>> Grace Weber: Alright, let's get started. So, welcome to our Corrosion Webinar series. My name is Grace Weber and I will be hosting today's webinar. So, we are part of the Materials and Corrosion Laboratory with the Reclamation Technical Service Center, located in Denver. We put on four Corrosion Webinars per year to share with you topics in our four main disciplines: cathodic protection, coatings, geosynthetics, and hazardous materials. Today we will be focusing on a cathodic protection case study for CP system issues and testing. But first, just a couple of housekeeping items. We are hosting today's Corrosion Webinar using Microsoft Teams Live Events and we will be recording the presentation. If you would not like to be part of the live recording, please leave at this time. The recording will be available after this webinar is over through the link that you received in your email. During the presentation, please feel free to ask questions as they come up. We have a live Q&A chat feature. So, just click on the Q&A icon, which looks like a chat bubble with a question mark inside to access this feature. We will be monitoring all the questions and hold a Q&A session at the end. So, with that, I would like to welcome our two presenters for today: Dr. Bobbi Jo Merten and Dr. Daryl Little. Bobbi Jo Merten has a Ph.D. in coatings and polymeric materials from North Dakota State University. She is an SSPC protective coatings specialist and has 10 years of experience at Reclamation as a TSC researcher and project manager on coating and relining projects. Dr. Merten's prior research includes coating life cycle and econometric analysis and development of a field technique for quantitative coating inspection. Daryl Little has been with Reclamation for over 15 years. He earned his Ph.D. in materials science and engineering from the University of Virginia. As a member of the Materials and Corrosion Lab, he has worked on many projects using his knowledge of material selection, corrosion, cathodic protection, and failure analysis. He has tested cathodic protection systems throughout Reclamation, as well as performed CP repair and system replacement. And now, I'll hand this presentation over to Bobbi Jo and Daryl.

>> Dr. Merten: Thank you, Grace. So, I think Grace's bio should have pointed out a key feature to all of you joining us today—My expertise is in protective coatings. And Daryl's is in cathodic protection. And I will be leading today's presentation from the perspective of someone who has some cathodic protection training. I've gone and taken the level 1 and level 2 cathodic protection classes that were offered by NACE International. I've gone out in the field and done support work to test CP systems. But it's not very often that I'm performing this work and it had been a year or two years at least since I had my hands on a system. So, I found myself in the position of being at a facility—I was on a detail to the Brackish Groundwater National Desalination Research Facility. And they just so happen to be going through some contract work on their water storage tanks. And their water storage tanks have a galvanic anode cathodic protection system on it. So, with my past experience, I should have been a great candidate for being able to do a quick system check for them. Make sure that anodes functioning properly. And so this presentation we'll go through what I encountered in my attempts as a person who rarely performs these tests. And we're hoping that it's going to be a useful tool to other people that find themselves in a similar position to me—in not being quite up to speed and practiced well enough to do the troubleshooting that I needed to do. So, Daryl, as my cathodic protection expert, was available for talking through the issues and steering me in the right direction. And he'll be providing that supporting role during today's webinar as well. So, here's a photograph of the three water storage tanks that are of interest for today's presentation. They're bolted steel tanks with a glass liner. While this is not the most common system at the Bureau of Reclamation, it is one that we have at a number of facilities. It has a concrete floor and the

