Dr. Jessica Torrey: [0:04] Again, welcome everyone to the corrosion webinar. Today as you see on the front screen, just a couple announcements before we start. A couple upcoming events are, as I said, corrosion website is being revamped. Our corrosion and coding school is coming up in October.

[0:31] Notices will go out soon about signing up for that corrosion and coding school. Our next corrosion webinar series is tentatively for October but that might get pushed back to February because of the conflict with the corrosion and coding school.

[0:54] A couple of things before we start. I'm going to ask you to please save questions to the end and the way to do questions with this go-to meetings software, is you can type them into the questions box and then I should be able to see those.

[1:07] As well, you can try raising your hand, but I'm a little bit iffy on that technology and that part of it. The question box is definitely the best way to try and ask me a question.

[1:25] Why are we doing this? This is our second webinar in the series and what we're trying to do is just to inform the Reclamation staff in general on the importance of corrosion and the importance of trying to have good corrosion mitigation management practices.

[1:46] Hopefully, we can give you a little bit of information today on our topics, which are corrosivity testing and ensure to corrosion mitigation.

[1:59] Our first slide, is this. Here is a picture of your friendly TFT corrosion staff. There's four of us here in the photo. From left to right is Roger, me, myself, and Darryl. In addition, we have three summer students working with us, Marcy, Grant, and Kevin.

[2:20] They're doing a lot of the soil testing that we're going to be talking about today. They've been in the lab working really hard and they'll also be...

Darryl: [2:28] Not registered.

Dr. Torrey: [2:30] They'll also be working, excuse me, on some of the website updates. The topics that we will cover today. First, we'll talk about corrosivity testing of soil and water. We test, in particular, for four components in our soil and water. This is pH, electrical conductivity, chloride concentration, and sulfate concentration.

[3:02] We also do in situ so resistivity tests we'll talk about. We'll cover a little bit how we use this testing. Why it's important and how we use it to determine what corrosion mitigation measures are required. I'll turn it over to my colleague Daryl and he will talk about corrosion mitigation methods.

[3:23] These include material selection, protective coating, corrosion monitoring, and cathodic protection. We have two different types of cathartic protection, galvanic and impress current. We'll just cover those

briefly in today's session and then we hope in a future webinar do little bit more in-depth into cathodic protection and CP system testing.

[3:45] First off, those of you who saw the first webinar have seen some of these pictures, but just a kind of introduction, and giving you some context on why corrosion is important. First and foremost, public safety concern. You can see here three situations where corrosion actually was the cause of extreme failures.

[4:13] In the two on the right, we have the Mianus River Bridge in Connecticut and the Aloha Airlines disaster. These both resulted in fatalities. The Mianus River Bridge was attributed to corrosion of a pin and a pin in Hangar design bridge and that caused...the corrosion of that pin created an undue amount of load on a small support structure and then there was the failure of the bridge deck.

[4:42] In the bottom, you see a picture from the Folsom Dam. The failure of Spillway Gate number three in 1995. Luckily, there was no loss of life here, no casualty, no flooding, but you can see where this could have been a much more extreme problem.

[5:01] It was also very very costly... Excuse me. Microsoft is giving me some messages. Sorry. The cost of replacement of that gate was about $20 million for the gate alone. That was in addition to a 40 percent drainage of the reservoir.

[5:22] That was attributed to corrosion of a trunnion pin which created friction. That gave a stress loading beyond the limits of what the gate...Are we good though? OK.

[5:39] This is a public safety. There's also a huge economic cost for corrosion. This is information from a new study that was done in 2002 between the National Association of Corrosion Engineers and the US Federal Highway Administration. They estimated that the annual direct economic costs of corrosion are 276 billion dollars. This is about three percent of the United States GDP.

[6:07] This study is very interesting. It breaks down the costs into various industries. You can see in addition to these direct costs, there's also indirect costs of corrosion which double that. That's 550 billion dollars a year. That report also gives some ideas for preventative strategies and things that we can be aware of that would help prevent this corrosion.

