

CATHODIC PROTECTION



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About The Program

Cathodic Protection is a program of training material intended for propane technicians who install residential and small commercial underground ASME tanks and piping. The program provides basic knowledge and requirements for the technician to properly and efficiently provide cathodic protection for underground steel ASME tanks and piping from corrosion.

The program is conveniently divided into five sections.

1. An Introduction covering the basics of corrosion, the principles of cathodic protection, and the methods to achieve protection.
2. Galvanic Protection including anodes, pre-installation procedures, installation procedures, electrical isolation, testing equipment, tank-to-soil potential tests, troubleshooting and retrofitting.
3. Impressed Current Overview which briefly covers installation and maintenance.
4. A 48 question fill-in-the-blank quiz with answer key.
5. A Skills Evaluation form.

The following training tools are available:

1. An instructional manual (either on CD or in paper format), including the optional quiz and answer key.
2. A companion DVD to be used as a visual aid.

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Introduction **1.0**

1.1 Basics of Corrosion

Corrosion is an aggressive form of rusting... and rust to a steel propane tank and metallic piping can be fatal.

Heavy steel propane tanks and metallic piping may seem indestructible.



But as steel ages, it begins to show its age as rust. Some rust is superficial and does not cause serious concern. However, if the steel is in a bad environment such as wet ground that contains natural or man-made chemicals, the rusting process accelerates. This is what we call corrosion.



Over time, the corrosion causes structural problems, creating pits or holes in the steel. Left alone and ignored, these holes may leak, releasing propane into the ground. The concern is that the leaking propane can migrate into a crawl space or basement of a building. Corrosion can virtually destroy a propane tank or piping, and leaking propane is potentially dangerous.



1.2 The Principles of Cathodic Protection

To live a long and productive existence, propane tanks and metallic piping also need protection . . . Cathodic Protection. In general terms, Cathodic Protection can be used to protect ASME (American Society of Mechanical Engineers) underground steel propane tanks and piping from corrosion. This is done by making the tank a cathode. Cathodes will be discussed further in the manual.

Corrosion can be defined as a disease of steel. Coating the steel tank like many of the manufacturers do in the factory is the first line of defense against corrosion.



Cathodic protection is the second line of defense. It will make a steel propane tank and its piping immune to the disease of corrosion.



1.3 Methods to Achieve Cathodic Protection

Underground propane tanks and metal piping can be cathodically protected in two ways.

The most common way is with magnesium anodes.



Another is with impressed current using power from the local electric utility company. Although the two methods differ greatly, what's important to remember, is that cathodic protection can extend the life of an underground tank by helping to prevent corrosion and rust. Impressed current systems will be covered later in the manual.





CATHODIC PROTECTION CATHODIC PROTECTION

Galvanic Protection **2.0**

2.1. Galvanic Protection and Anodes

Galvanic Protection uses anodes. Although there are dozens of different types of anodes, the three most commonly used in the propane industry include high potential magnesium, (AZ-63 or H-1) magnesium alloy and zinc.

Typical installations use one or more anodes based on container manufacturer's instructions, geographic location, advice from cathodic protection experts, and company procedures and policies.



High potential anodes may be used in dry or sandy areas where it's important for greater voltage, and therefore more current. These anodes produce a minimum of minus 1.75 volts, versus 1.5 volts for standard anodes.

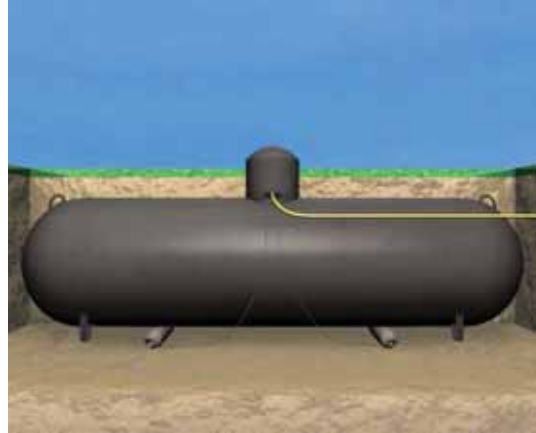


Zinc anodes can be used to protect underground propane tanks and piping in coastal areas where groundwater may be brackish or salty.



However, standard minus 1.5 volt magnesium anodes are more generally used in the propane industry because they work best in the majority of underground conditions found in the United States.

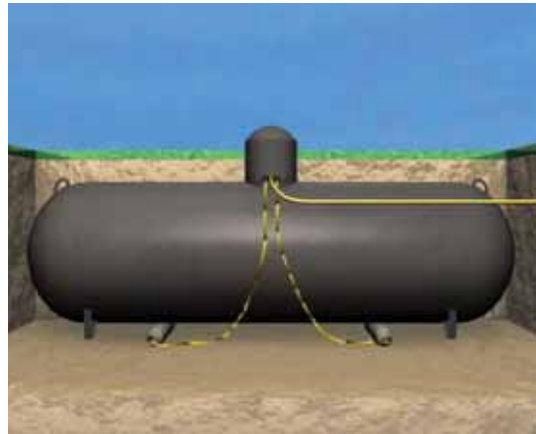
The purpose of the magnesium anode is to protect the tank and connected steel piping by providing current and electrons to the entire surface area of both.



In doing this, the anode acts like a light bulb, lighting up the surface of the steel tank.



This happens because electrons flow from the external magnesium anode along a wire to the steel tank...the cathode. At the same time, a small electric current measured in milliamps flows through the earth from the magnesium anode to the steel cathode. By using natural laws and processes where electric current flows from a high voltage source to a lower voltage receiver, man-made anodes of higher voltage metal such as magnesium will artificially prevent lower voltage metal like steel from decomposing. The electrons actually prevent the iron atoms in the steel from oxidizing into rust. And if enough electrons flow from an anode to the tank, it will not corrode, because the voltage of the tank will change.



2.1

This voltage can be measured with a voltmeter and a copper sulfate electrode.



Although different metals have different voltage readings, the voltage reading of steel is naturally around minus 0.50 volts.

