>> **Dr. Skaja:** So, this is the Protective Coatings 101. As I stated, I've been here for 11 years. Prior to that I was a graduate student at North Dakota State University in their Coatings and Polymeric Materials department. So, I've got a Ph.D. in that field. So, I know probably more than anyone else in Reclamation about protective coatings. Bobbi Jo Merten is a colleague of mine, she's got the same degree. She might have an edge on me on some topics, but I've got other areas of expertise. So, Protective Coatings 101. The webinar objective here is to first introduce protective coatings. What they are, what some of the requirements, bare minimum requirements for protective coatings. What properties they have to have. And then we want to get into selecting the correct coating system for the service environment. And then the importance of surface preparation. I've had this topic brought up—well, "we don't have abrasive blast equipment. Is there another means to provide adequate surface preparation?" And we'll get into that quite a bit as to why surface preparation is so important for longevity in a coating. And then there's application equipment and methods and equipment. So, the photo in this is of a scroll case. And I believe—you know what, I'm not even sure what facility this is at because they all look so similar. But this is a scroll case, so it goes around the turbine runner and the wicket gates. You can see the famous steel wicket gates right here. So this is a curb plate. And then the stay vane. And most hydro facilities are basically the same, just different diameters. So, protective coatings. It's the primary defense against corrosion. The annual cost of corrosion is estimated at about $450 billion annually in the United States, so that's about 2.7% of the gross domestic product. The primary purpose of coatings is to prevent significant metal loss. Prevent failures due to corrosion. Maintain aesthetic appeal so the public doesn't have concerns. And really, it's just to minimize future repairs and costs. You know, corrosion is an electrochemical process, so there's a little bit of electrochemistry involved to have that whole corrosion process. Some of the components with corrosion, you have to have an anode, a cathode, a metallic pathway, and your electrolyte. So, if you can try to mitigate one of those paths or components of the corrosion cell, you're going to cut and minimize that corrosion process. For protective coatings, it's primarily providing that barrier to that electrolyte. Now, what can happen is, you know, we're really looking at preventing failures. And most of the time people think, oh, well, you'll see the corrosion well before you actually have corrosion take place. And that is the case. But if you neglect the corrosion and just let it corrode, some things can go wrong. And here's an example at Shoshone Power Plant. It's run by Xcel Energy. And this is some penstocks that are riveted construction. And there's significant amount of corrosion that, where the—underneath the rivets and around that whole rivet, it blew out one of the penstocks. And yeah, a lot of water, I mean these are fairly small diameter penstocks. And if we look at the extent of damage done by just the water flow, it eroded all that rock and soil down through the plant and into their turbine runners. And it basically, I mean, it destroyed the plant. They had to start from scratch. And it's not only just the rubble, but the building itself, as well as it took out the transformers. I mean, by the time the water was shut off, basically, it destroyed the entire plant. They had to start from scratch. So, as I stated already, the coating is the primary defense against corrosion. And we use cathodic protection with coating systems. And the cathodic protection is typically used to protect