[6:35] Two of these things are changing the misconception that nothing can be done about corrosion, and then improving education and training of staff, and the recognition of corrosion in control.

[6:48] Another two of the points here that we hope to address in this webinar and give you some more information, so that when you're in the field and you see instances of corrosion, you'll have a better idea of how to react to that.

[7:05] First of all, what is corrosion? Corrosion is defined as the deterioration of a material and/or its properties caused by a reaction with this environment. We most closely associate this with metal, the metallic corrosion. We will also discuss a little bit the degradation of concrete. Concrete can also react with this environment with some pretty serious consequences.

[7:29] We can try and predict those through our core acidity testing program. This is a little schematic here of the corrosion reaction. It's an electrochemical reaction between a metal and electrolyte. Electrochemical reaction, these are things such as oxidation, or more commonly, rusting.

[7:50] You can also have electroplating, or anodizing, and use that other electrochemical reactions. Our metals, for reclamation, typically we're dealing with various metals to steel. We also have some instances of copper and aluminum, then an electrolyte. For us that reclamation is that the soil and water, usually fresh water.

[8:14] There are four required components for corrosion. You need an anode. The anode is the portion that corrodes. Then you need a cathode. This is a portion that is protected. This is usually because of a difference of charge between the anode and the cathode.

[8:32] An electrolyte is required, and again, that's soil or water here, and then a metallic return tap. That would be your pipe, or your tank wall, or your trash rack, or something like that.

[8:47] I'm going to talk a little bit now about core acidity testing. Core acidity is the aggressivity of a water or soil. A propensity of water and soil to react with your metal or concrete, and for that to then cause damage. In cases where a structure is going to be in direct contact with soil or water, we recommend core acidity testing.

[9:17] This includes both metallic structures and concrete structures. I'll go onto a little bit on what can happen to each of those types of materials. As I said before, core acidity testing is used to predict the likelihood of corrosion or degradation of the material in the environment in which it will be placed.

[9:36] These are just those examples. This is an image here of the soil samples that we typically get. We ask for...These are core-size plastic bags. We ask for two of them for location in order to do our soil chemistry testing. How will we request this information? As you see, we typically put this request in a field exploration request transfer.

[10:05] You'll see, in addition to the physical testings of the soil and the soil resistivity and other geotechnical, you'll also usually see a small section from us on the corrosivity testing.

[10:21] We also recognize that, too. We can do these tests here in our lab. All the tests, I'll talk about we can do here at the TSC in Denver. However, there are also several area offices that have these capabilities.

There's a lab in Boulder City that does soil and water testing. Also, in Boise, that are associated with the Reclamation.

[10:44] There are also a lot of private testing labs who can do these types of measurements. One thing that we like to say is that, if we do them here in-house, then we have control of the testing method. There are several different methods.

[11:00] It seems that each state's Department of Transportation has testing methods. EPA has testing methods and [inaudible] has testing methods. We've kind of gone through those methods and chosen the ones that we feel are the most rigorous for our applications and that's how we test here in our lab.

[11:20] If the testing is to be done or coordinated by area offices, then you'll see the request for that information in our design data request. Just a note, here is our corrosion Website. It's a Google site right now, so it's only accessible from Reclamation personnel.

[11:37] On that site, we have the document guidelines for corrosivity testing and it goes through just a little bit about which tests are requested, what the standard test methods are for those. My contact information, so where you can send samples, and then the second page here actually talks about how to collect soil and water samples.

[11:58] If there's ever any question on how to do that, you could always give me a call, and I'd be happy to walk you through how to take those samples. I'll get into the four tests that we specifically ask for. The first is pH.

[12:13] PH is very important and an acidic soil or water can indicate a higher risk for corrosion, metals, and concrete. That's why we ask for this test. We also will take note if samples are also extremely basic. This is either a very low or a very high pH. We also measure electrical conductivity.

[12:35] As you see here, these are soils that we've prepared in our lab. The way we prepare soil, is we dry them out, then we do a very specific ratio of soil to water and then we mix them. We prepare this.

