Jessica Torrey: [00:00] Today we're going to be talking about testing cathodic protection systems.

[00:04] We'll first give a brief review of corrosion, and cathodic protection, and the different types of cathodic protection. Talk a little bit about safety. What you need to know to be safe when you're CP testing, some system components, testing tools and equipment, obviously, some of the testing guidelines and regulations.

[00:24] Then we'll talk both about galvanic anode and impressed current cathodic protection, structure-to-electrolyte potential, then finally rectifier instruction.

[00:32] Just a brief review of corrosion, I've shown this slide before, if you've seen any of the webinars. Corrosion is defined as an electrochemical reaction between a metal and an electrolyte. The metal being, usually, a steel, copper, aluminum. The electrolyte is soil and water.

[00:51] You have to have four components in order to have corrosion. You have to have an anode, this is what corrodes. You have to have a cathode, this is the region we try to protect. Your electrolyte, the soil or water, and a metallic return path.

[01:05] If you can remove any of these components, then you can decrease your likelihood of corrosion. This is what we try and do in corrosion mitigation, for example, with cathodic protection or adding protective coating.

[01:18] How does cathodic protection work?

[01:24] DC current typically flows through the electrolytes from your anode to the structure in a normal setting. This polarizes the structure. We try to eliminate potential differences on the surface of your structure between anodic and cathodic sites.

[01:44] If you look at the little diagram, if that's the surface of your material, you'll always have anodic and cathodic sites on a single surface. This is a single structure. What cathodic protection does is try and add to the polarization so that the potential difference between those sites basically comes to nothing. This reduces or ceases your corrosion rate.

[02:10] Electrons in cathodic protection are provided from an outside source, a source outside the structure. You can do that via more active metal or sacrificial metal, and this is called galvanic anode or sacrificial anode cathodic protection. Or we can use a rectifier. This is called impressed current cathodic protection.

[02:32] Just a note, the most effective corrosion protection system for both buried and submerged structures involves a good, bonded coating and cathodic protection. That's typically what we recommend on reclamation structures.

[02:47] Briefly, galvanic anode cathodic protection, here's a little schematic that you can see. You typically have your test station. Into the test station comes two cables from your structure and one or more cables from your sacrificial anode. This is also known as sacrificial anode cathodic protection. I might interchange the two terms.

[03:10] This, basically, uses a metal that corrodes more readily than, for example, steel. You have your steel pipe, so you choose a metal that corrodes more readily such as magnesium or zinc or aluminum, and these are your anode materials. They sacrifice themselves so they get consumed to protect the structure.

[03:31] In this case, as in all cathodic protection, both your structure and your anode must be in contact with their electrolyte. They must both be buried in the soil or both be submerged.

[03:42] If you see a design systems for gates or trash racks, for example, you'll often see that we shift the anodes to the lower portion of the gate to make sure that they're underwater. Because if the water level goes below your anode, you're not receiving protection anymore.

[03:57] Here's just a couple. You can see a couple of photos of a galvanic anode cathodic protection system. For soil and freshwater, we typically use magnesium or zinc anodes, brackish water aluminum and zinc anodes.

[04:12] In the upper corner here, there's some images of the anodes themselves. You have some of these that are direct-connect anodes. Here's a rod anode, and this is an anode for soil. It's buried in a material that reduces the resistance between the anode and the soil.

[04:33] Typical applications for galvanic anode systems are pipelines, fittings and valves, trash racks, hot spot protections. If you have a system that's widely protected but then you have an area of particularly conductive soil, you might apply a couple of extra anodes to that area. Gates, tanks, and straight current interference mitigation.

[04:55] The features of this type of system, there's low current requirements. You typically use these to protect smaller surface areas. No external power is needed, so it makes it kind of nice for gates and trash racks and things like that. It's also fairly low maintenance, so on structures that are going to be submerged or are deeply buried, then this could be a good option.

[05:20] The other type of cathodic protection that we use is impressed current cathodic protection and you'll see the schematic here. In this case, we actually get external power source and we use a rectifier and then our cables come into the juncture box typically similarly to what they would in a test station.

[05:39] You have your anode cables, and two structure cables and we always recommend two structure cables so you have one to test and one as a backup. Then you will have test stations typically along the length of your structure. Again, both the structure and the anode must be in contact with the electrolyte.

[05:59] Here is some impressed current systems. These are hard to see but this is the anode right here. It's a mixed metal oxide disc anode and you can see them above the water line here so right now these anodes are not actually doing anything but then there's some other anodes down further in the water here.

[06:19] We use typically graphite, high silicone cast iron, mix metal oxide, or platinized anodes. They are normally connected, as I said, through calibrated shunt in a junction box and then you can install them linearly or often you can install deep anode graphite.