the defects in the coating. So, most coating are not 100% foolproof. You're always going to have a small percentage of surface area that needs to be protected. So, in buried and submerged structures, the best corrosion protection system is a good bonded coding system, as well as a cathodic protection system. So, you need both. And cathodic protection doesn't always work in submerged structures, especially in flowing water. It requires a lot more energy and design work in order to protect your structures in flowing water. So, for the most part, we've only used bonded coatings in those service environments. So, there's basically three components to a coatings job. We have surface preparation, the coating application, and then the coating material itself. And when you look at contracting out coatings work, the contractor is responsible for the surface preparation and he's also responsible for the coating application. So, we're trusting, putting a lot of faith in that contractor, that he's going to do things correctly. The coating material itself is what was specified in the specification. And usually we do not sole source, so the coatings are selected by the contractor as to what he's going to use. There's many different things that go into a coating job. So, they're going to select the materials that are going to work for their application procedures. Now, when we look at—this is the number one thing you should look at, is the coating life cycle cost. Because if you have to coat more frequently, it's going to cost you more money. That's the bottom line. Because majority of the costs that are associated with a coating job are labor intensive. It's not the coating material itself, it's what has to take place in order to get those coatings reapplied. So, we want to use the highest quality coating system for the particular application. Majority of the costs, like I said, are associated with that labor. So, if we have a coating system that's going to, say, provide a 30-year service life, we only have to recoat that system every 30 years. But if we have something that's less than that, it's going to be required to be recoated more frequently. So, this is just kind of demonstrating the frequency of recoating jobs. So, the associated cost with coatings job. So, like I said it's very labor intensive, there's mobilization, demobilization, scaffolding, containment. You know, transporting all the equipment to the site. There's the blast and coating removal. So, it has a very labor-intensive production rate. Typically, less than 100 square feet per hour. You, of course, have handling and disposal, cleanup, all that type of stuff which is very labor intensive. The coating application, depending on what coating systems you use, it can be a fast application, or it could be a very slow application. If you're going to use a brush or roller, it's very labor intensive and takes a lot of time to apply those coatings. If you're using a plural component spray equipment, man, you can do a lot of square feet in a very short amount of time. So, when we think of general cost, the surface preparation is going to be the most labor intensive. The coating application is the middle ground. And your coating expense, so the material itself, is typically a very small part of that application cost. So, when we look at the materials themselves, we have abrasives. Again, handling and disposal, it depends on the method that the contractor has selected, whether that's going to be a materials cost or not. But you're usually going to have drums of abrasive that you have to dispose of. So, there's the cost of the drum. Of course, the coating product itself. And sometimes we don't specify coatings, we go with a metallizing, so it's a zinc metallizing application. So, that's where the wire feedstock comes into the cost. Now, getting down into the basics, you know, we—for corrosion protection by coating, the initial driving force was actually around the World War II timeframe when the steel was in high demand, expensive, and there was a drive for corrosion protection. So, that was the initial segue into the development of corrosion protective coatings. So, the basic requirements here is that you need strong adhesion to your substrate. You also need a barrier to the electrolyte. The dielectric strength for preventing the cathodic protection currents through your coating system. You only want to protect those defected areas. You know, you also need to resist the exposure environment, so whether it's atmospheric weather or if it's burial service, immersion service. It could be chemicals, abrasion, impact, as well as age resistance. So, the age resistance is basically to prevent cracking of the coating system. You also want something that's compatible with cathodic protection. Not all coating systems are compatible. The other thing you need to look at is ease of application. If a contractor, you know—you may have the best coating system, but if it's difficult to apply the coating, you know, the contractor may have a challenge getting that applied correctly. So, all those things, you need to worry about in a coating system. So, if you have a coating system and you look at adhesion, there's a couple different ways to look at adhesion. Most people look at a straight tensile pull as their adhesion value. But that's not necessarily the only thing you need to be concerned about. Because if you have a defect and you do not have cathodic protection, what can happen is you get severe undercutting of that coating system. And it'll run, the corrosion will just run right along that interface, and you'll continue to have further and further delamination. And that corrosion spot is going to expand. And one thing that we've—I mean, we've