**>> Dr. Henderson:** I would like to welcome you to our Corrosion Webinar Series. My name is Dr. Chrissy Henderson, and I will be hosting today's webinar. This event is put on by the Materials and Corrosion Laboratory within Reclamation's Technical Service Center, located here in Denver, Colorado. We host corrosion-related webinars every year in order to share with you topics in cathodic protection, coatings, geosynthetics and hazardous materials. Today's presentation will be the final webinar for this fiscal year, focusing on coating failures. Our presenter will be Dr. Allen Skaja, our protective coatings specialist. Before we get started, I'd like us to go over a few housekeeping items. We are hosting today's Corrosion Webinar on Microsoft Teams Live Events and will be recording the presentation. If you do not want to be part of the recording, please leave at this time. The recording will be available after this webinar is over through the webinar link you received in your email. During the presentation, please submit your questions and comments as they come up. To access the live Q&A chat feature, click on the Q&A icon. It looks like a chat bubble with a question mark inside of it. And we will monitor the chat and hold the Q&A session at the end of this presentation. With that, I would like to go ahead and welcome you to our presenter for today. Dr. Allen Skaja obtained his Ph.D. in Coatings and Polymeric Materials from North Dakota State University in 2005. Allen is responsible for resurrecting the coatings testing program here at Reclamation, along with the much-needed evaluation of historical coatings, such as vinyl and coal tar enamel. The testing program helped to establish performance characteristics of both historical and current industry specified coatings, such as epoxies, moisture cured urethanes, and polyurethanes. And now with that, I would like to hand this webinar presentation over to Dr. Allen Skaja.

**>> Dr. Skaja:** Alright, thank you, Chrissy for that introduction. My name is Allen Skaja. Got a Ph.D. from North Dakota State University. And my thesis was in coating failures. And so, it's—I have a very strong interest in this. It's kind of like being a detective for coatings, as why they fail, how they deteriorate, etcetera, etcetera. So, it's very interesting to me. While I do not like to see coating failures, it is... I get—I have a very strong passion for trying to figure out what went wrong. So, what is the purpose of coatings? So, coatings provide a barrier between the electrolyte—so that's the soil or the water—and the metal surface. And this provides corrosion protection. Coatings are the primary corrosion protection method. Whereas the cathodic protection is another mitigation method, but it works best when it's paired with a bonded dielectric coating system. In order to provide the best corrosion protection, your coating must provide a defect-free surface for the entire structure. So anywhere where you may have a defect, that's where you would have your anode or your corrosion cell form. And with a cathodic protection system, that's where the cathodic protection would be focusing all of its current and providing corrosion protection—at that defect. A couple definitions. When I look at coating failures, I'm usually talking about premature failures due to errors during application or surface preparation. So, environmental conditions may cause these premature failures. And then there's always these complex problems, even specialists like myself don't even understand or fully understand. But there's these—it's usually during that application process or shortly after where we have problems. When we talk about service condition failures, this is premature failures due to short service life that are caused by the service conditions. And then coating degradation. This is the natural process of coating aging and degradation. So, I just kinda wanna throw those definitions out there because when I talk about premature failures, it's usually related to the coating application process. And there's a lot of things that can go wrong during the application process. The first step is always surface preparation. So, if you do not have adequate