[06:38] Application of pipe lines. For long lengths of pipe lines, impressed current is a really good option. Reinforced concreted, pumping plant pump sump, trash racks, engagement tanks, you can also use the impressed current.

[06:51] The high current requirements, you're going to be using more power but that means you can handle larger structures or poorly coated structures. They also effective in high resistivity soil.

[07:02] Depending on your installation, we can do some preliminary studies of your soil resistivity and soil porositivity and make a recommendation as to which might be best for you.

[07:16] This is just a slide to show the importance of corrosion management program. The one graph is from the Dome region in Ontario Canada and they kept very good records and have published those. You can see there is a system where they're having -- this is our [inaudible] cast iron water mains and initially they were not cathodic protected.

[07:39] They were having approximately 100 breaks a year and then they installed cathodic protection. They are now down to about 28 breaks they have in 2015. You can see the graph and what was projected how many breaks were projected versus how many actually occurred.

[07:58] This is a good example of how effective retro fitting your system can be. They installed over 17,000 anodes and 1,300 test stations. It took them $5 million to install the CP, and they've been doing it gradually, but that is less than 4 percent of the estimated cost of 135 million which would have been the estimated cost to replace all that pipe with a PVC option. It can be really cost effective and more [inaudible] as well.

[08:30] For now I want to talk a little bit of testing but first safety. Just a note, taking this webinar doesn't qualify you to test CP systems. It's intended only to familiarize you with the components to testing and the techniques.

[08:47] We really strongly encourage you to follow our training requirements and safety guidelines from your office and for your specific installation. Your TSC staff, we are available to help for all your CP systems testing, training and diagnostics as well.

[09:03] Just a little slide to scare you, electricity can be dangerous. For example, AC current which is coming in from the back of your rectifiers is at 60 hertz. It only takes one milliamp for you to actually feel it. About 10 to 20 milliamp of AC current is your let go threshold which...

Tech: [09:33] Do you want to take questions?

Jessica: [09:36] Yes, sir. We have a raised hand so go ahead.

Tech: [09:41] It's Raymond, asking. Should be on the phone.

Jessica: [09:44] Raymond, do you have a question?

Raymond: [09:45] Yes I do, do you hear me?

Jessica: [09:49] Yes.

Raymond: [09:49] Can you hear me OK?

Jessica: [09:50] I can.

Raymond: [09:50] I just want to know what the cost were for TSC to come out and do testing?

Jessica: [10:00] Can I get back to you on that? Maybe we can...

Raymond: [10:02] You bet, I'm curious.

[10:04] [crosstalk]

Jessica: [10:04] how big your system is, how many days it will take us to test. Just for example, I did the galvanic anode system and it was, I think, 70 miles of pipeline and had 40 test stations and that took us two and a half to three days to test and the travel time. We can talk about that specifically for your system.

Raymond: [10:26] I can call in for a quote from you guys?

Jessica: [10:28] Yes, definitely. You definitely can do that.

Raymond: [10:31] Thank you very much. OK thank you.

Jessica: [10:35] Thanks. Back to the electricity. 10 to 20 milliamps' only your let go threshold which means that if you go up and grab your rectifier case with closed hands, if you have more than 10 milliamps of current going through that, you are not going to be able to let go. Your body no longer has that pulse to release.

[11:02] Up to 100 milliamps can cause fibrillation of your heart. Three seconds max is considered the safe current at that level, and that is if [indecipherable] . If you see on the right side, the voltage required if you have wet skin, if you had [inaudible] ohms or something, it only

requires 100 volts to get to that current. And this is definitely levels that could be coming from your rectifier. Just be aware.

[11:34] Typically, at your test stations you don't have to worry. These are going to be less than two volts DC, probably you will never even feel shock. Your junction boxes or your rectifier output, it depends on your system but also be aware because you can have DC voltage output in the range that could exceed your let go threshold.

[11:54] You just want to be cautious when you are coming up to a rectifier or a junction box. You want to take some steps to make sure everything is safe before you go right in and start testing on the rectifier.

[12:06] Although the NACE and other regulations say that greater than 15 volts AC on a pipeline is considered hazardous and you should stop working and take steps to reduce the risk.

[12:20] These few minutes we want to be concerned about if you have those pipes that run below high voltage power lines you can get straight current interference. There's a method that you can use, for example, on [indecipherable] ground, so you're using charcoal in test station to mitigate some of the risk and keep it [inaudible] .

[12:37] For more notes on inspecting rectifiers, we're going to talk about that at the end. Here's a couple of steps that you should make sure that you take when you are approaching your rectifier.

[12:35] First survey the area. Look, listen, smell. Do you see any wasps forming around, they like to make nests, any other critters. Snakes and rats have been known to enjoy the comfort of a rectifier box.