been doing research for quite a while. And one of the things that amazes me with these old coating systems that we used to use, there is very little undercutting compared to the coating systems we can use today. So, the other thing with corrosion is that barriers to electrolyte. So, if you have your electrolyte out here, it's going to want to migrate through your coating, through all coatings. Even the old coal tar enamel and vinyl resin. They are semi-permeable membranes. So that means water will get through eventually, it's just at what rate. So, some of the coating systems, they incorporate flake-type pigments to help increase the path of that water or electrolyte getting through your coating system. And that's very important. So, if you can have some sort of flake pigment, typically they're going to provide longer service life than without. Getting into the protective coatings, actual early... I guess, understanding of protective coatings—there's two different types. There's a thermoplastic and then thermoset. Now, thermoplastics are typically a one container, where the solvents evaporate, and it forms a film. Or it could also be a hot application or a melt procedure. So, some examples of that are vinyl resin—which Reclamation used for many, many years—where that's the solvent evaporation, and it's leaving behind a film, a protective film. The other type that Reclamation typically used was coal tar enamel. And that is where they heated the coal tar up to about 400 or 500 degrees Fahrenheit, and then mopped or troweled or used the, um—what are those called? The... brush, what is that? Dauber. They used a dauber to apply that coal tar enamel to the infrastructure. So then, thermosets. That means that there's going to be a chemical reaction that takes place during the curing process. So, they can be either two or more components. Or else they could also just be a single component but react with the atmospheric conditions. So, like moisture-cured urethanes, they are one component, but they actually react by the moisture absorption through that coating system to cure. Same thing with siloxanes, it requires the moisture cure environment. Alkyds are a little bit different where the alkyd actually reacts with oxygen in the atmosphere to crosslink and cure. If it's a chemical cure, such as an epoxy, polyurethane, coal tar epoxy, something like that, there are two components. So, you have to mix those components together in order to cure. We've had situations where the contractor actually forgot to add component A and component B. And then the coating never sets, never sets, and it gets shipped, the equipment gets shipped to the site, and they try to pull it out of the crate and the coating is still wet. So, it's very important to have component A and component B mixed together during the application process. So, what goes into a coating system, or a paint? There's a binder, or the polymer. There's pigment fillers. And then there's the solvent diluent. There are situations where you may not have one of those components. You're always going to have a binder. But if, let's say it's a clear coat, you may not have the other pigments and fillers in there, and it might just be the binder and the solvent or diluent. Or vice versa if you have 100% solids product, you may not have the solvents and diluents, but you have the binder and the pigments and fillers. So, they don't always have to have three different components. They can have at least two, though. Binder is always going to be there, though. I guess if you think of a stain, a stain does not contain a polymer, it just contains the pigments and the solvent. So, that's the difference between a stain and a coating system. Now, when we look at barrier coatings—because that's what's primarily used in water immersion service—a barrier coating means that it's a barrier to that electrolyte, okay? And you have a high film build type coating systems, which are those coal tar enamels. You can have polyurethanes or an epoxy. But the other thing, since—it's the binder that actually is going to control some of that permeation through the coating system. So, you got to look at the polymer chemistry and at the actual formulation, as well. Because sometimes you can use products or materials that are not as water insoluble, and that will affect your permeation rate. Another thing, like I said, again, about the flake pigments—they seem to really increase that path of water in permeation. So, it's aluminum, glass, there's micaceous iron oxide. The old coal tar enamel systems used mica, so it's just a... mineral that's mined. And then they put that into the system. The other types of coating systems are sacrificial. So, what I mean by that is that they are using a metal that sacrifices itself to the steel. So, it's going to corrode preferential to your steel. So, the zinc-rich primers are an example of that, as well as metallizing or galvanizing. The last one, which we don't typically use anymore, it's inhibitive type pigments that they add in. So, that was the lead and the chromate. But how those coating systems work was that they actually were slightly soluble in water, and they could passivate your steel at any defect. Like I said, they're no longer used, and the basic reason was because of the health hazards. So, barrier—getting a little bit further depth into the barrier coatings. You know, vinyl resin and coal tar enamel have been the historical coatings used in Reclamation. And vinyl, it consisted of vinyl chloride and vinyl acetate. So, think of like—PVC pipe is very water impermeable. And it's because of the vinyl chloride polymer that creates that. And the vinyl acetate was just so they could actually get it into solution easier.