[12:53] What this does is, it dissolves all of the water soluble salt and the electrical conductivity is a measure of the water soluble salts and that is often directly proportional to the quantity of the soil. You can see here some of the test methods that we use for these measurements and this is our set up in the lab. There are simple probes. This is pH probe here.

[13:18] This is the electrical conductivity probe and they go in these mixtures of soil and water and we get a number. We also test for two and ionic compounds so these are negative ions, chloride and sulfate. Chloride concentration is mostly in relation to looking at corrosion of metals.

[13:47] In the presence of chloride, corrosion can be enhanced and, specifically, as you see in this image that I've found, pitting corrosion.

When you start having pitting corrosion, and you have a soil that's high in chloride, you can really accelerate this process, and end up with some serious problems.

[14:09] Chloride ions can also be a cause for corrosion in rebar and reinforced concrete. In that case, you can have a chloride concentration from the soil or water, but you can also have chlorides that are in the mix of the concrete that can create a problem. If you're using a source water and a mix design that has a high chloride, this can also affect corrosion of the rebar.

[14:39] Exposure to chloride comes...what we look for from the soil or the water, so the environment, but it also can also come through the icing salt. If you have grate on a deck, where you put a lot of the icing salts, you can expect that you will have some accelerated corrosion on the metallic surfaces.

[15:04] This is our ion chromatograph instrument. This is what we used to test and we have ASTM test method and an EPA test method that we use for determining the chloride concentration. The same test method or the same technique, the ion chromatograph is used to measure sulfates in the soil and water.

[15:27] This has an effect on the degradation of concrete. Pools and water high in sulfates can produce sulfate attack on concrete and this affects the mechanical properties. It is a chemical reaction with the concrete that causes a loss of cohesion between the cement and the aggregate.

[15:47] You can see in these images that this is from Portland Cement Association and that this was a controlled test of different concrete mixes in a high sulfate environment. You can see some of the concrete, this really did not perform well, whereas there's others that did perform well.

[16:06] If we know in advance that you have a soil that has high sulfate, then we can consult with our concrete engineers here, and our concrete experts, and design specific mix for your applications and your structure that will actually hold up fairly well under sulfate attack.

[16:27] Another task that we do and, we in the materials group help with this, the geophysics group at TSC, actually coordinate these measurements is the soil resistivity test. We did this as an [inaudible] measurements.

[16:44] This is a really good measurement because it's done onsite and undisturbed soil. We do what's called a Wenner four pin-method. You have four field pins that are inserted into the ground and then occurrences pass between the outer two pins and the voltage is measured at the inner two pins.

[17:05] If there's any kind of anomaly, so very conductive areas or highly resistive areas in your soil, then we can actually get a choosy measurement of where these things are. Last summer, we did a lot of work on looking at leakage and some of the earthing canals. We could see if there were water channels through the canals.

[17:31] Our geophysics will do our analysis for us. They get these, kind of, [inaudible] cross sections and then do an inversion modeling to get a one-dimensional resistivity versus depth measurement.

[17:46] Then, we can take that information and use it in determining if we need to apply corrosion mitigation methods. This image here is from our lab. This is a soil box.

[17:57] You can also do a Wenner four-pin method on a soil test in the laboratory. It's obviously not as accurate because you are taking the soil out of its native environment. We have to dry it, and then artificially saturate it to get the measurements. It's much preferred if we can do these measurements in C2 and at the right moisture and depth for the structures.

[18:24] Again, this request for this testing or information will come to the fore or the design data request. This, here, is a couple images of the Wenner four-pin method in New York from the corrosion staff having a little fun during that. [laughs] Resistivity measurements.

[18:44] How do we use this data? We have published values. We take the information and the data that we collect and compare this to published value. Then this becomes one portion of how we make our decisions as to whether to require, for example, coatings or cathartic protection on the structure.

[19:07] One example that I give here, for example, is this table on different sulfate concentrations. If you have a soil that's listed in the severe category, it's actually recommended that you use a Type V cement along with a low water-to-cement ratio. Then some additives such as Lutitium Flash or Slag.