galvanic anodes are mounted directly to that concrete floor. So, essentially—the presentation we're providing today should be applicable to any system, whether it's storage tanks or other structures that have a galvanic anode that can be disconnected and tested. So, while reviewing the inspection reports at this facility, a prior report had noted that the tank's cathodic protection system does not seem to be performing properly. So, this is what really piqued my interest, especially having that background and having some training in the area. I thought that I should be able to help. At minimum, determine whether or not it was functioning properly. Here we have a few schematics of the tank itself. The first drawing in the center top left is a plan view of the tank with three anodes shown bolted to the concrete floor. In the lower left hand corner is a photograph of what one of the anodes appeared to look like. You can see that there's a small cable running from the backside to the wall, and that's where the bolted connection occurs. And we have another inset for you, and a small schematic where you can see how the two sheets of steel are bolted together on that structure. There is an isolation sleeve where the zinc anode occur—uh, is bolted. And a—umm... A structure connection is made at the other bolt. And a shunt runs between the two. And the lower right hand corner is a photograph depicting of what it looks like on the outside of the tank where the structure connection is made. And I'll admit right here, my—the first challenge that I had at the facility was I hadn't even noticed these connections on the exterior of the tank. So, sometimes just getting your bearings on the system itself can be a challenge. The other type of galvanic anode system that you would commonly see is a direct connect system, meaning that your cable was welded directly to your steel structure. And that would prevent you from being able to disconnect as well. You'll see that we need to do that during this—um, this procedure here. So, for today's webinar, what we're really walking you through is how to check your CP system. So, these learning objectives include spot checking your system, showing with you the steps that we took using equipment to test it, and then troubleshooting. And here's just a preview of that procedure. In each of these steps, we are using a voltmeter and a reference electrode—a copper/copper-sulfate reference electrode. So, step one is to identify your system components and ensure that the anode is submerged. The anode does need to be submerged for you to perform a proper check of your system. The next test is to look at the "ON" potential. The ON potential is simply the system without making any changes to it—what potential reading do you get on your voltmeter? The "instant OFF" potential is the one that gives us our polarized potential reading. And to do this, we have to physically disconnect a nut and remove the cabling. And do all of that while viewing the voltmeter. And look for the second reading that appears on the screen. These readings should drop down, so the second one that you see visually is the one that we want to record. And the key here is to try to reconnect that system within two to three seconds. The longer it's disconnected, the more your structure can depolarize. And that takes you a little bit further away from getting an accurate reading. And that's why it's called an instant OFF potential. It's a very brief disconnection of your system. After that we will look at the anode itself. So, we have two readings that we can take on the anode. One is current and the second one is potential. And then anytime you're doing work on your system, especially if you disconnect anything, you want to do a retest. So we'll share that with you as well. Now, if you don't have the equipment available to you, a visual inspection is always useful as well. So, we'll just touch briefly on what you should be looking at if you're able to do a visual inspection, recognizing that you don't always have the anodes available to you. You might not be able to unwater the system or get a clear image of them. So, in with that, we're looking for the coating condition of your structure, any corrosion damage you might see on your structure, and then the anode consumption itself. Step one

is to identify the system components. You can see the photograph from an earlier slide here. And in this one we're pointing out the different components. So, first of all we see a shunt, which has a wire running between the two bolts and two posts that you will use in a later measurement. And this is the structure connection point. And another bolt stud over here is the anode stud. May be difficult to see in this photograph, but there is an isolation between this nut. At the bottom we see some ground cables. It's always important to note what you see as part of your system. It can all be an important factor to what's going on. And then we also have an insulated cable. And this insulated cable is running from the anode stud. And it connects to the shunt, which then connects to your structure point. So this is the connection that is keeping your system turned on. Daryl, is there anything else that you'd like to point out on this slide?

>> Dr. Little: No, but I just wanted to emphasize that you are correct in—being able to identify everything at a installation is key and critical. And providing—having that information and being able to provide that to someone else who's coming along and testing the system can help a long way in getting it done correctly and efficiently.

>> Dr. Merten: Step 2 is recording the ON potential. So, in order to make this reading, we have our multimeter, or voltmeter. We've connected the positive terminal to the manhole itself. So, that's the cable that's running up here. The manhole has exposed steel. It's rusting in this image. So, we just connected directly to an area that seemed to be a little bit cleaner so we had a good connection with low resistance. And the negative cable is connected to the reference electrode itself. And that's the cabling that's running into the tank. Our reference electrodes tip is submerged just below the waterline and we have it fastened to a PVC pipe, just to use as a pole to sort of hold it into position for us. So, with this, we see a reading on the multimeter of -597 millivolts. I had known enough about the cathodic protection system to know that this was not a good sign. That this reading is too low or too—um, not polarized enough. So Daryl, I'll let you help me out on what I'm seeing here and where I'm needing a little bit of help.