surface preparation—the surface cleanliness, that's the degree of your steel, so whether it's a white metal blast. So, zero shadowing or corrosion product on that surface. But you could also have near-white or commercial or industrial grade blast. So, the surface cleanliness, especially for a more severe service condition like water immersion, you need a very clean surface in order to have that coating adhere to your substrate as best as possible. Also, to do that, you have a surface profile. So, the larger the surface profile usually means that you have more surface area for that coating to adhere to. We look at—there's different abrasive blast media that can generate different profiles. And there's a whole area of study just looking at your surface preparation methods and what profiles work well, which do not work so well for coatings. Another thing that you look at is the dust contaminant. So, if there's any sort of dust or particulate contaminant—What you are actually applying your coating to is a powder, which is not your steel substrate. So, you can have failures because of that. And then that also leads to loss of adhesion. So, it's very important to do adequate surface preparation. So, some other possible areas where you can get coating failure is due to environmental conditions. So if you have high humidity and low temperatures, you can form—like with an epoxy type coating, you have amine curing agents—well they call that amine blush. So there's this secondary reaction that takes place with amines. And they react with carbon dioxide. And it's usually at cooler temperatures that it occurs. And this is—this kind of forms a slimy surface where your subsequent coats will not adhere to that amine blush. And it doesn't form a good solid bond to that substrate If you had condensation or precipitation that occurs on a coating, that's also a bad thing where, again, you're not adhering to your steel substrate or your coating surface. Cold temperature applications are always a challenge. And majority of our maintenance cycles are done in the fall, winter, or early spring when we have cooler temperatures. Application—so the coating application itself is very touchy, so you can end up with pinpoint corrosion if the coating is applied too thin. So, that means that your coating doesn't cover all the peaks of your profile. And if you have too thin of a coating, then that is something that could happen. Also, edge corrosion. So on edges—So, like on I-beams you have a lot of edges—and if you don't chamfer that edge or round off that edge, your coating tends to peel away, or pull away, from that edge, leading to a thinner coating application on that edge. A lot of times, what we do, is we do a stripe coat for those edges, those sharp edges. And just like that—so, the inside corner of those I-beams or a weld, you may have what they call bridging. So, if you apply the coating but it doesn't reach all the way into that corner—or the crevice, like if you have crevice corrosion—that's what they call bridging. So, again, it's a kind of a thin spot that doesn't have enough coating there or it could crack eventually. You can also have too thick of coatings. So, if you apply the coating too thick, a lot of these coating systems are solvent-borne systems. And if you apply the coating too thick, you could end up with solvent entrapment. So, that's one possibility. So, solvent entrapment could lead to premature failure. You could—if your coating is also too thick, you could get crazing or cracking, or what they also call mud cracking. This is typically seen on inorganic zinc coatings. And what happens is, it's moisture cured. So, if your coating ends up getting too thick, there's too much internal stress within the coating system, and it causes a crack to form. Wrinkling is also another one. That's usually seen with alkyd type coating systems. If your coating has an outer skin that forms, when it starts reacting further into your coating, like closer to your substrate, it forms what they call wrinkling. And it's... just a surface defect. It's not gonna cure properly, so that means your coating underneath, that is in contact with your steel, reacts at a slower rate. Internal stress. So that's—again, it leads to—So, the thicker your coating system increases your internal stress, usually. And that also can lead to some cracking or