[19:28] This will make your concrete mix much more resistant to sulphate attack. These are things that our concrete engineers will then help us design with the specifications for structures. As long as we have this information, then we can make some informed decisions on how to proceed with our corrosion mitigation method.

[19:51] We're gonna go through these five mitigation methods. Material selection, protective coating, monitoring systems and then galvanic and oppressed current cathartic protection.

[20:06] First, these are our design criteria. Corrosivity testing is one portion of how we make these decisions. Just a note: the oil and gas industry is actually regulated by law to provide cathartic protection for all their structures.

[20:20] We don't have this regulation, but it's very important then that we have good data and we use good engineering practice to make informed decisions about how we're going to address corrosion on our structures.

[20:35] These are four of the criteria that we use the nature of the electrolyte, which is what we just talked about, the results of the core

acidity testing. Also, we'll look at the structure details -- the type of structure, the shape of the structure, the size of the structure. We'll use good engineering practice.

[20:50] For example, this is a siphon from East Coast canal. The data came back from a series of severe measurements that suggested that there were areas of fairly high conductivity, although resource to the areas that would require us to apply coatings and cathodic protection.

[21:08] However, there was an existing structure assessment that they are going to pass second barrel right next to you. When this was unearthed, it showed very good behavior in the soil. It has been in the ground for 50 years and showed very little corrosion.

[21:22] What we've decided to do is just put a corrosion monitoring system on the second segment, so we can just monitor year to year and see if any problems are arising. However, the history of the existing structure leads us to believe that we shouldn't have too much problem in corrosion, even though some of our data suggested that there were some hotspots.

[21:47] We also will always take into account requests from the client. I'm going to go about material selection. Some materials are inherently corrosion-resistant. We know we have a problem. We can move towards some of these materials. For example, plastics. You know they tend not to corrode.

[22:09] In choosing the right materials for a given application, we can extend the service life of these materials. We can have a material with literally no maintenance requirements. We save money. We have also lower risk of catastrophic failure and lower risk to the public by doing an informed material selection.

[22:30] It's application-specific, it's environment-specific, and it should be done on a case-to-case basis. In addition to corrosion resistance, there are many other examples of things we should take into consideration. For example, strength of the material, flammability and Barrick ability.

[22:49] These are four classes of materials. We have metals, ceramics, polymers and composites. They each have their unique areas where they're very useful. We use a lot of metals for reclamation, steel, cast iron. Ceramics, we don't use them. These are for higher temperature applications. We don't have any of that.

[23:12] It's a very brittle material but it is very chemical and corrosion resistant. It's very good at high corrosivity and high temperature applications. We do use a lot of polymers, in particular, PVC, and high density polyethylene.

[23:30] You can often see this on yard piping, or some areas where you have smaller diameter pipe requirements, but not always small diameter. That's where we often see that. We also use a lot of composites. This includes reinforced concrete.

[23:48] Here's some images of some precast concrete pipe. Another thing that we've been getting into, is these fiber-reinforced polymers and they have been using those for repair, for pipe repair. Just a list of factors influencing material selection.

[24:12] We're always going to look at the performance requirements for each application and then we'll...here again, we'll use that information that we got from the corrosivity testing. What is the working environment? OK, we need to use concrete, but there's high sulfate, so maybe we'll use a different type of cement and a different mix design.

[24:33] We look at cost installation flexibility, availability, and sourcing, especially with our concrete. We have engineers here who will call local sources for concrete mixes and make sure that what we specify is available in the area that is being constructed. We look at maintenance requirements and maintain ability, compatibility with our system components.

[24:58] If any of you did the first webinar, you'll remember galvanic corrosion. If we have a mild steel pipe section in the ground, we want to be very careful at adding even new mild steel, or especially stainless steel, because you can have galvanic corrosion occurring between the two types of metals so we'll take that into account when choosing materials.