>> Dr. Little: So, one of the things that we looked at was... Bobbi Jo is correct in this was—this value is way too positive to be something that is cathodically protected. And looks closer to something that would be what's called a native or static potential, which is the potential of a structure that is not cathodically protected at all. The second thing we noticed was, uh, on the voltmeter—She was making the measurements in millivolts. And while in this case that was fine, we would recommend always taking that measurement using volts. Because if you get into a situation where the potential you're measuring is over 1 volt, then in millivolts it's going to produce what's called overload, and you will not be able to make a measurement. And that can actually lead to a little bit more confusion as to—what am I doing wrong? So, it's best to always start off reading potential measurements in volts. Make sure to do volts DC though.

>> Dr. Merten: Great, thanks Daryl. So, if I had turned this dial one to the left, it would go from DC millivolts to DC volts. So, that's just something to keep an eye on. Step 2 is the instant OFF potential. So, now we're starting to disconnect features of the system. So, I started by backing off the nut that was on the structure connection. And now I'm going to remove this eyelet while viewing the multimeter. So, we want to see that there's a change. And the change is going to be the

voltage, or the potential, becoming more positive as we disconnect that anode. So our ON potential, recall, was -597 Millivolts. Or point—uh, -0.597 volts. And that was staying pretty steady. And as soon as we disconnected the system, nothing changed. So, now I knew we really had a problem. If there's no change... You know, one key thing to think is that there's no polarization observed. Daryl, can you add some more?

>> Dr. Little: Yeah, that would be no polarization and there could be multiple reasons. And we're going to get into that on the next slide with the troubleshooting. But whenever you see an ON and an instant OFF where there is very little to no difference, then we know that there's something wrong with the system. It's not providing the protection and that is key to what we are looking for.

>> Dr. Merten: Alright, so let's troubleshoot what I've tried to accomplish thus far. Basically, we're seeing there's an issue and the possible reasons would be: that the CP system is not connected at all. That could explain why removing that eyelet and cable had no change on the multimeter. It could also be that the anode itself has been consumed. Cathodic protection systems are designed for a certain life cycle or lifespan. Typically it's a 20 year design life. So, if you're approaching the end of that 20 year design life, this could be a realistic possibility that your anode has been consumed and it's time to replace that existing anode with a like anode. The other one is that the anode type itself is incorrect or it's been passivated. So, if the anode is incorrect, then you will not have the correct level of polarization on your structure. It could either be too much, which could cause damage to the coating system. Or too little, which means your structure is not fully protected. On a passivated anode system, it's about similar to having no anode or no cathodic protection at all. The current output is very little. I would like to think of a passivated anode as like a sleeping anode. It's just not—it's not activated because it's in the passivated condition. So, we also weren't quite sure going into this What type of anode was on the structure. Zinc would be a really common one. There's two different types. Magnesium is also common. And there's a third type, aluminum. But aluminum is generally reserved for seawater. So we were pretty sure zinc or magnesium would be correct. And you can also look at the water chemistry to help understand what anode should be used in your system. And anyone who is performing cathodic protection design would always want to see the water chemistry for that system. The other piece here is that the lightning system—you know, the grounding cables that we were seeing seemed to be connected directly to the anode. So, the question there is—you know, is that something that could be causing an issue. So moving on to the possible solutions. The first bullet here is to clean the connection points to ensure electrical continuity. So, this bullet is directly related to the first bullet, above. If your connection points have some corrosion on them—if it's steel, your corrosion is going to be orange. If it's zinc, that corrosion product is going to be a little harder to see. It's more of a white color. And I think these may have been galvanized nuts, so it's possible here that there's just a little bit of corrosion product and that caused the resistivity between our system components to be too high. And in—in a sense—In essence, we lose our electrical continuity in that case. So, we're going to give you a couple more steps here. Checking the anode. That's going to help us to figure out which of these possible reasons is contributing here. And the other thing to do is to maybe get a technical expert involved at this point. The steps we've shown you so far are the basic steps. We would hope that if you were testing your system, you would have seen a change on your multimeter. And if you needed assistance understanding anything about that change that you saw when doing the instant OFF potential