These coating systems still contain about only 20% solids. So, it was 80% solvent and high VOCs. But the coating system itself was very polar. It prevented—it minimized that water permeation through that coating system. Same thing with coal tar enamel, that had a lot of aromatic rings. So, you ended up getting ring stacking. And the aromatic rings themselves are very polar and prevent water permeation. So, it's basically a bunch of benzene rings that are stacked on each other. The aromatic polyurethanes and epoxies. Again, this is aromatic in nature, so they're hydrophobic, and they prevent that water from migrating through that coating system easily. Coal tar epoxy—and then, again, that's combining some of that coal tar pitch with an epoxy system, so it makes it very polar. It gives us a fairly good service life, as long as it was applied correctly. Moisture cured urethanes. A lot of the moisture cured urethanes are actually aromatic urethanes, but they have that moisture reaction, so when that moisture reaction occurs, it actually crosslinks that coating system. So, those are the basic barrier properties, barrier coating systems that we can use or have used in the past. Again, showing you the flake pigments. Now, sacrificial. So, sacrificial coating systems, basically there's four types. There's organic zinc-rich coatings, inorganic zinc-rich coatings, galvanizing, and then metallizing. And basically we're just—it's just trying to minimize the corrosion rate by having a pigment sacrifice itself. It's—same way cathodic protection works, or galvanic anode cathodic protection systems work, where we're just trying to offset that potential of your steel and protect it. So, we have to have a negative shift. So, as you can see here, your mild steel is around the 0.6 to 0.7 negative voltage compared to your saturated calomel. And then your zinc is around [1.0] to [1.1]. So, there's just that potential shift. Or, when we talk about organic zinc-rich primers, that means that the binder itself is organic. And it's either an epoxy, a moisture cured urethane, possibly vinyl. The Corps of Engineers use a vinyl zinc-rich coating system. And when we talk about inorganic, that means that it's, the polymer, is inorganic in nature, so there's—it's not carbon-based. So, it's ethyl silicate or an ethyl silicate phosphate type chemical reaction. Again, the inorganics are primarily moisture cured systems. I think there's some that might be carbon dioxide-based curing mechanisms. But it's—They're typically a one or two component system. Now, when we talk about thermoplastics, and why does thermoplastics work? If—there is no crosslinking taking place. So, it's actually the degree of crystallinity or organization within that material that helps control that material's permeation properties. It also provides some other properties, mechanical properties, that are, I guess, looked at for coating systems. So, if we look here, this is just a demonstration of what I mean by crystallinity. So, that's the polymer chains themselves that are aligning within that material. So, the crystallinity is what provides that permeability. So, it reduces—decreases that permeability rate—when your crystallinity increases. So, there is no chemical reactions that are taking place. It's polymer chain alignment. So, all these materials are pre-polymerized. Like I said, there's multiple types, so you can have solvent evaporation or a melt, or a heating of the material. Typically, these are the most flexible type of coating system. They're not very rigid. And you get better impact resistance because of it. So, some common thermoplastic coating systems, the solution vinyl resins and the coal tar enamels. And then you get into some powder coatings like polypropylene or polyethylene, teflon, other fluorinated powder coating systems, nylon, as well as PVC powder coatings. When we look at thermoset systems—now remember, this is where they have a chemical reaction that takes place. So, you're increasing your crosslink density. So, when you increase your crosslink density, it's going to decrease your permeability rate. But at the same time, there's a negative effect where if you're increasing your crosslink density, it actually becomes more brittle. So, this is kind of the trade-off. So, you can have an open, more open structure, but then you're going to have a higher permeability rate in order to have a little more flexibility. So, it's a—This is one of the reasons that most epoxies are very brittle or cannot take large impact damage. So, these are typically a two or three component system, or else they react with the oxygen or moisture in the atmosphere. So, again, these are crosslinked systems, and they can't be melted and reformed, compared to with the thermoplastic systems. So, you can melt and reheat the coatings, and it's a little bit easier to repair a thermoplastic coating compared to a thermoset. So, with a thermoset, in order to do a repair, you actually have to abrade that surface, and you're relying on that mechanical interlocking in order to form adhesion between the old system and the new system. So, common thermoset coatings, epoxies, polyurethanes, polyurea, polyaspartics, polysiloxanes, silicates, alkyds, phenolics, vinyl esters, polyesters, moisture cured urethanes. I mean, there's a long list of different coating chemistries that you can—that are thermoset coatings. Boy, I talk way too much, I guess. Okay, so modern day—So, coating selection. There's epoxies and coal tar epoxies. Those are typically used for buried