[25:23] In many cases, these will be structures open to the public, so they need to have a nice appearance and a nice aesthetic and then again, client preference. Just another note about galvanic couple tends to be a question that we get very often. We have the galvanic series. There are some metals that corrode more easily than others.

[25:50] We want to take a note when we're making repairs or putting in new structures that we use models that are compatible with each other and won't cause corrosion of the existing structure. This happens a lot when we have new and old pipes.

[26:05] If we have old pipe in the ground that had been that had been passivated, which means it has a protective oxide, so it's already rusted a little bit, but that rust is actually protecting the metal. If we put a new shiny piece of steel next to it, it will actually accelerate corrosion on the new steel because it's not passivated. Just a note, to be aware of that.

[26:28] We also see this a lot when we have, for example, a stainless steel structure and people use mild steel bolts and so you'll end up with accelerated corrosion of the mild steel. Protective coating. This is a huge business in the United States.

[26:48] The [inaudible] estimated that the cost in the United States for [inaudible] protective coating was $108 billion every year. 50 percent of all the corrosion costs are preventable and approximately 5 percent, [inaudible] in the area of coating.

[27:05] Within Reclamation, protective coatings and this includes paints as well, are the primary means that we employ to control corrosion. We have an entire group that's dedicated to protective coating.

[27:21] They wanted me to stress to everyone the most important aspect to achieving good coatings is proper surface preparation and this is something that they go over in detail and they have several hands-on modules in the cuttings and corrosion school, which is taking place in October.

[27:39] There's three types of materials for protecting metals so we have inhibited coatings, barrier coatings, and sacrificial coating. Inhibited coating are coatings that form a chemical inhibitor with the soil or water, so it's actually a chemical barrier to corrosion. There's some examples listed there.

[28:00] Barrier coating form an electrolyte barrier so they are electrically insulative and isolate the metals from the electrolyte. This is how they prevent corrosion. We have sacrificial coating, which provide galvanic protection and, as I mentioned, the galvanic series, they actually employ this.

[28:23] For example, zinc will corrode more readily than steel, so you can coat the zinc or put zinc-rich coatings onto a steel and they will actually preferentially corrode the zinc and protect your steel. There's many different areas in reclamation.

[28:43] We typically have three different areas where we will use coating in immersion applications, varied applications, and for atmospheric corrosion. You can just see some examples of what types of coatings that we could use for each of the three applications.

[29:01] We also have a fourth area where we are starting to use some of these pearl component properties and polyurethane and these are widely applicable across all three. It can be quite overwhelming. There's a lot of different coatings available and that's why we really encourage people to contact our corrosion team here at the materials lab.

[29:23] They can help in deciding what types of surface preparation, as well as what types of coatings for a given application. Here's just some examples. This is our corrosion team. We have Alan, Bobby Joe, Dave, and Rick. These are the four [inaudible] guys. This is Alan, coating a trash rack from Parker Dam.

[29:47] We have some examples of the laboratory testing that they do, so coupon testing of different types of coatings in the laboratory. Here's a coatings repair they did on a pump from the Durango pumping plant. This is an inspection that I actually did at Seminoe Dam, and you can see there was a sump pump that was removed from the gate.

[30:08] This is the backside of the gate and it was repaired. The front side of the gate that was not repaired and you can see the nice corrosion here on this gate. That shows the importance of having good coatings and

coating repair. Here's some examples of epoxy coated rebar and galvanized rebar.

[30:29] I'm going to turn the rest of the webinar over to my colleague, Darryl Little.

Darryl Little: [30:41] First, we're going to talk about various systems that you'd want to put on a structure. Primarily, number one is corrosion monitoring system. We'd like to see this on every structure, obviously. Sometimes it's not possible, but this will allow us to monitor that structure, see how it's changing in its environment.

[31:04] Key components is a test station. You want to lateral continuity bonds, so that if you have a long pipeline, instead of each section being isolated from the others, we're not going to have it completely electrical continuity on the structure and therefore we can, if say later, we want to add a system to it, then it is possible.