reading, you can still reach out to the technical expert just to confirm that you're seeing full—full polarization on your structure and that you're adequately getting protection. So step four. Now we're moving our focus on to looking at the anode itself. We want to be able to determine the health of the anode, essentially. So, we had earlier mentioned the shunts in the left hand side of this photograph. And there's two shunt posts. So, using my support back at the Denver Technical Service Center, they were able to confirm for me that they were pretty sure it was a 0.01 ohm shunt. So, my next piece of instruction from them was to measure the voltage across these two posts. And what I saw for a voltage was 0.1 millivolts. I'm still on my millivolt reading here. Recognize this is a really low reading, but I went ahead with it and used Ohm's law, shown in the lower left hand corner here, and derived so that we can calculate current. So, the current itself should be that 0.1 millivolts divided by the 0.1 ohm shunt, which gives you a reading of about 10 milliamps. So, we're thinking that that's not much current output. And we're showing less than or equal to because of how low this reading was on our multimeter. I wasn't too confident in what the multimeter was showing me. It seems like it's possibly at the limit of the multimeter itself. So Daryl, can you add some more here?

>> Dr. Little: Um, actually you are very—you are correct in that is the limit of that Fluke. While Flukes are great voltmeters—We use them a lot, on most of our projects—it just does not have the accuracy to read below 0.1 millivolts. So, when you see 0.1, often that could be a lower number and it's just rounding it up internally. So, we use a different voltmeter when we're needing to make measurements of current, especially at low currents. But it is a little bit more specialized piece of equipment. So, in reality, yeah, that less than or equal to 10 milliamps is correct in the fact that it could be as low as 5 milliamps or maybe even a little lower. We just cannot get that—measure that value. Now, this is one of those cases that you would measure in the millivolt range because they are a lot smaller. So, if you put it on the volt setting on your voltmeter, it's not going to pick it up at all. So, this is where—when you're measuring across shunts, you always measure using the millivolt setting.

>> Dr. Merten: Great, thanks Daryl. And I think it may even be the case that if we switched between the millivolt and the volt reading that I would have seen 0.1 for both of them—or the lowest reading possible for both of them. And that may have been a good check for me to just switch between those two settings and see what readings the instrument was providing. Now in step five we're measuring the anode potential. And this gets us back into a place where we can trust our multimeter again. This is a more common measurement for this type of multimeter. So, if you recall the anode bolt stud has this isolation kit, or some kind of like a rubber washer, separating it from the—the steel structure, or the tank wall itself. So this is the—this is what we had essentially confirmed was going to be our anode. And not being able to get inside the tank or see inside, sometimes we're just making a guess here in this multimeter reading of the anode potential alone should be able to confirm for us if we're—if we've correctly identified it. So, in this case we kept the system disconnected so that it's not the polarization of the steel wall and the zinc anode itself together. These are separate, so it's the anode alone. And sure enough we saw reading of -1.066 volts. You can see I've switched over to the voltage reading, so I get a clean measurement here instead of an overload reading. And this is really close to, sort of, your published potential for zinc anodes. And this was basically our way of confirming that not only is this the correct stud for the anode, but it's also a zinc anode as opposed to the magnesium anode, which is a much more

negative potential. So, here on the lower right hand side you can just see the person placing the one end of the lead against that stud and the other end were—which is connected to your reference electrode, is still inside the tank as it was earlier. So we only have to move the one cable from the structure and move that over and touch the anode stud with that lead. So, basically, this is showing us that the anode is not passivated. It's giving the full potential we expect in this electrolyte that it's in. Daryl, can you add some more here?

