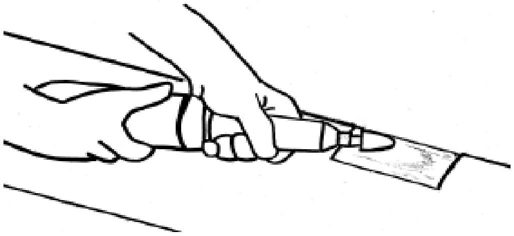


Figure 4

If necessary, the surface encompassing the pin braze area and adjacent earth connection shall be degreased before any grinding operation.

Scrape and clean the steel and clean an area for the earth device as near as possible to the braze area as illustrated in STEP ONE - figure 4.

The metal surface must then be prepared to a bright clean finish to ensure a sound electrical connection between the earth device and the substrate. Never continuously work the metal such that any wall thickness is reduced.

An area sufficient to accommodate the brazing pin and cable lug must be correctly located and cleaned to a bright metal finish.

To prevent the cleaned metal surface re-oxidising, we recommend that pin brazing must take place as soon as possible after surface preparation, i.e. not more than 5 minutes delay.

Note that when using the optional 18V grinder (part #273 199 0685) you must carefully read the specific instruction manuals for this equipment. The manuals detail the safe operation of the equipment and the PPE required during their use.

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2 LOADING THE PIN INTO THE BRAZING GUN

Load the gun with a brazing pin and ceramic ferrule individually by hand. Ensure that they are both back fully inserted and tight with the palm of your hand, as illustrated in STEP TWO – figure 5.

STEP TWO

Figure 5

DO NOT STRAIGHTEN THE KINKED END OF THE PIN FUSE WIRE.

The legs of the pin holder must be adjusted as necessary to ensure a firm grip of the pin while maintaining concentricity with the ferrule holder.

Important:

Under no circumstances should a brazing pin which has been inserted and then removed from the gun be re-inserted and used for brazing without checking the kinked end profile and fuse wire connection to pin.

3 ADJUSTMENT OF BRAZING GUN

Before connecting the earth device to the steel, adjust the brazing pin "Lift Height" as follows:

Hold the cable lug or stinger flat on the steel surface (for direct pin connection). Insert a loaded brazing pin into the hole in the lug and press the gun/ferrule against the surface of the lug evenly overcoming the internal spring. Turn the ferrule holder until the white adjustment indicator tube is flush with the gun's rear face. The brazing gun should now be correctly set, as illustrated in STEP THREE – figure 6.

When using threaded brazing pins, i.e. M8 brazing pin, the ceramic ferrule must be flat against the steel surface when checking the white adjustment indicator tube.

STEP THREE

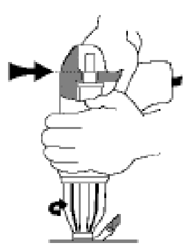

Figure 6

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4 LOCATION OF CONNECTIONS

The desired position of the required pin braze area should be accurately marked on the steel. Do not use any oil based marker e.g. spray paint, as this will contaminate the grinding burr.

When pin brazing onto a coated pipeline then sufficient coating needs to be removed in order to accommodate both the earth device and area of the pin braze, this would be a minimum of 14 cm x 4 cm using the standard earth device. If the earth device is placed on a separate earth point on the pipe then the area required at the pin braze point will be a minimum of 4 cm x 4 cm.

5 PIN BRAZING

STEP FOUR

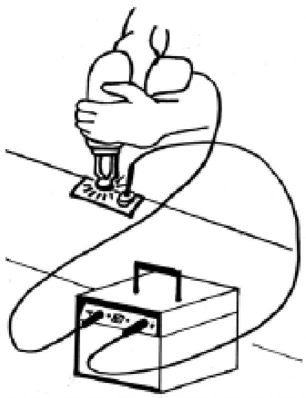

Figure 7

1. The magnetic earth device must be applied to the cleaned surface to ensure a sound electrical circuit.
2. The brazing gun must be correctly adjusted with the correct pin and ferrule fitted.
3. Locate the brazing pin so that the pin is in the centre of the hole in the cable lug. For vertical surfaces, the pin must be at the upper part of the hole in the cable lug.
4. Apply sustained pressure on the brazing gun so that full contact is made between the ferrule and the bond attachment (or the steel surface when using threaded pins).
5. When the operator is ready to braze, he should look well to one side to protect his eyes from glare. The operator's stance should be stable to enable this movement to be made without altering the critical positioning of the gun.
6. Hold the gun firmly and close the circuit by squeezing the trigger.

KEEP THE TRIGGER DEPRESSED UNTIL THE BRAZE IS COMPLETE

7. After about 2 seconds the fuse wire should rupture, disconnecting the circuit. The arc will extinguish and the pin or stud will be shot forward into the molten filler.