and immersion service, but they do chalk and degrade in atmospheric exposure, UV light. Aliphatic polyurethanes, alkyds, siloxanes, acrylics, silicone alkyds—those types of coating systems are good for atmospheric exposure, but they're not good for water immersion service. They don't have the hydrophobicity to prevent that, or minimize that, water permeation. We've got zinc-rich coatings. They're typically used for minimal water contact or high humidity, atmospheric exposure such as bridges, I-beams, etcetera. We do not typically use these in conjunction with an external cathodic protection system. We see that the—it causes a lot of blistering randomly throughout the coating system. Moisture cured urethanes and siloxanes, these are—sometimes they are good for atmospheric and immersion service. It depends on the formulation, actually. They are moisture cured, so it requires humidity in order to cure. So, this might be a limitation, especially out here in the arid west when we have humidity levels around 10 to 15%. So, you got to keep that in mind when you're using those products. Fusion bonded epoxies and nylon, they're—sorry, fusion bonded epoxies, they're good for buried and immersion service, but it's usually only for small parts or small diameter pipe because they have to fit into an industrial oven. Again, they're not designed for atmospheric exposure. Nylons, teflons, PVDF—again, they're melt-applied, so they require an industrial oven. Polyurethanes, 100% solids epoxies, aromatic polyurethanes—now, these are designed for water immersion service. It requires specialized equipment. The polyureas, we typically only use them for repairing cracks in canals because it requires a really, really aggressive profile, like quarter-inch profile, in order to get good, adequate adhesion. And then the last is vinyl resin. They're excellent for immersion service and atmospheric. Some of the case histories that we've seen. So, for cavitation resistance, I know we typically, in Reclamation, use stainless steel weld overlays. There's this other product that works really well, it's called—it's from Enecon—Flexiclad Duratough DL. This is a polymeric material that's elastomeric. And it actually withstands cavitation fairly well. We've got many years' experience with that at Yellowtail. Elephant Butte and Durango pumping plant—so, this was erosion resistance of pumps and on, I believe it was, the wicket gates at Elephant Butte. This is a 3M Thortex Ceramitech FG, very erosion resistant. As well as the Belzona Ceramic S metal. So, for zebra and quagga mussel control, we've been doing research since 2008. So, silicone foul release coatings work very well. In addition to that, there's a new product from Jotun that is a durable silicone epoxy that has provided 3 years of service life so far. Denver Water, they actually are one of the first applicators of the polyurethane, aromatic polyurethane, the rigid polyurethane. And that coating system, we got to do an inspection about a year ago or two years ago, and so about 20 years of age. And that coating system looked pristine after 20 years. It was in a low flow, low pressure environment. So, not exactly what Reclamation has, but some similar. The Yellowtail Dam radial gates—here's an example where we've had a 30-year service life plus of an epoxy with cathodic protection. And the coating system and cathodic protection system are still working fantastic. So, we're reintroducing vinyl resins to Reclamation. It's been a coating system that Reclamation used for a long, long time, and we've got a long—we know how long these coatings last. They're excellent at low temperature application because it's only solvent evaporation. There's no chemical reactions that take place, so there's no isocyanate sensitivity that we have to worry about. They're easily repaired. So, if you mess up and, like I have done in the past, you can just redissolve that resin using a solvent wipe, using a ketone solvent. And they also have an indefinite recoat window, overcoat window. And there's no proprietary chemicals, these are all formulation driven specifications from the Corps of Engineers. So, where we can use these—it has to be classified as impacted immersion coating system. So, the definition of high impact is that they're form—the coatings are formulated for a high-performance maintenance coating, recommended for application on steel structures subjected to immersion in turbulent, debris-laden waters. These coatings are specifically resistant to high-energy impact damage caused by floating ice and debris. So, this is—basically, we can use these coating systems under certain conditions. So, if we just have straight water immersion and there's no impact, we cannot use—specify these materials. But if we have log impact or sediment impact, we can use these products. So, inside scroll cases. Actually, so, right here is a photo of a big tree that's hung up on the TCD structure at Shasta Dam. So, we're just trying to remove that debris. But the Corps of Engineers formulations are right here. We can—I'm not going to get too involved in detail on that. But the biggest takeaway here is where we can use these radial gates—er, these coating systems. So, it's on radial gates, trash racks, drum gates, turbine runners, penstocks, draft tubes, surge tanks, etcetera. We have specifications developed and we've been using them for about six months. Some incompatibilities for vinyl—you do not want to use cathodic protection with it as of right now. Jessica Torrey is going to be doing some research