>> Dr. Little: I just kind of want to say, when Bobbi Jo presented these measurement values, the first thing that went through my mind was "woohoo!" Because she's right, it did—it showed that it is a zinc anode. Because it's very close to that one—the standard—ideal -1.1 volts. She is also correct in the fact that—no—that the potential reading is indicating that is not passivated. Passivated metals often show a much different um... potential when measured in water or whatever other solution. Now, the other thing that this kind of showed, and this is also indicated with the initial readings where, at the -0.597 volts, that there was no cathodic protection. Well that meant that the anode definitely wasn't connected. Well, this measurement is also showing that no—okay, it is not direct-connected, it is not shorted. So, therefore also the isolation is working. So, if we hook this system up, we could actually make—um... and it was working—we could make the measurements. We could test and get the correct values for how much polarization we are seeing on the structure.

>> Dr. Merten: Excellent. So, we were making some good progress, we thought here. It had been a long day of scratching our heads. I was hoping it was going to go much more easily than it did. But we just we went ahead and we reconnected everything and we retested to see what happened. And in our first reconnection, we saw that the potential reading for the ON potential had gone up. So, it was—or, it had become more negative, right. So, basically what we did then is sort of walked away for a few hours. Once you connect the system, we had assumed that we had actually made a connection to the system at that point. And in walking away, you give it a little bit of time to polarize and stabilize to the readings that it's going to be trending toward. And that's what I wanted to see. How much is this polarizing? What direction are we moving in? What readings are we gonna get if we just let it sit for a few hours and come back? So, when we came back a few hours later, we had an ON potential reading of -0.882 volts. And then we went ahead and disconnected to do the instant OFF potential. And it had polarized from that -0.597 to -0.672 volts. So this is a really big jump already. And, essentially, at this point, I was feeling pretty confident that, um, that what we were experiencing was a system that had disconnected itself over time. Likely due to the increased resistance at those connection points. So by us simply backing off that nut from the bolt stud and then putting it back on and re-tightening it, we had made a connection for the system again. So Daryl, do you want to add some more here?

>> Dr. Little: What I'd like to add is actually—that is—those—reading those values after a couple hours is very encouraging. We typically look at—by NACE criteria—an operating system will either have a 100 millivolt shift from the native for the polarized potential. So, if the native is -0.597 volts, then criteria would say, if the instant OFF potential, or polarized potential, was -0.697 volts, then that system is act—is adequately protecting the structure. The other criteria is the -850 millivolt, or -0.85 volt criteria. So, if this is—if the system is showing this after only a couple hours, then we

could—technically, I would say there's a strong possibility of—we will actually hit that -850 criteria. Which is even more encouraging and offers enough protection for the structure.

>> Dr. Merten: So I have one slide here just to touch on the visual inspection itself. Just to make sure people have an understanding of what they should be seeing when they look at an anode. So, the photographs on the left are three different anodes on these structures. What you can see is—looks like there might be a little bit of scale or roughness on the one on the left. The one in the middle actually has really cleaned sharp edges, and it looks like you may still be able to see some of the imprints from the original manufacturing. And the one on the right looks a little bit rougher again. So what we want to see is that we should move—be moving away from the sharp edges. The sharp edges are a brand new anode with no consumption. It should be rounding over time. It should be pitting. That metal itself is being removed and consumed during the cathodic protection. So we did just note that it seemed like there wasn't too much degradation occurring in each of the tanks. So this would be something important to note during your troubleshooting if you have access to these photos. Another point, just on this job itself—the interior ladder seemed to have some scaling or corroding. It seems to be an aluminum ladder. So you always just want to keep an eye on the other parts of your system or the other parts of your structure. We want to put this cathodic protection system in place to protect the steel tank liner. But we also want to be able to ensure that the rest of the system is in good shape as well. So Daryl, do you want to add some more here?