Commercially Pure Magnesium	-1.75
Magnesium Alloy	-1.6
Zinc	-1.1
Aluminum Alloy	-1.05
Commercially Pure Aluminum	-0.8
Mild Steel (Clean and Shiny)	-0.5
Mild Steel (Rusted)	-0.2
Cast Iron	-0.5
Lead	-0.5
Mild Steel in Concrete	-0.2
Copper, Brass, Bronze	-0.2
High Silicon Cast Iron	-0.2
Mill Scale on Steel	-0.2
Platinum	0 to -0.1
Carbon, Graphite Coke	+0.3

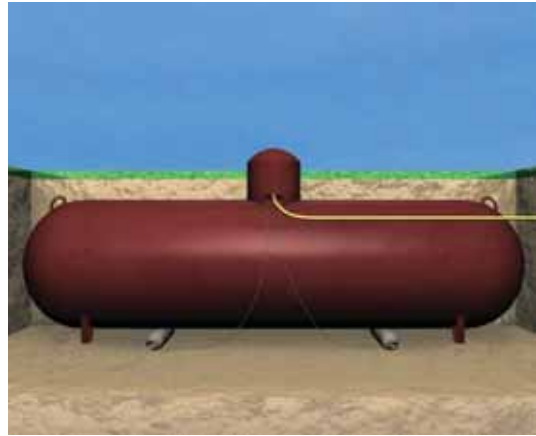
A voltage of minus 0.50 volts on a propane tank would indicate that the tank is unprotected and is susceptible to corrosion.



To avoid corrosion, the electrons must shift the voltage of the steel to a minimum of minus 0.85 volts or more. The rule is the higher the voltage, the better. However, the electrons should not shift the voltage above a minus 2.00 volts.



When a tank is totally protected from corrosion, it means that the entire tank has become a cathode. The length of the protection measured in years is dependent on the severity of the environment in which the tank is installed. If the tank is installed in non-corrosive dry sandy soil, it may be relatively free of corrosion and the anode will last a lifetime. However, if the tank is installed in wet, fertilized and sticky clay like under a lawn or flowerbed, the anode could possibly be consumed in less time.

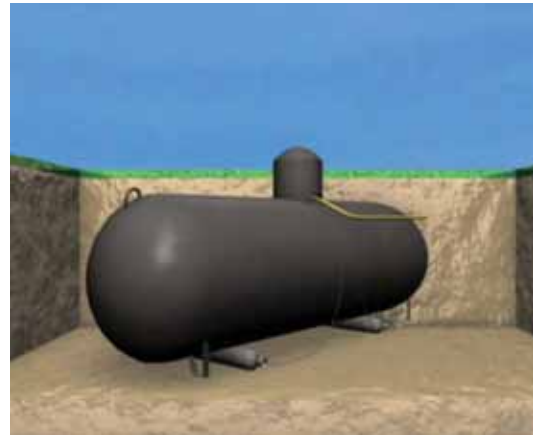


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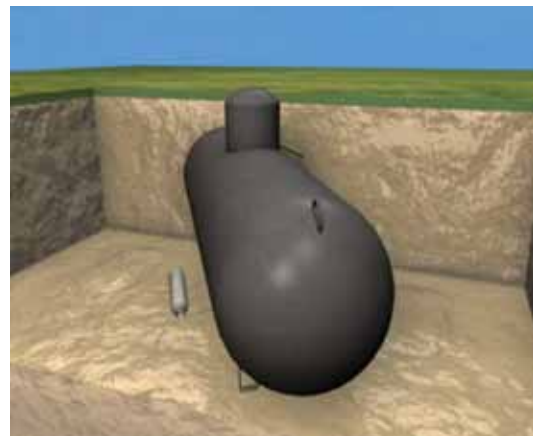
2.2 Pre-Installation Preparation

But remember, before you do any digging, first refer to your company's policy, or call the national hotline (811) or your local one-call system to prevent damage to underground structures.

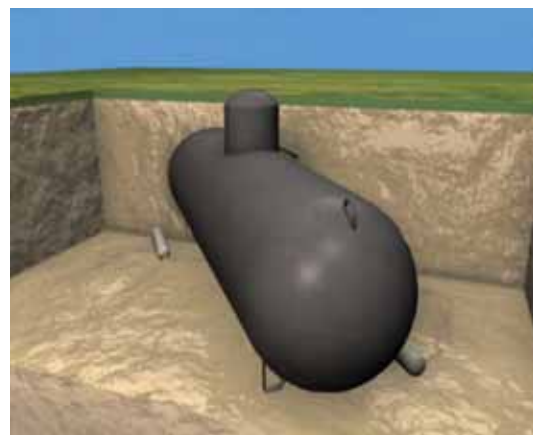
Although there are several locations where an anode can be placed, one way is to dig a hole so that the anode can be placed below the bedding of the tank. If two anodes are being used, you'll dig two holes.



Another way is to place the anode beside the tank. Again, if two anodes are being used, one can be placed on each side or each end of the tank.



When installing two anodes, they can also be placed diagonally from each other at the ends of the tank.



2.3 Installation Procedures

The first thing is to remove the outer box or plastic bag from the anode. The anode should be wetted. One good way to wet the anode is to place it in a bucket brought to the jobsite and then fill the bucket with water. The idea is to let the anode soak up the water. It will do this because the anode is packaged in a bag of gypsum, sodium sulfate and bentonite clay. After a couple of minutes, turn the anode upside down in the bucket so it soaks up the remaining water. Another way to wet the anode is to pour water over it from the container. Just make sure you get it good and wet and that the water soaks in. This procedure ensures moisture retention and good soil contact. That way the anode will work more evenly.

Once the anode is placed in the hole, unwind the wire and temporarily anchor it to the top of the hole with a dirt clog or rock. Then cover the anode with dirt from the hole.



2.3

Run the anode wire to the connecting lug or tank lead wire and make the connection with a silicon filled underground wire connector. This is where the manufacturers have made the job easier. There are no more Thermite welds that formerly needed to be performed.



The integrity of the tank coating is one factor in the success of the Cathodic Protection system. Once the tank has been set, make sure you've touched up any damaged areas on the tank that happened while loading, in transit, or unloading at the job site. Tank fabricators and coating manufacturers supply touch-up kits that are easy to use. Use a piece of coarse sandpaper to rough up the area around the ding. Wipe the area clean with a dry cloth and then apply the coating per manufacturer's instructions. Doing this puts less of a drain on the anode.



In desert or semi-dry parts of the country, and after the tank has been set, anodes should stay wet so that you get acceptable results on the tank-to-soil test. One way to do this is to place a two inch diameter, five foot long plastic pipe, or any kind of flexible tubing into the hole next to the anode. Keep it upright while the hole is being partially backfilled. After the tank has been buried, the top of the pipe should extend a few inches above the ground. In order to keep what ground moisture there is from evaporating through the pipe, place a cap on the pipe.



Once the installation is complete, you'll want to document it for future reference. Follow your company's policy and local codes, but remember, in snowy climates, NFPA 58 requires the tank location to be marked.



2.4 Electrical Isolation

When metal pipe like steel or copper is used, electrical isolation becomes critical. All metals have a unique voltage stored within them.

Bare copper lines must be isolated from the tank at the outlet of the regulator on the tank to prevent anodes from having to supply more electrical current than necessary to protect the tank. Care must be taken to isolate bare copper lines from metallic tank domes or the steel of the tank.