as to how we could possibly do cathodic protection with vinyl resin. The other incompatibility is using epoxy filler materials. Sometimes we use those to fill pits and crevices and such. One concern is that these contain high amount of solvents, so they're flammable. There's huge flammability issue. As well as you do not want to—you want to use supplied air respirators when you're applying these coating systems unless you have environmental controls like a spray booth. So, in confined spaces, you definitely want to wear supplied air. And I'm so far behind, do we want to keep going? Okay. So, during—so, coating application—there's many different techniques, guns, equipment that you need that are available. You need to look at your MSDSs and application sheets and follow those to a T. You need to be concerned about environmental effects. So, like if you're applying coatings in low temperature or in high humidity, what are the effects? So, you could have amine blushing if you use an epoxy coating system. Other things you need to be concerned about are your recoat windows, your downtime, your cure time. All these will affect your coating application, your temperatures. So, just read through your product data sheets. Know as much information as you can about the product when you're applying. The safety data sheets, that's for learning about the flammability and the dangers, hazards, involved with the material itself. So... surface preparation. You know, there's different types of surface preparation—abrasive blasting, water jetting, power tool cleaning. You need to be concerned about fall protection, hearing protection. With the coating application site, some of the hazards—you have isocyanates, amines, solvent, flammability, high-pressure lines. Again, fall protection, hearing protection. One thing I don't wanna see ever again is a fire in a penstock. This was an Xcel Energy plant where they were recoating. The Cabin Creek Fire broke out and five people perished within that penstock. So, we want to be very careful about allowing solvents and equipment inside a penstock. So, when we get down to the basics of adhesion—what is adhesion? It requires a mechanical, chemical, and wetting properties, as well as your cohesive properties. So, when we're looking at it, we want a very aggressive roughness, or they call that profile. So, the larger your profile, the more surface area your coating has to adhere to. And then your surface cleanliness—so, a white metal blast is better than near-white, versus a commercial blast. Your chemical bonding, that's a covalent bonding or a hydrogen bonding. And of course, a covalent bond is stronger than a hydrogen bond. So, if you look at an epoxy chemical reaction here, you're going to have—you're opening up this epoxy ring, which is going to, it's going to form hydrogen bonding through your OH group. But it also forms a covalent bond to your iron. So, that's why epoxies are typically used in industrial maintenance coatings because they form a covalent bond. Your wetting properties, you need to be able to wet out that substrate, as well as form a continuous film. Now, looking at the difference between cohesion and adhesion—adhesion, if you have an adhesive failure, it's delaminating right at that steel interface. We've seen this in a couple instances and it's not pretty. It delaminates the entire coating from your substrate, and then you're left with a corroding substrate. So, you've got to be very cautious as what products we actually use. What you would like to see—if you're going to have a failure, you want to see a cohesive failure. So, it's leaving some of that coating material behind, right here. If you are coating concrete, your concrete has a poor tensile adhesion, and you could have the substrate failure. That's another thing that you do not want to see. So, of course the best means of getting the surface profile that you desire is abrasive blasting. It's the most economical and effective. It's very important to have a good mechanical bond. So, here's some power tool cleaning methods. We always use scalers or chisels or needle guns, but there's many different types. This is a fairly new product, probably within the past 10 years it came on the market, and it's called a bristle blaster. It actually imparts a surface profile similar to abrasive blasting into your steel. So that's a very good tool. Don't use it on a lot of surface area because it's very slow. Water jetting and wet abrasive blasting—these are methods to remove chlorides, as well as to minimize the dust that's generated. Water jetting is a very useful technique for removing coal tar enamel. Another key thing to worry about is your surface cleanliness, or the level of dust on your surface. And you do not want to have something like this because your paints will only adhere to the dust particulates rather than your steel surface. So, we want to be up in this area of surface cleanliness from dust. The next thing I want to talk about is, you know, there's many different types of application methods. For stripe coating, it's very, very important to brush apply your stripe coats because if you do not, you can end up with voids in corners and crevices. And if that happens, you're going to—that's an immediate point of failure. And as your coating shrinks and cures or the solvents evaporate, it's going to crack that coating system right there. So, it's very important to brush apply and work that coating system in to those crevices. And I'm so far behind time, do we want to keep going? Okay.