[31:25] If we don't have those electricity continuity bonds, then you would have to dig up the pipe and install them. You can see, this is an example of the test station for a monitoring system. Usually, only see two cables that come up. Here are some examples of some continuity bonds and you see that we always have replicates.

[31:51] You're never going to have just one continuity bond. You're never going to have just one cable from the structure. We always have at least two, that way you have some, in case something goes wrong with one, you still have something left.

[32:07] The corrosion monitoring system, basically, like I said, it consists of electrical continuity bonds between the structures to be monitored and this monitoring functionality will be included in the design of many CP systems. It doesn't matter which one we're using, we need to have those cables in order to test it.

[32:28] It can be installed alone. Like say we have corrosive soils, but non-corrosive history of existing structures. We use good engineering practice to determine that we may not need cathodic protection.

[32:41] We still want to have a monitoring system on there and keep an eye on it, just in case we do see corrosion later on. Also, in borderline corrosive soils, it may not be considered corrosive, but again, we're a little hesitant.

[32:55] We just want to make sure that later on, if we need to do anything, we don't have to dig up that structure. That's typically where you're going to see a lot of damage, mechanical damage to them.

[33:06] Also, in areas of extreme wet-dry cycles, so often for submerged structures in water, you'll often hear it called the splash zone and that's an example of a wet-dry cycle. Here's the effectiveness or management program, so you can see down here when it's first installed.

[33:32] After eight years, this was just an example, but they have 83 breaks, but after 17 years, they're looking at 94 breaks. However, at that point in time, they apply a cathodic protection and you can see the number of breaks decreased dramatically. If we didn't have that monitoring system, being able to install cathodic protection would require a lot of work.

[33:55] If you installed cathodic protection at the beginning, you probably would not have that 94 breaks over 17 years, but every situation is different and that's important to realize. Economic benefits, you can see the cost for replacement are extreme. Really high.

[34:15] Continued repairs, it's not as much but it's still significant. Putting cathodic protection on a structure will decrease the amount of repairs you need. They say 58 percent less expensive than continuing with repairs.

[34:35] We're going to go over some cathodic protection. Basically, cathodic protection is a [inaudible] flow through the electrolyte from the anode to the structure. We're polarizing the structure to eliminate these potential differences.

[34:51] A good example is in this figure. You see it under what we call static potentials or nothing's done, it's just sitting on the ground. You can see these values are all different. You have anodic area and cathodic areas, and as you polarize a structure, using cathodic protection, these values become more and more the same, until you get a fairly even potential across the entire structure, and that is what's going to either...the corrosion rate on that structure will either cease, or at least is greatly reduced, to increase the service life of the structure itself.

[35:30] These electrons are provided from a source outside the structure. You need something active, like a metal that's sacrificed to cause this polarization, or a rectifier, which is an external source of power.

[35:51] Normally, the surface is coated to reduce current requirements and to allow better distribution of the current across the structure.

[36:00] Your two forms of cathodic protection are galvanic and impressed current. Galvanic, the structure is metallurgically bonded to an anode. The current provided by the natural potential difference between the metals is what causes the cathodic protection or that drive to protect the structure.

[36:22] An impressed current system, that current is supplied by an outside source. We'll go a little bit more into both types of systems, starting with the galvanic system. Again, you can see just like a monitoring system, you've got the [inaudible] , the electric bill continuity bond, and cables attached to the structure.

[36:46] Typically, we call it a bond cable and a test cable. The anode is attached to the structure through a test station. By doing this, you can see it here, it's a riser or a no value shunt. That allows us to measure

the current output of the anode. By measuring the current output, how long is that going to last in that environment.

[37:17] We typically design for a minimum of a 20-year life of the system. Here's some anodes, magnesium anodes. For soil, it's often put in a bag with a chemical backfill. That backfill is for the anode stays active in other parts of it and also maintains a hydrated environment around it. It's about that hydrated environment you can't push the electrons.

[37:58] Dynamic systems, also commonly known as sacrificial anode cathodic protection. It's providing that cathodic current by using the galvanic series and the difference in the metals to our benefit. Basically, you're going to sacrifice one material to prevent the other from corroding.