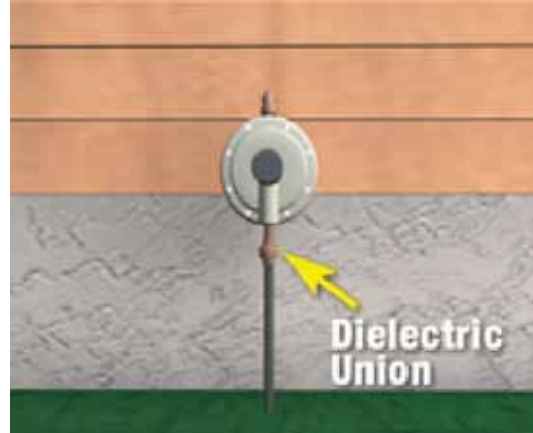


Black iron or steel lines may be protected using the same anode that protects the tank, but must be isolated from the building being served to prevent the anode from supplying electrical current to protect everything that's underground at the building that is not a propane pipe.



2.4

A dielectric union may provide the necessary isolation. Without a dielectric union to isolate the tank from bare pipe, or insulation to prevent a bare copper tubing from touching the tank through a metal dome, the current can collect on interconnected underground copper and steel pipe that connects a customer's well casing or the city water system and the electrical grid. This unwanted loss of current is like having the cathodic protection "light" illuminate all the unwanted previously mentioned structures.



2.4

2.5 Testing Equipment

Checking your cathodic protection system is vitally important. It's easy and takes just a few moments.

All you need is a voltmeter and a copper sulfate electrode to measure the voltage or stored energy surrounding the tank and its piping.



2.5

2.6 Tank-to-Soil Potential Tests

First, if the ground is dry where you're going to take the readings, moisten it with water. Also, make sure the electrode has been properly maintained per the manufacturer's instructions.



Next, set the voltmeter on the 2 volt DC or the 20 volt DC scale.



Then connect the voltmeter to the tank, with the positive lead connected to the multivalve©, and the negative lead to the copper electrode. Do this at the multivalve© rather than the dome. While many newer domes are made from a poly/plastic type of material, even if the dome is metal, it might be loose and you probably won't get a good reading. The multivalve© is well connected to the tank, and regardless of whether there is brass, steel or any other metal on the valve, the important thing is that it is a metal to metal connection between the voltmeter and the tank.



2.6

Then take a couple of steps to the side of the tank opposite the dome. You'll want to be just above where the side of the tank is underground. Stick the tip of the electrode into the ground where you have moistened it, and take your reading. Record your data according to company policy. Repeat the process on the opposite side of the dome, and then at both ends of the tank. It is important to take four tank-to-soil potential readings around a tank to get a complete picture of the cathodic protection level. It is possible to record a good reading above -0.85 volts on one end or one side of a tank and have a bad reading below -0.85 volts on the opposite end or opposite side of a tank. When this happens, the areas of the tank that have readings above -0.85 volts are protected while an area with a reading below -0.85 volts is not protected and could still suffer corrosion damage. A single reading would not detect an area of low protection. And remember, you'll want to record all four readings. This information can be valuable for future reference.



The voltage reading on a healthy tank should be equal to or greater than minus $.85$ volts. The voltage of an anode should be at least minus 1.5 volts. The voltage of an unprotected tank is usually around minus $.50$ volts. When the anode is connected to the tank, the two voltages average somewhere in between. If the average voltage is high or close to the voltage of magnesium, -1.50 volts or higher, this indicates the tank's coating is good. If the voltage is low or close to the voltage of steel, there may be any variety of problems with the tank or installation. Perhaps the *anode was not connected to the tank properly*. If the copper anode wire does not make good strong metal-to-metal contact with the tank, the reading could be low. Another possibility for a low reading is that the *electrode was not making good contact with the earth*. Additional reasons might be the *rubber boot was not removed from the electrode*. The *battery in the voltmeter was dead*. The *electrode and the connection to the tank were not good*. Or, the *anode has been consumed and needs to be replaced*.



2.7 Troubleshooting and Retrofitting

When a reading at an existing installation is zero, you'll have to do some troubleshooting. The following is a laundry list of things to check when troubleshooting.

1. Start with the voltmeter. Is it on?
2. Is the battery good?
3. Have you taken off the rubber boot on the copper sulfate electrode?
4. Have you set the voltmeter switch to the d.c. volt scale?
5. Have you connected one lead wire to the copper sulfate electrode?
6. Have you connected the other lead wire to the multivalve© securely?
7. Does your copper sulfate electrode have a blue liquid in it?
8. Have you set the electrode firmly on the ground?
9. Have you poured a glass of water on the ground if the ground is dry?
10. Are your lead wires and their connections good?



2.7

Bad Readings
-0.80
-0.70
-0.60
-0.50
-0.40
-0.30
-0.20
-0.10
-0.0



Good Readings
-1.80
-1.70
-1.60
-1.50
-1.40
-1.30
-1.20
-1.10
-1.00
-0.90
-0.85

If everything you've checked is okay, and the meter reading is below -0.85 volts, the following is a second checklist. But remember, not all of these items are going to be off mark at the same time.

1. In the dome, is there copper tubing leading from the regulator?
2. Is there a dielectric or insulating union between the copper tubing and the tank?
3. Is the coating on the tank peeling off or non-existent in the dome?
4. Is there a steel service pipe and no dielectric union in the piping at the building?
5. Is there electrical continuity between the multivalve© and the pipe into the building? Check this using the ohms resistance setting and a jumper wire between the multivalve© and the pipe at the building. A reading less than 20 ohms indicates there is continuity between the tank and the building.
6. The anode wire may not be securely connected to the tank.
7. The anode may have been buried still inside its plastic bag.
8. The anode may be dry.
9. The anode may be old and have been consumed.
10. The anode may have been too small (1 lb, 3 lb, 5 lb. anodes are too small).
11. The anode may be lying up against the opposite side of the tank.
12. Is there a plastic liner under decorative rock or bark between the electrode and the tank? If so, punch a small hole with a pencil and pour water at the hole before taking the reading again.
13. Are you connected to a metal dome and not the multivalve©?

If everything checks out that you can see, the ground is moist and your readings are still below -0.85 volts, try this.



Take an anode out of its protective plastic bag or box, lay it on the ground next to the tank, pour water on the anode and let the water flow onto the ground.



Using a 12" jumper wire with alligator clips on each end, connect one end to the multivalve[©] and the other end to an anode wire. The voltage readings on the tank should start to increase in the direction of -0.85 volts. If the voltage readings do not change, you could disconnect a copper service line at the first stage regulator inside the dome. If the tank-to-soil voltage readings immediately jump above -0.85 volts, you need to install a dielectric union inside the dome. If the voltage slowly increases, you can now think about retrofitting the tank by adding a new anode.