[13:04] Check for burn marks, or sounds of sparking. See if you have any signs of shorting. Check the signs of tampering. If everything looks good, check to see if your case is electrified. In the corner of this tutorial we have a voltage indicator, there's a pretty handy tools that are currently inexpensive.

[13:26] They also often come for you with the purchase of a multimeter. Use one of these to check your rectifier case or your junction box case. See if you have any voltage.

[13:40] Before you open the case, and if nothing else, just tap the cabinet with the back of your hand. That way, if it is electrified, if you grab it, you won't be able to let go. Never grab a case. Tap it with the back of your hand and this will at least throw you away from the case if it does happen to have current going through.

[14:03] Open the case, check again. Look for cutters, look for burn marks or lose wires or anything else that might cause shorting wire working in the rectifier case. If everything checks out, continue with your inspection.

[14:18] Just a note, that half of the current is important. Going hand to hand will go across your heart. This is the most hazardous. You can try and work with only one hand and your rectifier at a time.

[14:34] I just had an instructor for one of my [indecipherable] classes who was from China. He said the Chinese students are very good because they're using chopsticks all the time. They are really good at using two probes in one hand. I can say it's not terribly easy but it's a good idea to try.

[14:51] Instead of using the pointy probe where you have to almost have one in each hand because you have to hold it against your test lead. Try to use the lead with the alligator clips, that are holding the rim.

[15:06] This allows you with one hand to attach you clips to positive lead with the same hand attach the clip to the negative lead. You are only using one hand and you are not allowing that hand to hand current path.

[15:17] These are just some examples. This is [inaudible] out in most of their system. He had both of these instances where you had a big old wasp nest in the one junction box, then in the other, you can see this, someone incorrectly installed variable resistors and so those wires became detached over time and you can see where they shorted out to the front of the box. This is not recommended.

[15:51] Then applying a note on PPE. It's pretty standard PPE what you need for the testing and going to this specific to your job site. Make sure you know if you are working around a site that requires or have some steel toes, to have those if you needed that.

[16:07] Typically, if I'm going out to test, I take my work gloves and I pick the [indecipherable] then make steel toes. We'll need to know what your [inaudible] are and what kind of PPE is required.

[16:21] Now we are going to go through some of the components of the PPE system. These are above ground components wanted. This is what you'll see and this is where you'll be testing.

[16:35] This is a typical test station here that are on this three inch diameter PVC post, usually two to three feet above ground. Sometimes the system is ran over by a truck. Somebody tied this off, part of it, and moved this down low. It will be like a foot sticking out of the ground.

[16:57] Just have a little capsicles on the top. You take that off and you see this test station board here. It is typically three, four wires depending on your structure. Usually two structure cables and at least one anode cable.

[17:13] Here's an example of junction boxes you can use in both galvanic and impressed current system and this is the case if you have many anodes so each of these here are anode wires coming in and here's your structure wire.

[17:17] This is a really nice one here with all these diodes, variable resistors, and it's got the proper shunt uninstalled. This is a good example of perfect junction box and then the rectifier cases and we'll go through that a little bit more.

[17:37] Inside the test station, just so you know we are talking about, here's is your hardware, typically some washers and there's a couple of different kinds of hardware attachment that you can see in the test station.

[17:47] In junction boxes you'll see a busbar to connect all of your anodes in test stations, just as often the brown bars that connect between structures and anodes or anodes and anodes. We require shunts, which you see here, there are several different types, and variable resistors in our rectifiers and junction boxes, and typically you'll see just shunts in the test stations.

[18:10] We also specify a high molecular weight polyethylene sheathed copper cable. These are fairly heavy duty, they're not very flexible. These are meant for direct burial or submersion.

[18:28] We often see much smaller diameter cable with sheathing like [inaudible] , or something like that, that's not meant for burial and when you dig those up that sheathing just becomes brittle and falls off and you start corroding your cable. Things that don't match.

[18:45] Typically, you want to see this nice, smaller cable. It makes it a bit more difficult to test in a test station because it's not as flexible, but it's really meant for burial and that's what you want.

[18:55] Here's a rectifier. There's several different companies that make these. They can come in all sorts of fancy GPS remote monitoring, this and that. This is a very simple rectifier just to give you an idea of the parts that you'll see when you walk up to the box.

[19:24] Here on the top you have your course tap and your fine tap. These are to adjust your crank here.

[19:32] You have an AC primary breaker. You'll want to test that. That's one of the things you'll want to look for to make sure that your breaker is on, and not tripped when you come up to your rectifier.

[19:41] You also have an AC secondary breaker. Here you have a voltmeter and ammeter dial. These are often broken, so they are not to be trusted. You should always test with your portable electronic voltmeter.