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8. In the event of a fuse not rupturing after the normal time, the gun must be withdrawn completely from the work, keeping the trigger depressed.

9. After the fuse has ruptured, the gun must be held in place for a further 3 seconds to allow the braze to set

10. Remove the gun by pulling straight off the pipe or substrate in line with the brazed pin, then break out the ferrule if this is remaining in the ferrule holder. This can be achieved by levering against a suitable edge. Beware, it may be hot.

11. Hold the gun in a vertical position then depress the ejector button to expel the remaining fuse wire. Catch the wire in your hand to ensure it has been ejected, as illustrated below in figure 7(a).

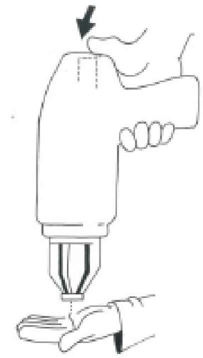

Figure 7(a)

6 TESTING A COMPLETED BOND

Threaded pin attachments should be tested by a torque device. For an M8 pin the torque device should be set to 10 Nm. The threads will fail at 25 Nm so do not use excessive force.

Direct braze pin attachments must be tested as per STEP FIVE – figure 8 as follows:

The shank of the plain pin must be carefully broken off with a hammer taking care not to damage the lug. This must be done before another pin braze is made to the bond. After breaking off the shank the broken surface should be level or thereabouts with the outer surface of the lug (figure 9 [A]). The lug shall be complete in all aspects.

STEP FIVE

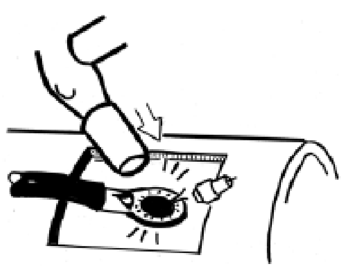

Figure 8

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If the surface of the broken pin is proud of the surface of the lug this is an indication that the brazing time was too short * (figure 9 [B]). The reason for a short braze time is usually the result of excessive current being drawn due to the gun "lift height" being incorrect. This short time can also be caused by a poor earth connection.

If the surface of the broken pin is below the surface of the lug, this is an indication that the brazing time was too long (figure 9 [C]). The reason for a long braze time is the result of insufficient current being drawn. Insufficient current is usually the result of a poor battery condition.

If it is known that the battery is good then the cause may be incorrect setting of the gun "lift height".

If the ferrule is not held against the copper lug and is in partial contact then the arc can escape out of the gap and this will result in the side of the copper lug burning away.

Warning: Repeated bond attempts must not be made at the same position as this may cause structural/metallurgical damage to the base steel.

**** When using cable lugs part number #278 100 9000 /#278 100 7360 this result (figure 9 [B]) is acceptable due to thickness of copper material at braze area. Height of remaining brass shank should not exceed 2mm.***

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FAULT DIAGNOSIS OF UNSATISFACTORY PIN BRAZE CONNECTION

Some common problems can be experienced by operators when first using the equipment. Listed below are a series of faults together with the most likely cause and remedy solutions. In the event of persistent problems or faults, contact the service engineer for advice or repair.

PROBLEM	POSSIBLE CAUSE	REMEDY
No arc or there is a short "pop" of the pin	Circuit not complete or highly resistive	*Check fuse wire on pin is engaged* *Check earth device is connected*
	Batteries flat	*Charge/replace batteries*
Arc time too short Figure 9 (B)	Excessive current drawn Poor earth connection	*Check gun adjustment* *Reset earth connection*
Arc time too long Figure 9 (C)	Insufficient current drawn	*Check gun adjustment* *Recharge batteries*
Bond falls off when tested	Too short brazing time Base metal not clean enough	*See above* *Thoroughly clean the area to be brazed*
Fuse wire stuck in contact nipple	Pin loose in holder Failure to eject previous fuse wire	*Tighten fit of pin holder jaws* *Replace contact nipple*
Brazing pin fails to push into molten braze material	Pin is out of line from the ferrule due to off centre ferrule holder jaws caused by heavy removal of spent ferrule	*Take care not to bend ferrule holder jaws when removing spent ferrule* *Replace ferrule holder*

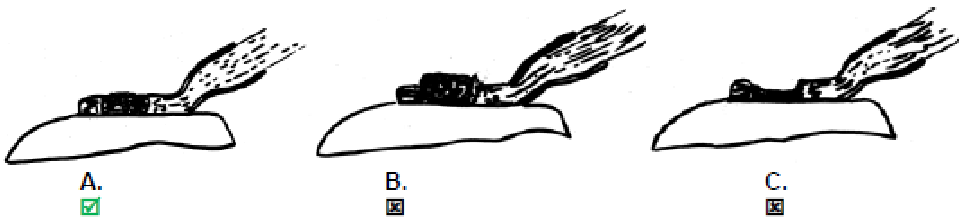

Figure 9

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