If you need to retrofit an existing tank, before you do any digging, refer to your company's policy, or call the national hotline (811) or your local one-call system to prevent damage to underground structures.

First, verify there are no sprinkler lines, low voltage electric wires, the propane service line or other owner installed bulbs or wires where you plan to dig.



Cut out a plug of grass five feet to the side of the dome with the shovel and set it aside.



Dig a vertical hole at least 3 ft. deep. If this isn't possible, you may have to lay the anode down horizontally. In dry environments, the anode may work better if it is laid horizontally in a ditch 18 in. deep where sprinkler or rain water will wet the anode. As stated earlier, if the tank is in a desert environment, set a PVC pipe in the hole with the anode so that water can be poured into the pipe to wet the anode.



Place the anode in the hole and pour water on it.



2.7 Touch the anode wire to the multimeter while taking a tank potential reading. The reading should be above -0.85 volts. If so, continue with the installation. If the reading is still not good, refer to the troubleshooting list on page 21.



With the shovel, wedge the grass apart from the anode to the dome, and push the wire down below the grass into the dirt.



With a portable electric drill, drill a hole through the dome...



...and insert a rubber grommet in the hole. Then, push the wire through the hole into the dome.



Connect the wire to the tank at the stud under the multivalve©, or to the riser pipe using a band clamp. Any water proofed secure connection between the anode wire and the riser pipe or multivalve© will cause the tank potential readings to shift to the protected level of -0.85 volts or greater.



Fill the anode hole with the dirt removed during digging and use the shovel handle to tamp the dirt around and on top of the anode. This fills in the voids between the anode and the hole you dug. If you don't do this, there will be a gap between the anode and the hole that the current can not flow across. This will reduce the amount of current your anode creates, and cause the readings to be lower than what is possible. Replace the plug of grass on top of the anode hole and push the separated grass back together where the anode wire was run.



Once you've completed these steps, one last major thing to do is to take a tank to soil potential test. This was covered on pages 18-19 of the manual. Remember though to take four readings, one on each side of the tank and one on each end, with a healthy reading being any voltage equal to or greater than minus .85 volts. But in the unlikely event that one anode does not increase the readings to a protected level of -0.85 volts or greater all around the tank, install a second anode on the opposite side of the tank. And...just like the original installation, once done, you'll want to document your work for future reference. Follow your company's policy and local codes.



If after following all these procedures and your reading still does not increase to -0.85 volts or greater, it is possible the container is too corroded and may need to be removed from service. Check with your supervisor for company policy regarding these guidelines.

2.8 Gas Piping Protection

The following are general recommendations for protecting lines connecting underground tanks to buildings or gas utilization equipment such as generators. These recommendations are based on commonly accepted installation codes and good operating practice. Any deviations should be with the recommendation of a corrosion specialist and approval of the authority having jurisdiction.

Coated Steel or Black Iron Pipe – The anodes installed to protect the tank will also protect coated steel or black iron gas lines where a dielectric union is installed at the building or gas utilization equipment.

Coated Copper Tubing – The anodes installed to protect the tank will also protect coated copper gas lines where a dielectric union is installed at the building or gas utilization equipment.

Uncoated Steel or Black Iron Pipe - Uncoated steel or black iron piping is not recommended. NFPA 58 and good installation practices requires black iron or steel pipe to be coated.

Uncoated Copper Tubing - Because uncoated copper tubing does not present corrosion problems in most soils that can result in reduced anode performance and life, this material must be isolated from the underground tank being cathodically protected. Use of uncoated copper tubing is dependent on local soil conditions and approval of the authority having jurisdiction.



Coated Steel or Black Iron Pipe With Uncoated Fittings - Uncoated fittings should never be used with coated black iron or steel piping. All pipe fittings must be coated and wrapped before burial.

Since coatings, pipe sizes, composition and lengths vary from one job to another, the -0.85 volt criterion will determine whether one anode or multiple anodes are needed to achieve protection. Multiple readings over and along a pipe may be needed to confirm that a single anode is protecting the gas line from the tank to the building.



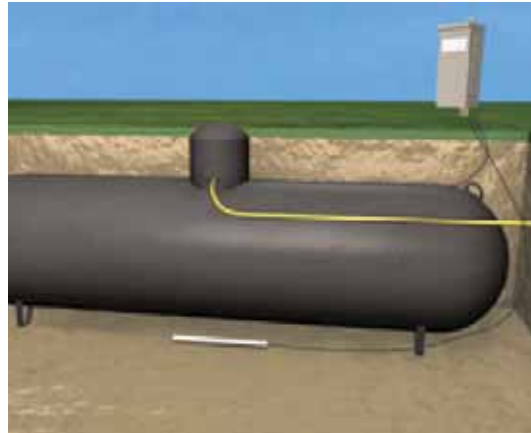


Impressed Current Overview **3.0**

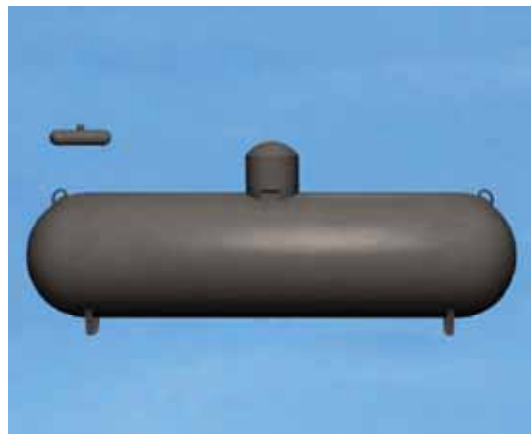
3.1 Impressed Current . . . An Overview

Earlier in the manual, we said there were two ways to protect underground steel tanks and metal piping from corrosion, with the most common being galvanic protection using magnesium anodes.

The second way is with impressed current. But there's a major difference in how the two work and where you use one versus the other.



Whereas galvanic protection works well with small tanks usually meant for residential and small commercial applications, impressed current is meant for large bulk storage tanks. And know that a company specializing in cathodic protection should design systems for installations larger than 4,000 gallons.

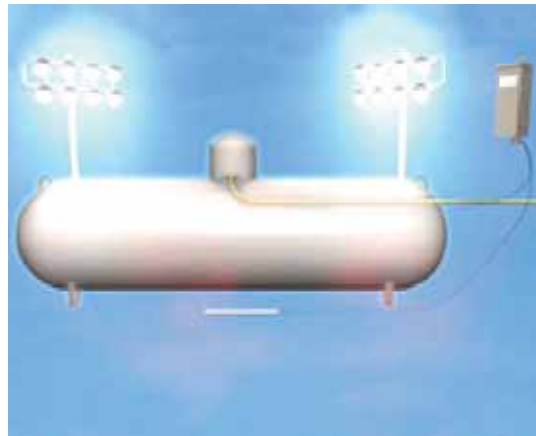


3.1

Earlier, we discussed the current from an anode as light from a light bulb.