[19:56] Here you have your shunt. This will give you your DC current output, and then you have your positive and negative DC output. Your positive output always goes to your anodes, your negative output always goes to your structure. It's very important to keep those where they are meant to be. Otherwise, you can start using your structure as an anode or something.

[20:26] This down here is a lightening arrester. Typically, one or two or combination of lightening arresters in case you have lightning strikes on your box.

[20:40] OK, what you don't see. Here are some of the buried or submerged components just to give you an idea of what they are. This is an installation of a galvanic anode system on a pipeline, these are magnesium anodes. Anodes themselves look like this and they have typically a steel core coming out. You can also get ribbons or rod anodes.

[20:49] When they are meant for burial, they come in these bags of backfill material. They absorb moisture, they reduce that resistivity between your anode and the soil and they actually become part of your anode and make your anode last a little bit longer.

[21:23] We require metallurgical bonds, here's an example that's me doing a metallurgical bonding to a steel pipeline. This is what they look like. We also uncover them with these handicapped or bitumastic coating. You want to make sure you repair the coating. You also really want to remove all the metal and make sure that it's really clean before you do your bond.

[21:53] Here's some example from impressed current systems. This is an installations of graphite anodes over here on the side, and they're installing a deep well anode bed, so they've got a roller here and they're using a rope and the cable. The rope releases the stress from the anode cable and then this pipe here is actually putting your backfill down in the anode bed.

[22:22] Here's some examples of some high silicone cast iron anodes, and then this is an example of submersion. This black mat is a dielectric shield material which allows the current to spread and not go directly below the anode. It allows the current from the anode to spread out. This is a PVC tube and your anodes will face down and appearlike this.

[22:48] Go ahead with the question.

James Darling: [22:50] James Darling.

Jessica: [22:51] James, do you want to ask your question?

James: [22:54] Don't we have to punch in a PIN in that thing?

Jessica: [22:46] I guess you have to punch in a PIN. Let's leave questions to the end and then I can always come back to these slides. If you want just go ahead and type your question, type them in the little box, and then we'll get to everything at the end. Thanks.

[23:16] Testing tools and equipment, what do you need to go out and test your structure? You will need a portable reference electrode. We use copper-copper sulfate. This is what they look like. Here's one in the ground with, again, your black lead, your negative lead. It's a plastic container which has this short copper rod that fits down in it and a porous plug, and they you pour a saturated copper-copper sulfate solution.

[23:44] What the reference electrode does, is it allows you to have a baseline potential against which you measure the structure potential, or the structure's electrolyte potential. Copper-copper sulfate is standard for our work.

[24:00] You always want to mix your copper copper sulfate solution with distilled water. Don't use tap water. You always want to make sure its saturated, which means that should have some solid crystals in solution in your reference electrode.

[24:15] On my projector it's bad but you might be able to see here in the bottom. This is not filled with solution yet but you can see some crystals in there, and then we typically just pour saturated solution over that.

[24:25] You want to periodically replace your copper sulfate solution. If you notice it's getting a little bit cloudy or a year after the first time you've tested you might want to just replace that copper sulfate solutions.

[24:39] You can clean the copper rod with some non-metallic sand paper. Don't use steel wool, but more like silicone carbide or something sand paper. Also clean you porous plugs. You can just soak that in water. Between each measurement, try and get some of the dirt off the plug and then between that test trip get some water and clean it a little bit.

[25:08] You can see here on this one, they come with this clear window so you can see how you fill it up. Try and put a piece of electrical tape over that window because the copper sulfate is actually sensitive to sunlight. That will just reduce the variability from sunlight exposure.

[25:23] You should try and calibrate your reference electrodes. You want to keep one electrode in your office or in your truck or in your lab and then calibrate and test those field electrodes. You just put your black lead on one and your red lead on the other and if there's more than a five millivolt difference between the two, you should clean and replace the solution.

[25:48] So, keep one in the truck, keep it clean, keep a good solution, and then periodically test your field electrodes on that one.

[25:56] Next you'll need a portable multimeter. There's all different kinds of those. These are three of the ones that we have in the lab. They just need a minimum input impedance of 10 mega ohms -- most of the Fluke models will have this -- capable of measuring DC voltages between plus/minus 01 millivolt and plus/minus 100 volts.

[26:22] As I mentioned before your electrically insulated test leads, and these alligator clips test leads works really well for that. It's worth it to spend a couple of hundred dollars on a multimeter that will last a long time. The Beta model ones are really worth it in their accuracy and sensitivity.

[26:47] For testing impressed current systems, you often need a current interrupter. You use this to automatically switch the currents on and off at a set time interval to measure your instant off potential. You can see here one that's hooked up to rectifier and your current interrupter is at the top. They look like this, there's lots of different brands and models.