>> Dr. Little: Um... Very true on the anodes. We definitely want to see that changing shape to say that yeah, they are working. So, by the fact that they are still fairly, like you said, sharp-edged and don't see a lot of deterioration—that means that these anodes could have been disconnected for quite a—for quite some time. Um... As for the ladder, yeah, aluminum is not the greatest choice for high chloride environments. And the difference in the static potential of the zinc versus that of the aluminum is—they're actually very close to each other. So, there might not be enough driving force to protect that aluminum using a zinc anode. Magnesium anode, there is a greater chance of protecting that aluminum ladder. But the—in this case, zinc anodes were chosen. So, the aluminum ladder is going is going to take the brunt of the corrosion that is occurring inside the tank. So... I'm gonna go ahead and summarize this. Big thing is always the cable connections. Always check that the CP system is operating. So, if you disconnect the anode And—not even to really take the measurement, but just disconnect the anode and monitor the potential of the structure, or the tank, and you'll see that—if—if when you disconnect, all of a sudden that—the numbers start dropping off or going more positive and continues, then you know that you had some polarization. If you disconnect an anode and see absolutely no change, you know that that's the other. The anode's gone or the anode was never connected. Or some other possible issue. The other issue or the other thing that we saw was—the external connections around the outside of the tank are very vulnerable to damage. I mean something could snag a cable, pulling apart—disconnecting the cable from the eyelet, from the connection. Potentially damaging a bolt, damaging that isolation. Anything like that can be done. Plus the fact that now they are exposed to the atmosphere, so you get the oxidation of the surface, which could increase the electrical resistivity of the connection. So, having these things in a box, or like a—what we call a test station, can help avoid a lot of that. Also, going around periodically and checking the bolts to make sure they're not somehow coming undone or loosening. Another useful tool is actually labeling all the cables and what they go to. Like labeling that that bolt

is the anode, that's the structure connection. Those can all help for someone who's coming along in the future and testing the system. It will make it a lot quicker and a lot easier to understand what's going on without having to re-diagnose all the connections. Now, while the lightning grounding system was not detrimental to the operation of the cathodic protection system, it's probably not the best way to connect the system in, by connecting to the anode. They should always be connected to a structure or a bolt for the tank. So, basically connected directly to the tank. By connecting it to the anode, any kind of a lightning strike or a surge is now going to run through that small insulated cable and that tiny—that small gauge shunt, and it's actually going to destroy that connection. So having lightning strike and—if this is a tank in the middle of nowhere—you could disconnect your entire system and not know it. If it's just connected to the tank itself, your—most of your—um... any kind of electrical surge is going to go through the tank and the grounding system. And you should not have any damage to your shunt. Visually inspecting the anodes is a very useful tool. We don't always get to see it, especially with buried structures. But for submerged structures, it's really useful. Because you can see whether or not you're getting a change in shape or the—it's degrading with time, it's pitting. As soon as you see that degradation or pitting on the surface, you know that, hey, that anode is actually working. No change can definitely mean that it's potentially passivated or not connected, both of which are not very good for your tank. Now, the potential readings can aid in determining the anode passivation. But, in this case, we really needed to do—to see both. So if you have the opportunity to look at anodes to see if they're working, that much—that's much better. Plus it gives you an opportunity to inspect coatings and any kind of corrosion. The other thing about the visually inspecting the anodes is, it helps to determine when you need to replace an anode. So if you go in and look at it and it's got a lot of degradation, you know that, hey, this anode needs to be replaced in the near future. If you can do it—inspect it every so many years, like you would do for a coatings inspection, you can then tell like, okay, it's lost this much anode material. Now, down the road it's lost another—this—an additional amount. And that might be another way to predict the exact time, or rough time, to replace the anode. Um, in this—in the case of the tanks, uh... While draining the tank in this case was the one—one way to do the testing, the ideal would be to test the—do the actual testing of the system with the tank completely full, which can only be done from the top. But, due to the other reasoning—the other aspect of this was to visually inspect the inside of the tank and look at the anodes and see the system. This turned out to be a very useful uh, inspection. Because... It does take time to drain the tank, so you are kind of under the gun on the some of this. So when you can do it, great. When you can't, there's other ways to test the system. Bobbi Jo, do you want to add anything?