Current from an impressed current anode is similar to light from a bank of stadium lights. Therefore, one or two impressed current anodes is enough to bathe in light . . . or protect the entire surface of any size commercial tank . . . its liquid lines, vapor lines and anything else nearby.

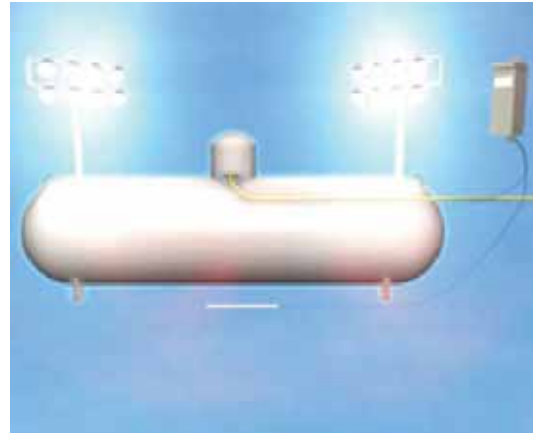


How does this work? The impressed current anode gets its power from a rectifier which is like a transformer and is as small as a shoebox. This rectifier turns a.c. voltage into d.c. voltage like a battery charger.



3.1

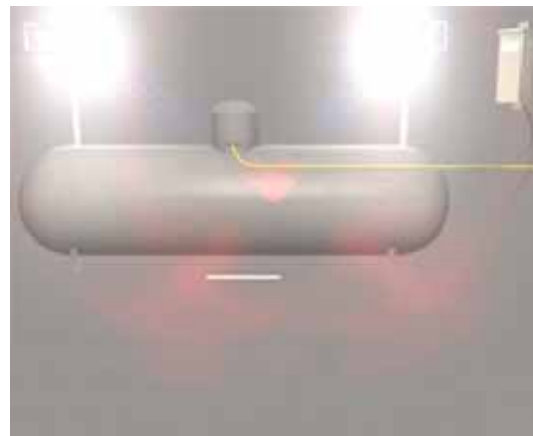
Whereas a magnesium anode has the power of a 1 volt battery, a rectifier and its anode or anodes have the voltage of a car battery and more! With more voltage, you get more current, or as in our example here . . . more light.



If there is resistance in the ground, that resistance will block the current from an anode like smoke blocks light.



But the impressed current rectifier has the power to force the current through the resistant earth like a searchlight through smoke.



3.1

Although we simplified it, what we've just discussed are a few of the major differences between galvanic protection and impressed current protection. Of course there are a lot of other differences.

Impressed current anodes are made of a special alloy of cast iron, silicon and chromium. Unlike magnesium anodes which are covered with dirt from the hole that was dug, impressed current anodes are first encased in coke breeze backfill, a good electrical conductor, and then covered with dirt from the excavation. Also, if the coating on the tank disintegrates as it gets old, the additional current from the impressed current anode can compensate for the lack of coating. Finally, as alluded to earlier, if there are electrically grounded structures to the tank, or a long run of underground steel liquid or vapor lines, the rectifier system can also protect them for many years.

Installation

When it comes to installation, know that high voltage is very dangerous! Impressed current can also, on occasion, harm unrelated buried structures around a commercial tank system. Impressed current systems need to be designed and installed by people trained in the science of cathodic protection . . . people who are qualified and know exactly what they are doing. Talk with your supervisor before attempting to work with impressed current.



Maintenance

An impressed current system requires maintenance to be certain it is on, and that required current is always flowing to the anodes.

Rectifiers have amp meters that show how much current is flowing to the anodes. As long as there is an amp meter in the rectifier that shows some amperage flowing into the anodes, the system is on. A person should write the amperage output down, date it and initial the reading for future reference.



If there is ever any doubt that the rectifier is on, you should check the output voltage with a voltmeter across the + and - terminals of the rectifier, just as you would across the “+” and “-” terminals of a car battery.



Because this manual has been designed around cathodic protection for residential systems, we just wanted to give you a brief overview of impressed current. For further information and training, talk with your supervisor and see what your company offers. Just remember, impressed current systems must be inspected and maintained by persons or companies specializing in cathodic protection systems.



CATHODIC PROTECTION

Vocabulary List

Vocabulary List

A

Anode

Metal that is oxidized and consumed as it corrodes while giving up its electrons to a cathode.

In usage, a bar, rod or ingot of magnesium or zinc connected to a steel tank or pipe to provide protection from corrosion. Anodes produce an electrical current and in doing so gradually waste away (see Sacrificial Anode).

- Standard (H-1) magnesium anodes are used in average to corrosive soils.
- High purity magnesium anodes are used in dry, sandy soils.
- Zinc anodes are used where groundwater is salty or brackish.

Impressed current (rectifier) systems work by using current from the electric utility and use silicon iron anodes.

ASME

American Society of Mechanical Engineers. The ASME publishes standards for the fabrication of propane tanks.

B

Backfill

The white powder inside a bagged anode that surrounds the metal ingot. Backfill consists of 75% gypsum, 20% bentonite and 5% sodium sulfate. In usage, backfill is designed to lower electrical resistance between the anode and surrounding soil and extend anode life.

Bagged Anode

A zinc or magnesium anode encased in a cloth bag and surrounded by backfill consisting of gypsum, bentonite clay and sodium sulfate.

Bentonite

Volcanic clay used as an absorbent to absorb water in an anode.

C

Cathode

The engineering term given to any metal to be protected by an anode. More specifically, metal that is “reduced” (not oxidized) and receives electrons from an anode in a corrosion cell reaction.

Cathodic Protection

A procedure used to protect buried steel from corrosion by using anodes.

Cathodic Protection Specialist

A person certified by the National Association of Corrosion Engineers (N.A.C.E.) as qualified to solve corrosion problems using cathodic protection principles.

Coatings

Tough, chemically inert materials designed to protect metal from contact with soil. Coatings must prevent penetration by water, oxygen, chemicals (including fertilizer), mild acids, and resist mechanical abrasion from rocks, earth movements, and tree roots. Coatings must resist biological organisms that may feed on asphalt compounds.

Coke Breeze

Black granular carbon from coal or petroleum that is placed around an anode in impressed current (rectifier) systems. It is designed to lower the resistance between the anode and the earth.

Connecting Lug

A bolt welded to a propane tank by the tank fabricator used to connect the anode wire to the tank.