>> **Dr. Torrey:** If that's okay, you can skip, go ahead. Otherwise—

>> **Dr. Skaja:** So, I'll just kind of go through this airless spray equipment. It's one of the most commonly used application methods right now. This is an airless, cordless spray gun. So, it only goes through about a quart of material, so it's really good for, maybe, spot repairs. This is plural component equipment. So, you've got your pumps and your fusion gun. And you have two different lines that hook up right here so that you don't mix the materials prior to application, it mixes right in this little chamber, and that's your only clean-up area. Whereas the plural—or, airless system, you usually mix the coating system together and push that material in through one line. This is a cartridge gun, again, for plural component coating systems for application on small structures. So, you have component A and component B, and it pushes this plunger through the cartridge, and it pushes the material out through a static mixer, which mixes your coating. And then out through a nozzle, right here, to atomize your coating system. The other application method that is starting to really take place for penstock linings, as well as pipelines, is a robotic application system. So, this was used in this penstock, these three penstocks. So, there's pretty steep grades. And it's just spinning, rotating the heads and applying the coating system. One concern I have about this technique is—see all these riveted structures? They're not stripe coating prior to application, so there could potentially be a lot of voids, as well as remedial work because it may not have bridged those rivets or those crevices. I'm going to skip this particular slide, but one of the things I need to talk about with curing is, if you have an amine cured product, so an epoxy amine system, there's this potential for amine blush at low temperatures and high humidity because there's a secondary reaction that takes place that reacts with your amine. The other thing

to worry about with low temperature cure, it affects your cure rate. So, it's going to take much, much longer for that coating to meet a complete cure than if it was applied at a warmer temperature. So, we don't typically want to see anything applied below 50 degrees Fahrenheit. There are products out there that cure lower than that, you just need to be concerned and aware that you're not going to meet a complete cure. Just to—this is one of my last slides here. The Coatings Laboratory has gone through some renovations this past couple of years, and we just got a new spray booth, so that's right here on the left. And then, while I was waiting the two years to get this new spray booth, we actually, uh... built a cavitation testing apparatus to evaluate coatings and materials for cavitation resistance. So, we're going to do a three-day class in Denver, a coatings and corrosion class. We're still "to be determined" on the date. The Corrosion Webinars are offered twice a year, February to March or June and July. And email Jessica Torrey any ideas that you have. This is our team of people right now for our corrosion and coatings needs. So, contact any one of us and we can direct you in the right direction. So, we are going to open this up to questions, so please email or put in the—

>> **Dr. Torrey:** So yeah, thank you Allen. And if you have any questions for Allen, please go ahead and type those in the questions box on your "go to meeting" little command center that you have. And I'll read those out and get those to Allen. Just to reiterate, if you want to make sure that you get the announcements, I just keep a mailing list in my Google account. So, if you want to get on that, then you'll be sure to get the announcements for future webinars and also for the coatings and corrosion class that will happen in October. We'll send information out through those channels when we get dates set and things like that. I don't see any questions coming in so—oh, here we go. Any advice for painting surfaces with sharp edges like nuts and bolts?

>> **Dr. Skaja:** So, on sharp edges you really need to take the edge off, otherwise you end up with a thin coating application and then a point of failure. So, what you really need to do is try to grind those surfaces. But if it's a bolt, you're not going to want to grind those surfaces, so you're just going to want to do the best that you can. Brush apply those areas. And you probably want to put extra coats on those areas as well. You don't want to just do a one or two coat system, you're going to want to put a three or maybe even a four coat system on that.