[38:19] Obviously, we want to put a material that we don't care about. We want it sacrificed because we need to protect our structure. Both the structure and the anode must be in contact with the electrolyte. You can see some examples here on some gates in this case. The anodes are direct-mounted on the backside of this gate.

[38:41] Here at Delta Mendota Canal, these bars, are basically what's left of the anode. You can see the anode was sacrificed, but the coating and the gate surface around those anodes does not exhibit rust. There is no corrosion that major corrosion. It's going to protect that structure and it is.

[39:08] Our standard out-patients for the galvanic systems, our pipelines fitting, and valves, trash racks, sometimes for a hot spot protection, gates, tanks, and also straight current interference mitigation. If you have a gas or oil pipeline, which is required to have cathodic protection, sometimes that can cause interference between the reclamation pipe and the foreign pipe.

[39:39] That's one method that can be used to help prevent this interference and cause corrosion issues. The requirements we need, obviously low current requirements, and typically we're looking at protecting only smaller surface areas. The long pipelines, really large gates, the galvanic system may not be the right one to choose.

[40:06] Anodes for soil and fresh water, we often use magnesium and zinc. For brackish water, aluminum and zinc. Now, those zinc anodes are different. You can use one that will be used in fresh water soil and brackish water and vice versa.

[40:26] Here we can see at Palo Verde Diversion Dam, there's galvanic anodes, direct-mounted to the surface, in there. This is what the new anodes look like. You can see it's pretty square looking. You can see these old magnesium anodes from the surface and you can see how they've deteriorated over time in order to protect that structure.

[40:49] You see little to no rust. There are some pros but there's also some cons of the sacrificial system. Some of the pros are you don't need external power. It's fairly easy to install, low maintenance, uniform

current distribution. If you need more power sometimes, you can just add more anodes.

[41:16] You only need a minimum right of way which nowadays is very important with all the various structures and land that we can acquire in order to put our structures in. Some of the cons are it's got a limited driving potential and turn output. Effectiveness definitely depends on the quality of the coat and you want to decrease that surface area.

[41:42] At the end, it needs protect. The larger the surface area, the more the anode needs to discharge and therefore the shorter time it'll last. Maybe an ineffective and really high resistive soils, and there is a higher cost per amp than the impressed current.

[42:03] Speaking of, let's go and look at the impressed current system and this states again we have the test station and cables. You're using a monitoring system for the impressed current system. You still have a lot of continuity bonds, anodes, used anodes go to a junction box where they're run through shunts so that we can measure and balance the current output of the ounce.

[42:31] We want all mode to be putting out about the same amount of current. That way they're all used at about the same rate. The rectifier changes the AC power to DC so that the DC can be used to drive the system.

[42:48] I often like to see a circuit breaker right after rectifier for when we're actually doing any work on it. It's quick and easy to be able to turn off the power and maintain safety.

[42:59] Here you can see a rectifier mounted on a pole. These are some examples of junction boxes. That right there are some variable resistors. We'll often want to have variable resistors in those junction boxes just so we can balance the current output, make sure they all deplete at the same rate.

[43:24] This system provides spot of protection using an external power source versus the sacrificial which use just the difference some potential of the metals. This direct power source forces the current from the anodes through the electrolyte onto the structure to protect it. Again, both the structure and the anode must be in contact with the electrolyte.

[43:50] Here at [inaudible] dam, you can see these are mixed metal oxide disc anodes that are on the surface and they need to be submerged. These are the anodes that are actually used to protect the structure.

[44:11] Some of the applications for the impressed current system, pipeline, reinforced concrete, piping plant pumps, pumps especially this on the right. See the anodes that were put into the pump to protect the columns, trash racks, tanks, gates.

[44:29] Now for this, the requirements for impressed current are often the height we need for the high current requirements. The galvanic was below current requirements. This is where if we need more, this might be the system that is recommended.