[27:13] When you're purchasing or renting one of these you want to make sure that the rectifier output current is less than the current rating on your interrupter. You can get lots of different bells and whistles including GPS synchronization and various programming options.

[27:34] The one thing to note is that to get a true instant off potential you need to interrupt all of the rectifiers on a pipeline. If you have 10 miles of pipeline and it's got three or four rectifiers on it, you actually need to interrupt all of those in order to get a true off potential.

[27:55] It often means more than one interrupter is needed for testing. That's something that, if we come out and help you test, we can figure that out and design it and decide if we need to rent some equipment or if we can use just what we have in our lab.

[28:14] We'll talk about post interval surveys. There's just a couple of extra pieces of equipment that are required.

[28:21] This a chainer. It's an electronic distance counter. It has a really thin [inaudible] coated copper wire on a spool, and you'll use that to string out between our test stations and yourself, and your voltmeter.

[28:35] A data logger, these are really nice and handy because you're going to be taking a lot of measurements, you're going to be walking along your pipe. This will automatically capture your on and off potentials for you.

[28:46] A portable reference electrode. Often because you're walking along and using these as walking sticks. They have these poles that you can have little switch on the end to measure or not measure, turn that on and off. Those are really handy as well.

[29:06] Then general tools. On the one side, you can be like everything in my tool bag. Typically, I have a tool bag that I take with me and then I have a tool bag in the truck with all the extra stuff. If you're just testing, these are pretty much the essential tools that you'll need.

[29:25] Some [indecipherable] pliers, hex nut driver, a flat-head screwdriver, your reference electrode, some extra hardware, I have some extra shunts in here, some nuts and washers. You'll invariably drop one of these down your test station, and then go, "Darn, I need an extra one of those," and your multimeter.

[29:47] As well as I tried to put in the picture, a bottle of water. when you put the reference electrode in the ground you want to make sure that you have really good connection between the cone, this porous cone, and

your soil. It often takes a pouring a little bit of water on there. And I've got my tool bag.

[30:04] You can read through this is you if you want, I've got a copy of the presentation. I've got different kinds of things that you could use, like GPS, the cameras to takes photos. If you need to do some repairs we've got a PVC [inaudible] here, some cloth and some electrical tape to clean things up and make repairs.

[30:21] Now we're going to get into our testing guidelines. We're a water infrastructure. We are not regulated in the way that the oil and gas industry is regulated. The oil and gas industry is by law required to have cathodic protection on all of their pipelines.

[30:41] We don't have those requirements, so often, some of this testing falls to the side, but there are standards and there are guidelines that we can use for our testing.

[30:53] The main one that we use per reclamation, is the NACE standard SP0169, which is the Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

[31:05] This gives us our criteria for cathodic protection levels. It gives us information on what records to keep, on when to do our testing, on some different safety things. There's a lot in that standard and that's what we reference in all of our specifications. Other references for us, give us a call. If you have questions. We're here to help.

[31:32] I just went to a NACE training and we got this book that listed their second cathodic protection survey procedures. It is actually pretty nice. It has step-by-step of a lot of these testings and way more different types of testings than you'll ever want to know about. I just listed a couple of other NACE standards, guidelines, and recommended practices here.

[31:50] When to test. Do not test if there's a forecast for thunder and lightning. This is bad. Even if you can see it way off in the distance, lightning can travel many miles down a pipeline and it's not worth getting shocked, having the lightning strike, and your hair goes all fluffy down the pipeline 10 miles.

[32:20] The other thing is try to test at the same time every year. For example, let's say we want to test every April. Pick a month, any month, but try and test at about the same time every year. The condition of your soil, the wetness and dryness of your soil, the temperature, these things can affect your measurements. If you are consistent in your testing schedule, then it really helps to compare your data.

[32:48] I'll say this again, but the hard numbers that you collect, they're worth something, but what's really valuable is a history of testing. If you can compare one year to the next, and if you've done your testing at about the same time every year, you just eliminate some of the variables in trying to get some interpretation of your data.

[33:12] Don't test if the ground is frozen. Frozen soil doesn't really conduct very well.

[33:19] How often to test. The NACE standard ST0169, oh I said 0169, sorry about that. They recommend you do structure-to-electrolyte surveys annually and rectifier inspections every two months. That's also what we recommend. Additionally, corrosion inspection, if you have gates, trash racks, or things with galvanic anode systems, try to inspect those annually.

[33:46] If your pipeline's being dewatered or your trash rack is being pulled for maintenance, just do a quick inspection and see how the anodes look. Can you actually see some corrosion? Do you see some damage to your coating? Try and do that whenever those are out and available.

[34:08] Close interval surveys.

[34:09] These don't need to be conducted as often, maybe every five years. If you do have a leak in your structure though, this might be a good test to survey adjacent lines and see if you have additional problems. If you find that your rectifier has been off for a long time or your system has been down for a long time, it might be a good idea to do a close interval survey.