other disbondment type situations. And then of course, you got your runs and sags and drips. So, they're just unsightly, and usually they're a point of coating failure. So, we could have recoat window issues. So, a lot of coating systems have a minimum and a maximum recoat window. And so if you don't apply the coating within that recoat window, you could have failures. So, some examples might be—where you have loss of adhesion for an out of recoat window. And you have disbondment occurring. Contaminants—you could get contaminants from air or the surface. So, this may be like an oil in your air lines or water droplets in your air lines. And what happens is that they can form bubbles or air voids in your system. They also form what they call "fish eyes." It looks like a volcano crater, is what I kind of envision it as. And there's no coating that would adhere to your oil—the contaminant from your air supply—which would be your oil. You can also get blistering. So, osmotic blistering, that's if you had salt contamination. The salt wants to be solubilized in your water. So, if you put your coating in water and you have salt contaminant, there's a natural osmotic driving force that wants to have equal concentrations of salt on both sides of that coating, which is like a membrane. So, you would end up forming osmotic blisters. You could also have blisters that are solvent-filled blisters. So, if you had that solvent entrapment issue, you can form blisters due to that solvent. And when you heat up that coating surface—let's say in atmospheric—it can form blisters based on just the... the solvent wanting to evaporate. And it forms that blister, you can also get CO2 off-gassing. So, moisture-cured urethanes—this is the big reason or problem with blistering on moisture cured urethanes, is that you have to release carbon dioxide from that coating system as it reacts and cures. And this forms blisters if you get too thick of a coating system. So, other materials issues—so, these are not necessarily failures, immediate failures. But they're unsightly. So, you could get crawling, which is—a lot of times these low VOC coating systems, or the coating manufacturers, introduced a solvent that is highly fluorinated. It is an exempt solvent. And if you try to apply a coating system prior to that fluorinated solvent being pulled out of the coating system, or evaporating out of the coating system, that next coat could form what they call "crawling." And it basically phase separates. And it has... Just a weird look. So, "oil in water" type look. You could also get bleeding. So, if you had applied a coating system to coal tar enamel or coal tar epoxy, some of those solvents or low molecular weight reactants in your coating system actually want to bleed out and dissolve that coal tar from that coating system. Another coating issue that I did not know existed when I started with Reclamation—This is a cold wall effect or a heat sink phenomena. And I will go into that in more depth later in the presentation. And then, also this off ratio or iso spit. That's another material problem during application. So, I'll just kind of start going through some of these and what I mean. So, flaking paints due to painting over a particular contaminant. So this happened to me. I thought, you know, purchasing door frames or doors that had... a primer system from Home Depot. I thought I could just paint right over that without any other surface prep. Well, what happens is, there was some loose particles—so, primer particles—on that surface. And I did not bother sanding or wiping it down first. And so, within a couple years, all of a sudden I have flaking paint coming off of that doorframe. So, the picture on the right is the top layer. And... on the underside of that paint chip, you can see white. It's no longer cream colored. And that is all the loose pigment particles that I applied the coating over. And it resulted in catastrophic. failure. So, you have to remove any loose material, chalking, or dust from abrasive blast media. You have to get all that loose material off your surface so your coating can adhere directly to what you're trying to apply it to. So, the best way to mitigate is just to remove that stuff, wipe it down. And if you want to really prevent it from happening, you need to sand and make sure that surface is clean. So, another

problem—common, very common problem—is what they call amine blush. So, this is, like I said, it's a secondary reaction with CO2 and moisture. And it's exasperated at low temperature and high humidities. And what happens is, you don't necessarily know it formed unless you actually touch the surface, and it feels like a... slimy grease on the surface of your coating system. And usually this occurs when people, or the coating contractors, are... have the environmental conditions change on them. So, when that occurs, they're not necessarily using dehumidification equipment. And... The high humidity and CO2 can cause that to—that secondary reaction—to occur more readily. So to prevent this from happening, you should be using dehumidification equipment or heat in order to prevent that. Some other things. So, flash rust, due to environmental conditions. In this photo, we have one penstock that is dewatered, one penstock that has cold water flowing through it. So, we could only take one penstock offline at a time. That meant the contractor had to control his environmental conditions very carefully. What happened is they abrasive blasted, and then before they were able to coat it, they had the humidity. conditions change. So, then the pipe on the left had surface temperatures probably around 40, 45, maybe 50 degrees Fahrenheit. And their dew points dropped to below that and had condensation on the surface, which led to flash rusting. So, they had to wait—the contractor had to wait until their environmental conditions improved. So they no longer had dew points above the surface temperature of your steel. So, once again, mitigation. The contractor had to re-abrasive blast the steel surfaces and then coat during... when they had optimum conditions. Another way they could have done this is they could have shut down the entire plant and recoated in dry conditions. But that was not feasible for the contract. So, edge corrosion. This is where we have sharp edges. So on I-beams and where you have a 90-degree bend, the coating system tends to pull away from that edge and it's gonna be thinner. So if you did stripe coating, which would just fill up that thickness a little bit on the edge. Or you grind off that edge, so then you can build the coating thickness up. Those are your two options. But this is what happens on a lot of our structures. And even though we have it in our specifications that the contractor is to grind all edges, sometimes they don't follow those specifications, and it's on our inspectors to enforce that they grind those edges. So... Inside corners. They're challenging. Just because it's, like, you can bridge and have a void or an air gap at that corner. And if you... have that, what can happen is your coating pulls away and it'll crack. We get this same thing on crevices. So, if you have a crevice where you do not have... the continuity—so, welded interface. You will end up with quite possibly having a bridge, as well as eventually having a crack in that crevice, which will not provide corrosion protection. So, solvent entrapment is not always readily recognized. You don't know whether or not a coating system had solvent entrapment until you do further investigations. So, on this project, the client saw rust staining within a year after the coating application. So, we had to go out and start doing some investigative work. So, detective work, to try to figure out what went wrong on this project. And yes, we could see the rust staining. But even in the areas where we do not see rusting, we could see these microcracks on the surface. So, the microcracks led us to start thinking—well, there's some sort of internal stress problem with this coating application. So, we took some paint chip samples. Brought them back to have them analyzed under a micr—well, SEM microscope. And what we saw was that the first—the primer system—was applied very thin. And that did not lead to solvent entrapment, but it kind of threw off the whole system. So, while we had dry film thickness measurements in the range of what we were expecting, there was—so, the intermediate coat there, that cream color coat—that was applied at the correct dry film thickness. And then, because they were still under the dry film thickness, the contractor applied a really thick top coat. And that's where he went wrong. If