>> **Dr. Torrey:** Okay. We have several questions about if the slides will be available for reference. Yes, I will send the slides out to the Corrosion mailing list. And then as well, we'll work—we need to get the recording closed captioned before we can put that up on the website. But once we get that done, we will post both the slides and the recording onto The TSC website. And I will also send that link out. But in the short term, look for me to be sending the email out so that you guys can all have these slides for reference.

>> **Dr. Skaja:** And if you have questions on any of the slides, please contact me and we will work out whatever issue or questions you had.

>> **Dr. Torrey:** Another question here: Is it true that sometimes the absence of coating itself is the way of coating? Because when metal corrodes in a controlled fashion, the corrosion itself is sufficient coating for the metal.

>> **Dr. Skaja:** In some cases, that might be acceptable if you have a very, very low corrosion rate. But anytime it's in buried or immersion service, that is an electrolyte, so it's going to be much faster than if it was an atmospheric exposure. And we recommend using a coating system. And whenever you can, also have the cathodic protection in conjunction with the coating system.

>> **Dr. Torrey:** If I could add to that, it's only true for some metals. So, for mild steel, which is what we typically use at Reclamation, that corrosion product does not passivate and it's not good enough to consider as a protective barrier. Sometimes in stainless steel—that's how stainless steel works, is the corrosion product is the more dense product, and so it can passivate. It's called passivation, it will passivate your stainless steel and prevent further damage. And we still recommend—it's not good enough for long-term service or for the service that we often ask of our structures at Reclamation. So, we still recommend that you use alternative corrosion protection. And Xcel Energy, on my first slide with that Shoshone Power Plant, they neglected corrosion because they—that was an atmospheric exposure, obviously. Inside the tank—er, the pipe, it was water immersion service, and they just neglected the corrosion protection. And then they had a catastrophic failure because it—on the rivets themselves is a crevice corrosion area. And as soon as you get enough corrosion, it's going to pop. So, it's just, it depends on the service conditions whether or not you should coat or just allow that to corrode.

>> **Dr. Torrey:** We have another question: For a water storage tank, do you think zinc primer is a good idea, with or without cathodic protection?

>> **Dr. Skaja:** A zinc-rich primer on the interior surface?

>> **Dr. Torrey:** A storage tank.

>> **Dr. Skaja:** So, you definitely do not want—the zinc-rich primer, in my opinion, on a water tank is not a good selection of product. Because your zinc-rich primers, as soon as you get a little bit of permeation through there, your zinc is going to want to start corroding. And it's going to form blisters, it's going to do all sorts of things that are not the way you want to do a coating system in immersion service. You really want just a barrier coating system in immersion service. And then you wouldn't—you could put cathodic protection with a barrier type coating system. I would not ever use cathodic protection with a zinc-rich coating.

>> **Dr. Torey:** Okay, another question, are there cheat sheets available that describe recommended coating types for various uses? For example, what to use for a penstock interior, penstock exterior, exterior metal surfaces, etcetera.

>> **Dr. Skaja:** So, things have changed in the past ten years since I've been here, and we still need to update. There's—on the intranet TSC website, you can go to the specs and there used to be a list of tab selection and category selection for the various pieces of equipment. We need to update that. I'm going to try working on that within the next year and get that all updated so we are using the most current products and application techniques for those infrastructure. So that coatings selection guide, I would wait until I get that updated, and I will send out an announcement with that when it's complete.

>> **Dr. Torrey:** Last question here, do you recommend coating for concrete tanks for water storage?

>> **Dr. Skaja:** It depends. I mean, if it's an old tank that's cracked, has a bunch of cracks in it, we could go in with something like an AquaLastic or a polyurea, fill all those cracks to prevent the leakage. On a new concrete water tank, I would not bother with a coating system because you're not going to have the cracks developed for some time. So, it all depends on the situation.

>> **Dr. Torrey:** [unintelligible] keep an eye for an email from me with the slides for this presentation. And thank you also, Allen, for the most recent installment of our Corrosion Webinar Series.

>> **Dr. Skaja:** You're welcome. Thanks.