[34:38] CP system data analysis.

[34:38] There's some nuance to the data analysis. We ask that if you do take these yearly tests, then it would be great if every three to five years, you send us your data. We can take a look at your system and help you determine if you're having problems, where you might have some problem spots, what the health of your anode is, and all these kinds of things.

[35:03] Recordkeeping.

[35:03] This is common sense stuff. Try and keep as good a record as possible, your tester's name, the date and time of the test, your weather conditions. Now we have handheld GPS locators. I know that that's really helpful for mapping out your test stations along a pipeline, or something like that.

[35:22] Your measurement data.

[35:23] You're going to want to record your type of measurement. It's always recommended that you measure both the on and the off and label them. Then if you ever have to go back to that data, there's no question as to what your off potential is. That's the one that we use for determining your cathodic protection criteria.

[35:42] If you only measure the off, and you don't specifically label it on every single thing, you might go back and be like, "Oh, no. Is that my on potential or is that my off?" It's always a good idea to measure and record both, and you want the value and the polarity, so those plus/minus signs are really important. Also, your units. Are you in volts, are you in millivolts, milliamps, etc.?

[36:02] The type of reference electrode.

[36:06] We'll mostly be using copper sulfate electrodes, but if you do use something different, make sure you note that.

[36:12] Other useful information, especially if you're going to call us and say, "Hey, we have these problems on our rectifier," it's really hard if we're not able to look and see what's going on. You can do drawings, photos, or maps of the site. It's really fast now to whip out your phone, take a photo of your rectifier and send it off to us, and say, "Hey, I saw this. It's not good."

[36:39] As well as the site. If you're installing new, having as-built drawings is invaluable. Sketches of the rectifier junction marks the test stations themselves. Any general description. If you have any problems, or you do troubleshooting, or you're doing any repairs, just make a note of them.

[37:01] As I said, asterisks here down at the bottom, good historical recordkeeping is the best way to determine the health of your CP system. You can look at the data from one year and that's better than nothing, but if you have 5 years or 10 years of records -- these systems are designed for 20 years, so it really is a long time.

[37:21] Having to use hard copy records or electronic records rather than just in your head, "Oh, yeah. I was the person who went out last year and tested them, so I know what's going on." If the person changes the job, having these historical records is really invaluable.

[37:40] Now we're into the good stuff, actual testing. Testing of submerged CP systems.

[38:11] We've had a lot of people ask recently for anodes on gates or retrofitted gates, then some designs for trash racks, and then insides of tanks. These are often galvanic anode systems. There's not a lot that you actually need to do. As I said, give them a quick inspection.

[38:27] You see here, this is a photo from the Delta Mendota Canal. This is now just the core, so this anode is gone. This needs to be replaced. You can see that. Here's a new magnesium anode. As the anode gets consumed, it'll start to look more like this, or this, so just take a note. As you see less and less magnesium, just be aware that you might need to replace your anode soon.

[38:41] Also take a look at the brackets. There's often something like this. These are support E brackets that we've just used in a design. Take a look at your metallurgical bonds. Make sure they're still intact. Sometimes you'll have a system on a gate, so you'll actually mount the anodes on the frame, for example. Make sure any cable that needs to be connected between the gate and the frame is still intact.

[39:06] If you're using an IC system, it's covered on the same sections as for the galvanic system. Testing is very similar to what I'll talk about

in the next slide that's performed on the junction box on the pipeline. The difference will be that your reference electrode is going into water, so your electrolyte in these cases is water, not soil.

[39:24] This is just a weighted submersible container, so you can actually put your reference electrode in here. You've got a cable and a rope, so you don't put stress on your measurement cable. Then you'll put this down in your water to the depth of your anode.

[39:40] We're going to talk about testing on pipeline. These are similar to tanks, or other types of gates, or something as I said, but we're specifically talking about pipelines. In this presentation, we're going to talk about structure-to-electrolyte potential, also called pipe-to-soil potential, the close interval survey, and the inspection of a rectifier.

[40:05] The structure-to-electrolyte testing, or pipe-to-soil potential.

[40:10] For galvanic systems, interruption is done manually. For impressed current, you'll need to hook up an interrupter at your rectifier. As I said, to get a true off potential, all the rectifiers in the line must be interrupted.

[40:25] I'm going to use these terms, on potential, off potential, and native potential. This comes from the NACE criteria. For example, this is time on this axis, and here's your potential more negative here. When you measure the test station, when you have your reference electrode in your ground, and you're just hooking up to your attached wire, your structure is attached to your anode. That's your on potential.

[40:56] However, that includes any kind of IR drop. This is the resistivity of your soil. This is what we try to minimize by testing at the same time every year. The number that we actually want is our off potential. We'll talk about what that is on the next slide.