he would have just applied the coating at the recommended dry film thickness, they would not have had any failures, probably. But as you can see in the photo, there are some areas where there's—it looks like a bubble. And that is actually probably due to solvent—it entrapped in the coating system. And wherever you have that, it leads to internal stresses. So that... Because of the coating being—the top coat being excessively—having high thickness, applied in high thickness—what happens is, that solvent will escape as its curing. So it cured dry to the touch, right. And then it has internal stresses because that crosslinked coating is locked in and the solvents can't escape. And when they finally do escape, from the temperature fluctuations, then it results in cracked coating. Those cracks can eventually lead all the way down to the substrate, and that's why we see the rust staining on that coating system. We also, on this project, saw some wrinkling and sags. And that's excessive film thickness again. Fortunately enough, we did not see any cracking in those situations. But it can lead to that if it's applied incorrectly and... you end up with solvent entrapment, it can lead to cracking as well. So, this heat sink phenomena. This is something that I was not taught in school. And then also, when I reached out to the professors at my old university, they had never heard of this heat sink phenomena. So, it was a very challenging problem. And I was called up to this facility because on application, they had blistering and disbondment. And it was so interesting to me. I wasn't 100% sure what happened. But the application had sections where there was no coating failure. It looked perfect. And then it had sections where it had these defects. These blisters and disbondment all over the place. And it was, by far, one of the most interesting problems that I had no idea—walking into this situation—what happened, what went wrong. So, we went in, looked at it. I was asking the contractor questions like, what were the application conditions like? So, environmental conditions. Did they use dehumidification and heat to bring the temperatures up? So that they had no moisture on that steel surface because it's in a buried section of pipe. We started asking them about the person applying the coating, if they applied it all in a single step or if it was multi-staged. We asked them questions like—on the equipment side, if there was iso spit in certain areas or they changed out the drums. That wasn't the problem. So, we kept trying to figure out what went wrong and it took me most of the day to figure this out. But eventually the NACE inspector came with this 3-inch binder for coating application of this product. And we were paging through it... And there was a one-paragraph section on heat sink phenomena. And what it is, is—whenever you have fast-cured polyurethane or a polyurea system—if this coating is applied to a cold pipe but the atmospheric air temperature is significantly higher, what can happen is that the initial layer of paint on that steel reacts much slower than the coating that is in contact with the air. And as a result of the different curing rates, the coating on your steel—that's in contact with your steel—results in forming blisters from off-gas. I had no idea this problem even could exist. And once we saw this... heat sink phenomenon paragraph, we went back into the pipe and started measuring surface temperatures. And in the—we were getting 58, 57 degrees on the section where the coating was applied perfectly. And then I got to this section where it failed and the steel temperature was 54 degrees. Three degrees difference caused this coating to fail. And it was... You can't blame that on a contractor, that is a materials problem. The... I'm not 100% sure why 3 degrees made or broke the system, but that's what we found out. And we no longer recommend fast-cured polyurethanes or polyureas to be applied in buried conditions, because of this. But there must—it must have something to do with the temperature differential between your air temperature and your steel temperature. So, the contractor, if he would have applied this particular coating where his air temperature was maybe 5 degrees cooler, we never would have seen this problem. And I never would have known that this