[44:46] Some of the anodes that are used are graphite or high sodium [inaudible] , mixed metal oxide, platinum, materials like that. You can almost see any material in this situation that we've even seen that were used in the past. Railroad rails.

[45:04] The anodes normally connected through the [inaudible] in the junction box as I mentioned before. These anodes are installed in a linear or shallow bed or a deep and ground bed which is usually a vertical hole drilled into the ground. Again, there are some pros and cons just like the sacrificial systems.

[45:28] Pros, there's flexibility to handle the high voltage high current requirements so we can protect the larger structures. Structures that are poorly coated such as if the structure's old. We know that that coating probably degraded over time.

[45:44] Then, we're going to need more voltage and current out of the anodes, so this might be a system that will be recommended in that case. More effective in the high resistivity soils and one anode that can supply a large amount of current compared to the sacrificial systems. Virtually no auto corrosion of the anodes in this case.

[46:07] The cons, it does require an outside current source and, often, can require a larger right of way for the installation. This installation can be more difficult than sacrificial systems such as when I mentioned deep wells. You've got to get a drill rig out there, and some of the holes can get pretty deep.

[46:25] The system is more expensive to install and operate. You have costs such as power. You have increased maintenance. We've seen some pretty interesting things such as farmers stealing our power, so you've got to really keep track of it. Like I said, it does require more maintenance.

[46:43] Also, to do testing it's more of a monthly versus a yearly. You need to make sure that the rectifiers are operating. You might need to adjust them, takes some equipment. There's more of a risk of stray current interference on formed structures.

[47:04] The most effective corrosion protection system for any buried or similar structure involves a good, bonded coating and cathodic protection. You want to make sure that you look at both of those when you're putting anything in the ground. What do you need to protect that structure?

[47:24] We've written a few manuals such as "Guidelines for Field Installation of Corrosion Monitoring and Cathodic Protection", "The 10 Percent Soil Resistivity Method", what we use for determining if the soil may be corrosive, "Guidelines for Reporting Corroded Pipe", "Guide to Protective Coatings-- Inspection and Maintenance", and coming soon, a "Corrosivity of Testing Soil and Waters".

[47:54] These are available if you contact us, but, also, will be available or linked to the MERL website in the near future. Some of the

upcoming events...We have our corrosion coating school October 22-24th. The corrosion website will be updated this summer and, like I said, those reports will be linked on that site.

[48:22] The next corrosion webinar, we have a tentative either October or February. It depends on the corrosion coating school. It will be on cathodic protection, system components, and testing. Also, let us know what you want to hear about because whatever topics you might suggest, we can use for future webinars.

[48:48] Here's a basic list of coatings corrosion school topics, introduction to corrosion, material selection, introduction to protective coatings, surface prep, and etc. There's a lot of hands-on because we're looking at more operation maintenance students, so we want you to know what to do in the field. That will include testing, application, evaluations.

[49:28] Here's another picture of us and our names and contact information. [laughs] Feel free to...

Dr. Torrey: [49:40] As I mentioned at the beginning, we are lacking our tech support. If anyone has any questions, please, write those in the questions box and we will try and answer them as soon as they come up. Then, some of you should also be able to raise your hands.

[50:07] Let's see what we have here. [laughs] Here's all the comments that I needed at the very beginning that I didn't see when we were starting. I'm sorry that I didn't catch this one about downloading the software. I hope that you figured that out.

[50:26] Can you email a copy of the PowerPoint slides, those on the webinar? I'm hoping to get these up. We do have that internal Google site that's operational right now, and I will put the PowerPoint slides on that Google site. I will send that link to everyone that was on our mailing list for this webinar.

[50:49] Are there any other questions? From people in the room, any questions? All right. In this instance, though, we did record this, and the files have been very, very large. We're working on trying to compress them.

[51:08] We will, also, get those posted and everyone who's attending this webinar will be on our mailing list in the future. I'll send a quick email out when those things are posted, as well as when we have plans for the next webinar.

[51:25] Thank you, everyone, for attending. I hope it was fairly useful for you all. Thanks again.