Copper Sulfate

The blue crystals dissolved in the distilled water solution in a copper sulfate electrode (half-cell).

Copper Sulfate Electrode

A copper rod enclosed in a plastic tube filled with distilled water and copper sulfate crystals. In usage, it has an electrical connection on one end and a porous ceramic tip on the other, and is used in conjunction with a voltmeter to measure the stored voltage of a metal in contact with earth, water or other electrolyte in a tank-to-soil potential test.

Corrosion

The electrochemical reaction that occurs when metal is buried or exposed to an electrolyte.

Corrosion cell

The components required for corrosion to occur form a “corrosion cell.” A corrosion cell consists of three components:

- A metallic path for electric current.
- An electrolyte
- An electrical potential between two metallic objects.

Corrosion cells can exist between two different metals (such as steel and copper), between two different types of the same metal (such as between the head and the shell of a tank) or between two stress areas of the same metal (such as between the welded and non-welded areas of a tank).

Installing an anode on a steel tank or line creates a corrosion cell in which the installer can determine which metal will corrode (the anode) and which metal will not corrode (the tank or line).

D**Direct Current (DC)**

Electrical current that flows continuously and does not fluctuate between positive and negative. Batteries, rectifiers and anodes all produce direct current. In usage, in a corrosion cell consisting of an anode and a buried tank, the DC current flows from the surface of the anode, through the earth, to the surface of the tank.

Dielectric Union

A connector in a metallic pipe incorporating “O” rings and rubber or plastic gaskets, installed to physically prevent one metal from touching the other. In usage, these fittings serve to isolate the metal being protected from dissimilar metals, electrical currents, and underground objects not requiring protection.

Dome

The rounded top to an underground propane tank that houses and protects the multivalve© on the tank.

E

Electrical Isolation

Separating underground pipes and tanks from other underground and aboveground structures. Without electrical isolation, anodes may be trying to protect well casings, city water systems, electrical grids and other underground metal.

Electrode

Most often means “copper sulfate electrode” or “half-cell electrode.” It can be used to describe an “anode” or a “cathode” in a corrosion cell.

Electrolyte

Soil or water through which DC current flows from a buried anode to a cathode such as a buried tank. In usage, anodes must be buried or submerged in the electrolyte in order to protect the tank or line.

Electrons

Sub-atomic particles that create electric currents that flow along the wire from an anode to a tank.

Exothermic Weld: A convenient brazing process used to connect anode wires to tanks or pipes. The weld metal consists of copper oxide flakes and finely ground aluminum starting powder. It takes some experience to make an exothermic weld. Anode wires must always be welded to a special welding pad or other non-pressure surface of an ASME tank. Two common brands of exothermic welding are Cadweld[®] and Thermoweld[®].

F

G

Galvanic Anode

The term given to magnesium or zinc anodes that provide galvanic protection.

Galvanic Protection

The process of using a galvanic anode metal to protect another metal from corrosion.

Galvanic Series

A list of metals and metal alloys arranged according to their corrosion potential from the metal most likely to corrode to the metal least likely to corrode (also known as the EMF Series). The list most often has magnesium at the top of the list with gold or similar metal at the bottom of the list.

H**Half-Cell**

Another term used for the copper-sulfate electrode.

H-1 Alloy

Anodes containing zinc and aluminum purposely added to magnesium. Similar to the AZ-63 alloy or “Grade A alloy.”

I**Impressed Current System**

A cathodic protection system using a rectifier that converts Alternating Current (AC) from the electric utility into Direct Current (DC). Impressed current systems are typically many times more powerful galvanic systems.

Impressed Current Anode

An anode used with a rectifier in an impressed current cathodic protection system. Impressed current anodes are typically high silicon cast iron buried in coke breeze backfill.

Insulated

A term used interchangeably with “isolated” to describe the state of being electrically separated from another structure.

Insulated flange

See dielectric or insulated fitting above.

Ion

An electrically charged atom or group of atoms. Examples are sodium and chloride atoms that break apart when salt dissolves in water. Soil and water contain thousands of ions of varying chemical compositions which all conduct electric current through soil.

J**K****L**

M

Magnesium Anode

The most common galvanic anode used to protect buried tanks or piping. Magnesium anodes are available in many shapes and sizes.

Milliamps (Ma)

A measurement of how much current (amperes) is flowing in a circuit. A milliamp equals 1/1000 of an ampere. Galvanic anodes generate a few milliamps to 200 milliamps of current depending on soil conditions.

Multivalve©

The location inside the dome where a dielectric union would be installed to separate copper tubing from the steel tank. Connecting lugs are often located on the riser below the multivalve©.

N

N.A.C.E. (National Association of Corrosion Engineers)

A professional association of engineers and other people involved in corrosion protection. NACE develops and publishes standards for cathodic protection.

O

P

Protective Coating

See “coating” above

Q

R**Rectifier**

The power supply for an impressed current cathodic protection system. It converts alternating current (AC) power into direct current (DC) power.

Reference-Cell

Another name for the copper-sulfate electrode.

Resistivity

The term used to describe how well soil, water or other electrolytes conduct electric current. Clay and highly mineralized soils that have a low resistivity to current flow are considered “high corrosion potential soils.” Dry desert sand has a high resistivity to current flow and is considered “a low corrosion potential soil.” The unit of measure for soil, water or other electrolyte resistance is “ohm-centimeter.”

Rubber Boot

The protective covering for the tip of a copper sulfate electrode. It keeps the tip from drying out and must be removed before taking a tank potential reading.

Rust

The iron oxide byproduct of the corrosion process on steel. As a verb, “rust” describes the process of atmospheric oxidation of steel aboveground, and can be used to describe the aggressive corrosion of steel underground.

S**Sacrificial Anode**

Galvanic anodes waste away when producing electrical current to protect buried tanks and pipes, therefore the name “sacrificial” anode.

Sacrificial Protection

The process of protecting a structure using a sacrificial anode as opposed to an impressed current anode.

Soil Resistivity

See “Resistivity” above

T

Tank-to-Soil Potential

The DC voltage reading taken between a tank and a copper sulfate electrode using a voltmeter. The reading is recorded in volts or in millivolts. A minus (-) sign should precede the number because the direct current voltage is understood to be negative. For example: -1.55 volts (V) can be written minus 1550 millivolts (mV)

U

Underground Wire Connector

A wire connector filled with a silicon compound and designed to splice wires underground or in the dome of an underground tank. Plain wire connectors must never be used when splicing anode wires.

Union

A connecting device used to connect two separate joints of pipe together.

V

W

X

Y

Z

Zinc Anode

Zinc anodes are commonly used to protect tanks and pipes buried in areas where the groundwater is salty or brackish.