problem exists. So, I guess it was a good thing that we had this problem occur on the very first job we tried this particular product. So then I won't ever use it again in this situation. So, off-ratios. So, when we have disbondment from off-ratio, the probable cause is that a lot of these newer coating systems are applied with plural component equipment. And if the gun—so the coating is applied right at the tip of the gun, and it has two heated lines for each component. And if there's a problem with the pump or the gun clogging, you can end up with off-ratio material coming out of your gun. And when that happens, you end up forming blisters under your coating. And again, it's probably due to some sort of off-gassing, eventually. And it'll form blisters in your newly applied coating system. And basically all you have to is remove those blisters And... You gotta do solvent cleaning because it's not reacted anymore, so it's unreacted material. So, you need to remove all that... gooey, gross stuff off the steel surface, solvent clean back to bare metal, probably do some abrasive blasting or some sort of surface prep. And then... to prevent this from happening again, you need to make sure that the product is on-ratio. So, usually what we do is... you pull that trigger on that gun and waste a few gallons of material before you start spraying on your structure. So, that's the only way you can make sure and verify that there's no off-ratio. Some service conditions can cause premature failure. So, we have uplift forces that cause delamination—erosion, impact, cavitation, UV degradation. Some coatings are not designed to be in atmospheric exposure, so you get chalking and loss in gloss and maybe even yellowing. Slight movements or vibrations can cause cracking. So, when you have like riveted or fasteners—rivets or fasteners—this could be a source of cracking because it's a discontinuous surface. It's not... a welded connection, right. And then cyclic wetting and drying is also possibly premature failure. So, uplift forces—this is a hard lesson to learn as well. No idea that these coatings could delaminate. But what happens is a crack forms at an interface. So, at a sleeve coupling, let's say. That sleeve coupling has just slight enough movement where it could crack the coating, so the coating will crack. And you have what they call uplift forces. So, when you have high enough water velocity, it starts pulling at that leading edge, and starts peeling your coating off. So, in both situations here, that's what is causing the corrosion to occur, and eventually will cause delamination. So... We did not—I did not understand this mechanism of coating failure well enough. So, we had to start doing some lab testing to better understand what's actually occurring in this situation. So here, with these particular polyurethanes, we left a leading edge. That leading edge, we put in water, so we had a little bit of corrosion that pushed that coating off the steel, and it had a disbonded area. But once you put it in flowing water, it starts acting like a sail and it starts peeling back. And even though you had a 3 mil profile, white metal blast, it still—it will peel your coating from that steel surface. And it's all due to your water velocity and the uplift force that it causes. So, this is a pretty breakthrough technology, learning what happens in high-velocity water. You can also have erosion. So they—these pumps are kind of set up as run-of-the-river. And... You... They only pump during the season—the spring run-off season. So, you have more sediment that gets into your pumps. So, that causes erosion. And the erosion can be so severe that it causes corrosion within a year. So, it erodes all the way through your coating system within a year. The coatings that have better erosion resistance will last longer. So, we had a study looking at various coating systems and trying to improve the erosion resistance. You could also have cavitation. Cavitation is the process where you have a pressure drop across a structure. So, you—so, for instance on turbine runners, you have high pressure above that turbine, and it goes to low pressure downstream of that turbine. And when you have that, you cause water to have a vapor—a transition, a phase transition. And it forms vapor bubbles. These vapor bubbles implode upon themselves and create a jet. And that jet impacts