>> Dr. Merten: Yeah, I think I would just summarize that the key takeaways here are to make sure that you are performing a system check of your CP system, especially if it's a system like this one, a direct—or a galvanic cathodic protection system where you can disconnect and measure that polarized potential. That's a really important reading to be monitoring. And we recommend—our group recommends doing that about once per year. So, we're hoping that this information was useful to you and that you can translate it to your own systems. I also want to underscore the fact that I went through this as someone who probably hadn't thought about a cathodic protection system for a year or two. I had some prior training, maybe even a similar level of training to what other folks out at Reclamation offices have during our Corrosion School. So I thought I could apply my knowledge, but I did need a little help. Fortunately, I had some cellular service out at those

storage tanks, so I was able to sit on a video call with my colleagues back in Denver and they walked me through this troubleshooting process. So hopefully you'll think of our group in Denver as a resource. First and foremost, please test your systems. And second, if you're having an issue, give us a call. But thank you everyone for attending today. We really appreciate you joining in and we're available for questions.

>> Grace Weber: Thanks Bobbi Jo and Daryl. So, as Bobbi Jo mentioned, we will now begin our Q&A session. So, if you haven't already, you can go ahead and use the chat box to ask any of your questions and we will address as many as we can. So, to start off—How would this process change for a galvanic anode system that's buried with anodes buried underground versus immersed in a tank?

>> Dr. Little: The one thing that would change is the visual inspection. Now, if we—if those anodes were directly connected to the structure that's buried, then—because both the anode and the structure have to be buried—but if they were directly connected, we can measure that ON potential, but we can't get that true polarized potential. But we often connect those anodes through a test station, so we could make the same measurements of the ON, the instant OFF, the current output, and the anode potential. So, we can still get that information to see whether or not the structure's adequately protected.

>> Grace Weber: Thanks, Daryl. Another question: Can TSC come out and do CP testing for facilities?

>> Dr. Little: Absolutely, we would love to come out and test your cathodic protection systems. What our standard procedure is—we would like whoever would be doing the testing to be on site with us. We can actually—we will train any personnel. And we can also put together what's standard operating procedure, standard test procedure. Along with tests sheets, collect drawings and put it into a nice package. That way you have that to continue testing yourselves. Or we are still available if you want to want us to test it again.

>> Grace Weber: Perfect, thank you. Another question, could you explain the passivation a little bit more and how these troubleshooting solutions would have changed in the case of passivation?

>> Dr. Merten: Daryl, do you want me to try to take that one and you can fill in any gaps in my knowledge?

>> Dr. Little: Yeah, I felt like I was talking too much.

>> Dr. Merten: So passivation is essentially when you have your metal surface and it becomes oxidized. So—and the oxidation layer that forms above—above the metal surface acts as a bit of a barrier for current flow to the metal itself. So that's basically what we're seeing when we talk about a passivated anode. It's that the current flow through that new barrier, or that new. passivation air—uh, passivation layer—is greatly impeding the system. So the current output becomes very little and you're not getting the protection that you would have needed. So, when it comes to the

troubleshooting, had it been passivation, I think that's also a case where you'd want some technical experts involved in your troubleshooting. You want to be able to go through the other options and confirm that it is passivation itself. I think in everything that we try to confirm, we try to confirm it in more than one way. So positive confirmations of what we think it is, but then also excluding all the other options to really feel certain. 'Cause if it is a passivation issue, you're probably looking at needing to redesign your system to potentially use a different anode. So that is—that is sort of a serious issue and one that we try to avoid.

>> Grace Weber: Thanks, Bobbi Jo. Those are all the questions I'm seeing for now, so I think we will close out for today. Thank you everybody for joining. Thanks Bobbi Jo and Daryl for presenting, and we'll see everybody next time.

>> Dr. Merten: Thank you.

>> Dr. Little: Thank you.