CATHODIC PROTECTION QUIZ

Cathodic Protection Quiz

Cathodic Protection Quiz

1.1

1. Underground propane tanks and metallic piping are subject to an aggressive form of rusting due to wet ground containing natural and man-made chemicals. This process can cause pits or holes in the tank which could release propane into the ground that could migrate into a crawl space or basement. What is the name of this form of rusting?

1.2

2. What is the term used to describe the process of protecting an underground ASME propane tank by making it a cathode?

3. What is the first line of defense against corrosion of a tank or pipe?

1.3

4. What are two ways of cathodically protecting underground propane tanks and piping?

1. _____

2. _____

5. An important point to remember is that Cathodic Protection can extend the life of an underground propane tank by helping to prevent _____ and rust.

2.1

6. What are the three most commonly used anodes in the propane industry?

1. _____

2. _____

3. _____

7. What type of anode would work best in brackish or salty groundwater? _____
8. What type of anode would work best in dry or sandy soil where you need a driving voltage of -1.75 volts? _____
9. What type of anode is used in the majority of underground conditions found in the U.S. and has a voltage of -1.5 volts? _____
10. What is a typical voltage of unprotected steel in a propane tank? _____
11. What is the minimum voltage steel needs to be protected from corrosion? _____
12. _____ flows from an anode through a wire to the tank.
13. _____ flows from an anode through the earth to a tank.
14. The voltage of an anode or tank is measured in _____
15. Current flows from the _____ to the _____ in the soil.
16. Is a tank with a voltage of -1.5 volts protected? _____
17. Is a tank with a voltage of 1.5 volts protected? _____
18. Is -1.00 volts better than -0.85 volts on a tank? _____
19. In the process of protecting a tank with an anode, what is the cathode? _____

2.2

20. Anodes should be placed _____ or _____ a tank.

2.3

21. _____ should be added to an anode to make it work better.
22. The anode wire is attached to a _____ on the tank.
23. In desert or semi-dry areas of the country, a _____ can be placed next to the anode so that it can be watered.
24. After the underground propane tank is in place, it is important to _____ any defect to the tank coating per manufacturer's instructions to avoid an unnecessary drain on the anode.

2.4

25. Steel tanks must be isolated from bare _____ service lines in the dome.
26. What is the term used to describe the separation of steel tanks and bare copper service lines? _____
27. What is installed on the gas piping at the building regulator to isolate the metallic service line from the building's underground copper and steel water pipes, the electric utility ground grid or a water well casing? _____
28. In the past, it was common to install bare copper or coated steel service lines to a house. Without dielectric isolation in the dome, a tank anode will try to protect both the _____ and the _____ which will consume the anode sooner.
29. Tank anodes can also protect coated metallic service lines to a house by shifting the steel tank's potential from -0.50 volts to a minimum -0.85 volts. Uncoated bare _____ gas tubing is difficult to protect because the anodes have to shift the voltage from -0.20 volts to a minimum -0.85 volts.

2.5

30. What two components are used to test the cathodic protection on a tank or its metallic piping?
1. _____
 2. _____

2.6

31. When taking a tank-to-soil potential test, you can get a good stable reading by adding _____ where the copper sulfate electrode is placed on the ground.
32. To read a tank-to-soil potential, you must have the voltmeter set on the 2 volt or the _____ D.C. volt scale.
33. When taking a reading, one wire is connected to the _____ and the other wire must connect to the _____.
34. How many readings should you take around a residential underground tank? _____
35. What is the typical voltage of a magnesium anode? _____

36. What is the typical voltage of a copper service line? _____
37. What is the minimum voltage needed on a tank or metal pipe? _____
38. When taking a tank to soil potential test on a cathodically protected underground propane tank and you get a low reading, list five things that may be the result of the low reading.
1. _____
 2. _____
 3. _____
 4. _____
 5. _____

2.7

39. How many reasons can you list for a voltage reading to be zero?

40. What would cause a tank potential reading to be -0.20 volts? _____
41. What method can be used to attach a new anode to an old underground propane tank? _____

3.1

42. Galvanic magnesium anodes are used on residential tanks. What type of system might be used on a large commercial tank larger than 4,000 gallons? _____
43. If you could see the current from a magnesium anode, it would illuminate a tank like the light from an ordinary light bulb. Which anodes illuminate a large tank like a bank of stadium lights? _____

44. A magnesium anode has the power of a 1 volt battery. Where does the power come from with an impressed current anode? _____

45. Resistance in the ground such as dry soil is like smoke that blocks the current (“light”) from an anode. This causes the tank potential to be low. List two options to getting more current to flow through the high resistance soil (“smoke”) to a tank.

1. _____

2. _____

3.2

46. Impressed current rectifiers convert alternating current to direct current, and the input and output voltage can be _____ to your health.

47. Can a magnesium anode harm a tank, pipe or unrelated structure? _____

3.3

48. To verify if a rectifier is on, you should check the output voltage with a _____.



CATHODIC PROTECTION

Answer Key

Answer Key

1.1

1. Underground propane tanks and metallic piping are subject to an aggressive form of rusting due to wet ground containing natural and man-made chemicals. This process can cause pits or holes in the tank which could release propane into the ground that could migrate into a crawl space or basement. What is the name of this form of rusting? **Corrosion**

1.2

2. What is the term used to describe the process of protecting an underground ASME propane tank by making it a cathode? **Cathodic Protection**
3. What is the first line of defense against corrosion of a tank or pipe? **Coatings**

1.3

4. What are two ways of cathodically protecting underground propane tanks and piping?
 1. **Sacrificial Anodes**
 2. **Impressed Current**
5. An important point to remember is that Cathodic Protection can extend the life of an underground propane tank by helping to prevent **corrosion** and rust.

2.1

6. What are the three most commonly used anodes in the propane industry?
 1. **High Potential Magnesium**
 2. **Magnesium Alloy**
 3. **Zinc**
7. What type of anode would work best in brackish or salty groundwater? **Zinc**

8. What type of anode would work best in dry or sandy soil where you need a driving voltage of -1.75 volts? **High Potential Magnesium**
9. What type of anode is used in the majority of underground conditions found in the U.S. and has a voltage of -1.5 volts? **Magnesium Alloy**
10. What is a typical voltage of unprotected steel in a propane tank? **-0.50 volts**
11. What is the minimum voltage steel needs to be protected from corrosion? **-0.85 volts**
12. **Electrons** flows from an anode through a wire to the tank.
13. **Direct Current** flows from an anode through the earth to a tank.
14. The voltage of an anode or tank is measured in **DC Volts**.
15. Current flows from the **anode** to the **tank** in the soil.
16. Is a tank with a voltage of -1.5 volts protected? **Yes**
17. Is a tank with a voltage of 1.5 volts protected? **Yes**
18. Is -1.00 volts better than -0.85 volts on a tank? **Yes**
19. In the process of protecting a tank with an anode, what is the cathode? **The Tank**

2.2

20. Anodes should be placed **under** or **beside** a tank.

2.3

21. **Water** should be added to an anode to make it work better.
22. The anode wire is attached to a **threaded bolt or pigtail wire** on the tank.
23. In desert or semi-dry areas of the country, a **watering pipe** can be placed next to the anode so that it can be watered.
24. After the underground propane tank is in place, it is important to **touch-up** any defect to the tank coating per manufacturer's instructions to avoid an unnecessary drain on the anode.