the surface of your steel or your stainless steel. And it can cause microfracturing. We're doing active research on cavitation-resistant coatings right now. And the majority of the coating systems that we've tested fail extremely fast because they can't absorb the energy created from that implosion of that water vapor. And... It will microfracture the coating and chip it off really fast. So, that's what you see here, is that the coatings that were applied to the turbine runner, as well as the draft tube, cannot withstand that impact. The coating systems that we found that work better are elastomeric. And we—that is going to be a different talk, some later time during a webinar. So, I'll leave that to that point in time. You could have cracking due to vibration. So, this aboveground penstock was coated with a three coat system. So, epoxy primer, epoxy intermediate coat, and a polyurethane topcoat. And it vibrates—the pipe vibrates because it's aboveground. And when you have that occur, and then you have a thick 1-1/2-inch riveted collar, what happens is that that dampens and concentrates that vibration energy right at that collar. Which results in, if you have a brittle coating, cracking. The cracked coating leads to corrosion. And every riveted connection on this pipe has this same problem. So, we have to use a more flexible coating system at these interfaces, or a caulk material. You could have natural degradation. So, this I consider like UV degradation... or possibly cracking due to internal stresses, or maybe barrier breakdown. So... On radial gates, we have water immersion, we have air, and it's fluctuating. So it goes from water immersion to atmospheric. And you can see... The water level changes on these gates. So... When you have... I guess... All these different stresses that occur—you have what they call hydrothermal stresses. So, your water uptake and it's—your coating acts like a sponge. So then when it dries, wets and dries, it goes through this cyclic... stresses. And your coating can end up causing cracks and failing that way. So, UV degradation. That's just chalking, cracking, microcracking. This is what happens naturally. It was not until around the 1960s when they started figuring out what causes UV degradation. And you reduce the number of aromatic rings in your backbone of your polymers, or coatings. And you can have better UV stability. So, a lot of these old coating systems had aromatic rings in the backbone—so, phenolics. And so, this is—this pipe has a phenolic aluminum topcoat. And it has aromatic rings, which absorb UV light and cause degradation. You could also have long term blistering. So, some blisters that don't form for many, many, many years. And then they start forming. So, on like coal tar, coal tar epoxy. You have these blisters that form. Well, those blisters are actually filled with a liquid. And when you have—if you open them up, you see white metal underneath that blister. So, what's going on? Why did that occur? Well, if you have an anode that develops, you also have a cathode reaction that occurs right adjacent to that anode. And the cathodic reaction forms a base. So, it will form, say, a potassium hydroxide or sodium hydroxide, which is passivated. And that passivation actually is protecting that steel underneath, even though the blister is formed. So, if you see this on coating systems that are aged, long term, you may wanna maybe pop one open and see what—if it's white metal underneath. But if you do that, you will automatically start the corrosion process underneath that blister that you just broke. Because now it's no longer passivated. You're going to have an anode right there. Coatings crack. So, we've all seen coal tar in penstocks and outlet works. And... what happens is that the lower molecular weight coal tar oils leach out of that coating system. And they form internal stresses and will crack. You could also have the crack occur when you have aboveground situations where the coating gets kind of baked and it volatilizes those lower molecular weight coal tar oils, resulting in cracked coating. And then this final one. So, this is barrier property. When we talk about the barrier protection of coatings, This is when—at the point where you have breakdown of your barrier, a hundred percent. So this... top of the car. Eventually, it aged

long enough where the barrier properties have given up. And now you have corrosion coming through your coating system. So, that's what I think about when we talk barrier property degradation. So, we have techniques right now, thanks to Bobbi Jo Merten. She's led the way, developing a field technique to measure barrier properties. It's called electrochemical impedance spectroscopy. And you can bring this out to the field. We can monitor your coating systems. And... if they're getting to the point where they're low barrier, we don't wanna necessarily just do a spot repair or a touch up anymore. We're gonna have to start planning on a full recoat. Because we're to this—getting close—we're approaching this stage. So, Keep that in mind for when you do condition assessments. And we can help determine whether or not we have this situation approaching. But now we'll go to any questions. So, please feel free to ask questions in the chat. Or unmute yourself.

**>> Dr. Henderson:** Well, thank you very much, Allen. For those of you that are attending the presentation, please go ahead and submit any of your questions and comments in that Q&A icon up at the top and we will address as many of them as we can. So, here is a question for you, Allen. Can you give an example of techniques or testing methods that you used and employ to determine some of these failures?