[41:20] The NACE criteria states that you need to reach a level of -850 millivolts for your off potential or a 100 millivolt shift between your off and your native. Your native potential is the potential on your structure with no cathodic protection.

[41:43] You can actually detach your structure and anode cables and wait for this polarization curve to decline your native potential, but this could take ages. We often don't know what the native is, but most of the time, you'll hear us referring to -850 as an off potential.

[42:04] Here's your instructions for structure-to-electrolyte testing.

[42:07] I'm going to go through this here, and then we have a video that I hope we can play. First off, you want to bury your copper-copper sulfate. You bury that porous cone, in the soil above the pipe. You want to be as close to vertically over your pipe as possible.

[42:30] Most of the time, your test station is right at your pipe as well, but sometimes test stations will be 50 feet away. You don't want your reference electrode at your test station. You want it at your pipe. Then,

you want to make sure that your contact is good, so pour some water on it, if necessary.

[42:46] You walk up to your test station, first thing you're going to do is your on potential. Multimeters to DC volts, your positive leads go to your structure, your negative or black lead goes to your reference electrode. You record the value. That simple.

[43:02] Next, we're going to do instant an off potential. Here, you get out your nut driver. You take out your hardware. You still have the positive lead to your structure cable and your negative to your reference. You detach that structure cable from the test station.

[43:21] It's tricky to describe, but you'll see usually a drop drop and then a continued dropping of the values in your multimeter. You want to record the second value after the disconnect. Hopefully you'll be able to see it in the video.

[43:26] If you have multiple structures or multiple anodes in a test station or a junction box, and they're electrically connected to each other, you're going to need to remove all the structures from all the anodes in order to measure instant off potential.

[43:57] The next thing that you can measure is your anode voltage, so you leave that negative lead on your reference electrode, and you're going to move your positive lead to your anode cable. You're going to detach that anode cable and you just want to look at whatever that value is.

[44:14] For magnesium anodes, it's typically -1.5 to -1.7 volts. That's what you want to see and then you just record that value.

[44:24] Connect everything back up and move and go test your anode current. Ideally, you'll have a shunt in your test station and we've rectified this. If you don't, you can carry one with you and hook it up between your anode cable and your structure cable. Then you want to set your multimeters to millivolts, DC. Place one lead on either side of the shunt and record that value.

[44:47] Then you'll need to do a little bit of math. Your shunt will have a rating. Your shunt has a known resistance and you'll want to divide your reading by the shunt resistance, and that will give you the current output of your anodes. That helps you determine the current output of your anodes.

[45:04] Here's what a test station will look like. This is a pretty simple version. We have the front side over here. In this case, I put some red shrink wrap on this and it's really nice if you have it color coded, because this will indicate your anode cable. Here are your two structure cables.

[45:23] This is where your anode and your structure are connected through the shunt. This is the one that you'll want to remove for your instant off potential.

[45:23] On the back side, you'll have your shunt. It's got two little posts sticking out of it. This is a Cott Shunt. This is where you measure. You attach your leads on to each of these little posts and that's where you measure your anode current.

[45:46] Your junction box is pretty similar. For a galvanic anode system, you're going to measure your on and off potentials at your structure cable.

[45:59] If it's a galvanic anode system, you can measure off potential by actually manually removing that cable as we did in the test station. You can measure your anode current across, one, two, three, four, five, six...I think this is just the general cable, so six cables. You measure across each of these shunts.

[46:26] You don't need to measure your anode voltage unless the system has been new and off for a long time. For an impressed current system, you do that interruption at the rectifier, and that's how you get your on and off potentials. You don't need to measure an anode voltage.

[46:42] We're going to try really quickly to run this video. It's a test video that I did in the field. It was really jumpy earlier, so we're going to try and do a very hacky version and just put the camera on the screen and show it that way, because it was too big and it wasn't going through very well. I'm going to move the speaker. It's three minutes long, so if it doesn't work, I'm sorry. You'll be able to get a copy.

[47:14] [playback begins]

Jessica: [47:02] We're going to do a video of how to test a site [inaudible] . First you want to turn your multimeter to millivolts, then we're going to put one probe on each end of the shunt. Then we can measure the voltage across a known resistance shunt. We're measuring 02 millivolts on a 001 ohm shunt, which will give us 20 milliamps of current using V = IR.

[47:29] Next, we well measure the on potential, so turn your multimeter to volts. We're going to put our reference electrode in the ground. We're going to dig a little hole. Take the cap off. You want the shunt completely in the hole.

[47:09] [background sounds only]

Jessica: [47:09] [inaudible] . You're going to put your negative electrode, your negative probe through the black hole. Then we're going to come up here and we're going to measure the black structure wires using our red probe. It's -1.260 volts.