2.4

25. Steel tanks must be isolated from bare **metal** service lines in the dome.
26. What is the term used to describe the separation of steel tanks and bare copper service lines? **Dielectric Isolation**
27. What is installed on the gas piping at the building regulator to isolate the metallic service line from the building's underground copper and steel water pipes, the electric utility ground grid or a water well casing? **Dielectric Union**
28. In the past, it was common to install bare copper or coated steel service lines to a building. Without dielectric isolation in the dome, a tank anode will try to protect both the **tank** and the **pipe** which will consume the anode sooner.
29. Tank anodes can also protect coated metallic service lines to a building by shifting the steel tank's potential from -0.50 volts to a minimum -0.85 volts. Uncoated bare **copper** gas tubing is difficult to protect because the anodes have to shift the voltage from -0.20 volts to a minimum -0.85 volts.

2.5

30. What two components are used to test the cathodic protection on a tank or its metallic piping?
1. **Volt Meter**
 2. **Copper Sulfate Electrode**

2.6

31. When taking a tank-to-soil potential test, you can get a good stable reading by adding **water** where the copper sulfate electrode is placed on the ground.
32. To read a tank-to-soil potential, you must have the voltmeter set on the 2 volt or the **20** D.C. volt scale.
33. When taking a reading, one wire is connected to the **Copper Sulfate Electrode** and the other wire must connect to the **Multivalve**.
34. How many readings should you take around a residential underground tank? **4**

35. What is the typical voltage of a magnesium anode? **1.5 Volts**
36. What is the typical voltage of a copper service line? **-0.20 Volts**
37. What is the minimum voltage needed on a tank or metal pipe? **-0.85 Volts**
38. When taking a tank to soil potential test on a cathodically protected underground propane tank and you get a low reading, list five things that may be the result of the low reading.
 1. **In the dome, is there copper tubing leading from the regulator?**
 2. **Is there a dielectric or insulating union between the copper tubing and the tank?**
 3. **Is the coating on the tank peeling off or non-existent in the dome?**
 4. **Is there a steel service pipe and no dielectric union in the piping at the building?**
 5. **Is there electrical continuity between the multivalve© and the pipe into the building?**

Additional Answers

6. **The anode wire may not be securely connected to the tank.**
7. **The anode may have been buried still inside its plastic bag.**
8. **The anode may be dry.**
9. **The anode may be old and have been consumed.**
10. **The anode may have been too small (1 lb, 3 lb, 5 lb. anodes are too small).**
11. **The anode may be lying up against the opposite side of the tank.**
12. **Is there a plastic liner under decorative rock or bark between the electrode and the tank? If so, punch a small hole with a pencil and pour water at the hole before taking the reading again.**
13. **Are you connected to a metal dome and not the multivalve©?**

2.7

39. How many reasons can you list for a voltage reading to be zero?

1. Start with the voltmeter. Is it on?
2. Is the battery good?
3. Have you taken off the rubber boot on the copper sulfate electrode?
4. Have you set the voltmeter switch to the d.c. volt scale?
5. Have you connected one lead wire to the copper sulfate electrode?
6. Have you connected the other lead wire to the multivalve© securely?
7. Does your copper sulfate electrode have a blue liquid in it?
8. Have you set the electrode firmly on the ground?
9. Have you poured a glass of water on the ground if the ground is dry?
10. Are your lead wires and their connections good?

40. What would cause a tank potential reading to be -0.20 volts?

Copper service line not isolated from the tank

41. What method can be used to attach a new anode to an old underground propane tank? **Band clamp on the steel riser**

3.0

42. Galvanic magnesium anodes are used on residential tanks. What type of system might be used on a large commercial tank larger than 4,000 gallons? **Impressed Current**

43. If you could see the current from a magnesium anode, it would illuminate a tank like the light from an ordinary light bulb. Which anodes illuminate a large tank like a bank of stadium lights? **Impressed Current**

44. A magnesium anode has the power of a 1 volt battery. Where does the power come from with an impressed current anode? **Electric Utility**

45. Resistance in the ground such as dry soil is like smoke that blocks the current (“light”) from an anode. This causes the tank potential to be low. List two options to getting more current to flow through the high resistance soil (“smoke”) to a tank.

1. **Add water to the anode**

2. **Add more anodes**

3.2

46. Impressed current rectifiers convert alternating current to direct current, and the input and output voltage can be **dangerous** to your health.

47. Can a magnesium anode harm a tank, pipe or unrelated structure? **No**

3.3

48. To verify if a rectifier is on, you should check the output voltage with a **voltmeter**.

Skills Evaluation Cathodic Protection **(Galvanic Protection Only)**

- Student explained the basics of corrosion – what leads to the corrosion of an unprotected tank or metallic piping. (What is corrosion and how does it happen?)
- Student explained the principles of how galvanic protection protects underground tanks and metallic piping. (What is galvanic protection and how does it work?)
- Student followed proper safety procedures while installing cathodic protection by complying with company policy.
- Student performed pre-installation preparation, including referring to company policy, calling the national hotline (811) or the local one-call system.
- Student properly selected and installed a sacrificial anode on an underground ASME propane tank.
- Student properly isolated piping and above ground system from an underground ASME propane tank.
- Student demonstrated how to correctly activate a sacrificial anode.
- Student demonstrated how to determine if test equipment is working properly and properly tested:
 - An unprotected tank
 - A tank not adequately protected
 - A properly protected tank
- Student demonstrated how to troubleshoot when getting improper voltage readings while testing an anode.
- Student demonstrated how to properly retrofit an unprotected underground ASME propane tank with a new anode.

Skill Evaluator (print)

Skill Evaluator (signature)

Student Name (print)

Student Signature

Date

CERTIFICATE OF INSTRUCTION CATHODIC PROTECTION

Company providing training: _____

Company receiving training: _____

This is to certify that _____
Full Name of Person Receiving Training

has successfully completed the Cathodic Protection

Quiz and

Skills Evaluation

The training was conducted at: _____
Name

_____ *City* _____ *State* _____ *Zip*

On _____
Month Day Year



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