**>> Dr. Skaja:** Yeah. So, you can use various analytical testing techniques. So, if you... I don't know, if you wanna look at the chemical analysis, there are FTIR techniques. So, you can look at the chemical composition if you suspect like, say, off-ratio. We also do microscopy. So, if you have delamination or disbondment, you can look at... how much the... coating was applied to a loose material, like the chalked coating that I showed on one of the first slides. Let's see, what else? And sometimes, you know, it's not always apparent as to what happened or what went wrong. And I think the instance when we did the cold wall... er, heat sink phenomena—if I—the NACE inspector and myself did not look through that 3-inch ring binder and found that one paragraph, we probably would have ended up blaming it on the contractor that they did something wrong and moved on. But in reality, we're pretty confident that that is what happened. Because... Sometimes it's just intuition as to what coatings—what happened with the coatings. A lot of times with delamination between coats, amine blush is the culprit. And you just need to go back and figure that one out. So, there's amine blush kits available—commercially available for that test. Does that answer your question? ... You wanna move on to the next question, Chrissy?

**>> Dr. Henderson:** Yes, thank you. Here's another question. How can you identify coating failures on a coating that is covered in mud or dirt, or is always underwater?

**>> Dr. Skaja:** Okay, so a lot of times when I go out and do condition assessments—the times... if you have mud and silt, you usually want to wash that off or wipe it off. You can wipe off certain areas. But what I do for looking for blisters, is I have a light that I hold fairly close to the steel surface. And that can cast the shadow. And then I can find that blister easier. If I did not do that, it is much harder to pick up blisters and identify where they're located. When you have cracked coating, you really have to wipe off that silt and dirt and muck in order to identify those. So, cleaning that pipe might be your only way to identify all those areas. I've seen it where the coating severely cracked—coal tar was severely cracked. But unless you can get up and wipe off that surface, you would never even see it because that silt fills in those cracks. And it masks all the corrosion that's

occurring. And sometimes those cracks don't go all the way to the substrate either. So, then you really have a hard time if the crack is filled with the silt.

**>> Dr. Henderson:** Alright. Next question. Is it generally better to leave a blister in place or fix the blisters? So, in general, it's probably better to leave them in place. If you want to know for sure—is it just a blister that has been formed because of long term water immersion and it has that sodium hydroxide—you can pop a blister, cut it open, and see. If you see white metal underneath, I would not pop any more blisters. Just leave them because that is protecting your steel from corrosion. However, if your blister has corrosion product underneath it and it's pitting, that's when you know it was probably due to some sort of salt contamination. And then, you probably wanna plan on replacing that coating as soon as possible. Because that means other blisters are probably the same. They probably have some sort of salt contamination under it.

**>> Dr. Henderson:** Alright, if there are any other questions—oh, looks like we might have another one. What is the most common cause for coating failures at Reclamation—inadequate surface prep, environmental conditions, or application problems?

**>> Dr. Skaja:** A lot of times it's always—not always—most of the time, I should say, it is related to the coating application. So, we require NACE certified coating inspectors to try to eliminate as many of those failures as possible. So, I showed the solvent entrapped coating system. On those gates, the NACE inspector was hired by the irrigation district part-time. So, they were on site three days a week. And because of that, they didn't catch everything. And... The reason that they were hired originally in the first place was because that primer coat was applied extremely thin. And when you have that happen—they were concerned about quality control. So, the irrigation district hired a NACE inspector, but didn't have the funds available to hire him permanent—so, on-site 24/7—well, not 24/7, but whenever they were doing work. They could only hire them three days a week, and they still had problems with the application.

**>> Dr. Henderson:** Alright, it looks like that is all the time we have for today. If there are any other remaining questions for you on this webinar, please feel free to reach out to Dr. Allen Skaja or myself, and I'll make sure your question gets to the right person. And also, keep an eye out for our future webinars during this next upcoming fiscal year. We will be focusing on much of our research efforts. And we will present to you what we have been doing here in the labs.

**>> Dr. Skaja:** Alright, thank you everyone!