[48:52] Both of the structures should measure the same because they're electrically connected, and the anodes we have to measure. This looks good. Now we're going to measure the instant off potential, so we're going to disconnect our structure cable that's in the shunt.

[49:21] [background sounds only]

Jessica: [49:21] Again, hook up your positive lead and you want to be just touching the test station. Then you'll watch for the second drop on your multimeter. The disconnect drop drops to -1.226. This is your connected, -1.59. That drops to -1.226. While you have that disconnected, you can measure the size of voltage on your anodes. It should be somewhere around -1.7. In this case, -1.622. OK. That's it.

[50:12] [playback ends]

Jessica: [50:28] I hope everyone was able to see that. We'll have that available as well if you'd like to view it later if it didn't work for you. Let's move on. I'm running a little bit behind here.

[50:39] Just want to talk about close interval potential surveys. These are basically what we just measured. You measure your structure potentials along the pipeline. You hook up that one test station in and you take a hike.

[50:55] You do this to assess the effectiveness of the CP and to identify possible corrosion problems over the entire length of your structure.

[51:02] You can see in this little graph at the bottom, these are your potentials. You'll have regions where you're meeting your 850 criteria, but you might have your pipe going through a swamp, and you're not meeting the criteria. This will help you determine that.

[51:17] You do it the same way. You have that copper reel wire. You have your reference electrodes on the poles, you have your data logger and you just walked along, collecting on and off potentials along the length of your pipe. Typically, at about three foot, one meter interval.

[51:36] If you have some more of the pipe locater to guide your way, that's great. For ICCP systems, from impressed current systems, you use a current interrupter at your rectifier, and you can also take on only surveys for galvanic and cathodic protection.

[51:54] Last thing, rectifier inspection.

[51:56] Another know on safety, rectifiers are electrical equipment. Treat them with respect. Even if that primary AC breaker is off, there is still power coming into the back of the rectifier. We'll often have a main circuit breaker above the rectifier. This needs to be completely off or else you still have current going in there. Think safely, work safely.

[52:24] Perform your critter and your current check on the rectifier before opening the box. Inspect for damaged wires, debris, etc.

[52:28] Is the rectifier on? If yes, that's great. Proceed with your testing. If it's not, check that main, primary breaker. If it's off, turn it on. If it trips again, you've got a problem.

[52:43] The manufacturers of rectifiers are really good resources, so it helps to call them while you are standing in front of the rectifier and

they can walk you through some trouble-shooting stuff. Or you can try calling us. We all have had rectifier school, rectifier training. Oftentimes, though, we'll call the manufacturer too.

[53:05] If you can't call from there, document your problems, take some photos, make a quick sketch or something so that we can help you out with that.

[53:13] If your rectifier is on, you just need to check it maybe every two months. Read your DC voltage and your DC current. Don't trust those gauges, they don't work. Use your portable voltmeter. While you are there, remove any debris. Try and clean it up and then close and lock your cabinet.

[53:34] This is how you do your rectifier testing. You'll measure your DC output voltage here. You've got your multimeter on DC volts. Your red lead goes to the positive -- and hopefully that's labeled "positive" with a big old red so it's really clear where you are measuring. That's your anode.

[53:55] Your black goes to your negative, which is your structure, and then you take that measurement and that's your output of your rectifier.

[54:03] Then also measure across the shunt, so you measure here to here, and that gives you your DC current. That will tell you if your rectifier is working properly.

[54:11] We're not going to go into troubleshooting here, that's a lot more information. But if you can do and check and just make sure you are getting DC output on your rectifier every couple of months it's really great to make sure your cathodic protection is working.

[54:30] Resources. We're winding up here, sorry for being late. You can call us. We can test your systems. We have that question about what's the cost for you guys to come out and test. I mean, it'll depend on what kind of system you have, but we can definitely do that for you.

[54:45] We can write SOPs and testing protocols specifically for your systems and can train you guys or your people or whoever staff is going to be doing the testing, specifically to your system. We can also help analyze your data, every three to five years send us your data and we can help analyze and troubleshoot problems.

[55:07] We also have the corrosion and coding school. It's every October. Unfortunately, this past year it was during the furlough so we couldn't have it. That gives a little bit more in depth lecture and training.

[55:16] This is an example. The student, the high school intern Evan, helped me build this. This is a demo that we have now in the lab.

[55:23] On this side is a pipe without cathodic protection, on this side is a steel pipe with magnesium anode, and these are now completely buried, and we have a test station there with shunts and everything else. You can actually do some hands-on training in our lab during the coding school and corrosion school.

[55:42] We have various manuals that are available. Hopefully, we will be getting our steel guide to testing and troubleshooting cathodic protection systems out this year.