1
0001,000 -- 0015,000
Good morning, everyone. My name is Allen Skaja. I've been with Reclamation for 11 years now. I want to point out a couple things about the...
2
0015,000 – 0048,000
We are going to do a Corrosion and Coatings class held tentatively this fall. We encourage everyone to sign up for this class. Two years ago when we offered the class, it filled up really fast. Then we went to management to ask for more funding, we got more funding. We had a second class that also filled up really fast. We ended up having three classes that year.
3
0048,000 – 0115,000
The biggest takeaway here is sign up early and hopefully you'll get into the class. It's all based on funding available. Usually they give us funding for one class. If there's funding available, then we'll have a second or maybe even a third class.
4
0115,000 – 0129,000
The next Corrosion webinar is tentatively for February of 2017. The topic is to be determined. We're not sure what topic we're going to present at that time.
5
0128,000 – 0157,000
This is the Protective Coatings 101. As I said, I've been here for 11 years. Prior to that I was a graduate student at North Dakota State University in their Coating and Polymeric Materials Department. I've got a Ph.D. in that field. I know probably more than anyone else in Reclamation about protective coating.
6
0157,000 – 0208,000
Bobbi Jo Merten is a colleague of mine. She's got the same degree. She may have an edge on me on some topics, but I've got other areas of expertise.
7
0208,000 -- 0232,000
Protective Coatings 101, the webinar objective here is to first introduce protective coatings, what they are, what some of the bare minimum requirements for protective coatings, and what properties they have to have.
8
0232,000 -- 0253,000
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 to use. Is there another means to provide adequate surface preparation?"
9
0253,000 -- 0308,000
We'll get into that quite a bit, as to why surface preparation is so important for longevity in coating. Then, there's application equipment, and methods and equipment.
10
0308,000 -- 0346,000
The photo in this is of its scroll case. I'm not even sure what facility this is at, because they all look so similar. [laughs] This is scroll

case, so it goes around the turbine runner and the wicket gates. You can see the stainless steel wicket gates right here. This is the curb plate and the swathing. Most hydro facilities are basically the same, just different diameters.
11
0346,000 -- 0406,000
Protective coating, this is the primarily defense against corrosion. The annual cost of corrosion is estimated at about $450 billion, annually, in the United States. That's about 2.7 percent of the gross domestic product.
12
0406,000 -- 0428,000
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. Really, it's just to minimize future repairs and costs.
13
0428,000 -- 0452,000
Corrosion is an electric chemical process. There's a little bit of electrochemistry involved to have that whole corrosion process. Some of the components of corrosion, you have to have an anode, a cathode, a metallic pathway, and your electrolyte.
14
0452,000 -- 0506,000
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.
15
0506,000 -- 0534,000
For protective coating, it's primarily providing that barrier to that electrolyte. Now what can happen is—you know, we're really looking at preventing failures. 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.
16
0534,000 -- 0606,000
But, if you neglect the corrosion and just let it corrode, some things can go wrong. Here's an example at Shoshone Power Plant. It's run by Xcel Energy. This is some penstocks that are riveted construction, and there's significant amount of corrosion that was underneath the rivets and around the whole rivets.
17
0606,000 -- 0636,000
It blew out one of the penstocks, and yeah, a lot of water. These are very small diameter penstock and if we look at the extensive 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 destroyed the plant.
18
0636,000 -- 0707,000
They had to start from scratch. It's not only just the rubble but the building itself, as well as it took out the transformers. By the time the water was shut off, basically, it destroyed the entire plant. They had to start from scratch. As I stated already, the coating is the primary defense against corrosion and we use cathodic protection with coating systems.
19

0707,000 -- 0732,000
The cathodic protection is typically used to protect the defects in the coating. Most coatings are not 100 percent foolproof. You're always going to have a small percentage of surface area that needs to be protected.
20
0732,000 -- 0747,000
In buried and submerged structures, the best corrosion protection system is a good bonded coating system, as well as a cathodic protection system. You need both.
21
0747,000 – 0813,000
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. For the most part, we've only used bonded coatings in those service environment.
22
0813,000 -- 0838,000
There's basically three components to a coatings job. We have surface preparation, the coating application and then the coating material itself. When you look at contracting out coatings work, the contractor's responsible for the surface preparation and he’s also responsible for the coating application.
23
0838,000 -- 0906,000
We're trusting and 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 are many different things that go into a coatings job.
24
0906,000 -- 0939,000
They're going to select the materials that are going to work for their application procedures. This is the number one thing that 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 the majority of the costs that are associated with the coatings job are labor intensive.
25
0939,000 -- 1000,000
If not the coating material itself, it's what has to take place in order to get those coatings reapplied. We wanted to use the highest quality coating system for the particular application. Majority of the cost, like I said, are associated with that labor.
26
1000,000 -- 1034,000
If we have a coating system that's going to provide a 30-year service life, we only have to recoat that system every 30 years. But if we have something that is less than that, this is going to be required to be recoated more frequently. This is just kind of demonstrating the frequency of recoating jobs. The associated costs with coating each job. Like I said, it is very labor intensive.
27
1034,000 -- 1107,000

There is mobilization, demobilization, scaffolding, containment, transporting all the equipment to the site. There is the blast and coating removal. That is very labor intensive, production [inaudible] , typically less than 100 square feet per hour. You of course have handling and disposal, clean up, all that type of stuff which is very labor intensive.
28
1107,000 – 1139,000
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 is very labor intensive and takes a lot of time to apply those coatings. If you’re using a plural-component spray equipment, then you can do a lot of square feet in a very short amount of time.
29
1139,000 -- 1204,000
When we think of general cost, the surface preparation is going to be the most labor intensive. The coating application is the middle ground. Your coating expense through the material itself is typically a very small part of that application cost.
30
1204,000 -- 1250,000
When we look at the materials themselves, we have abrasives, again, handling and disposal depends on the method that the contractor has selected, whether that is going to be a materials cost or not. You are usually going to have drums of abrasive that you have to dispose of so there is the cost of the drum. Of course, the coating product itself. Sometimes we don't specify coatings. We go with a metalizing, so it is a zinc metalizing application. That is where the wire feed stock comes into cost.
31
1250,000 -- 1329,000
Now, getting down into the basics. 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. That was the initial segue into the development of corrosion protective coating. The basic requirement here is that you need strong adhesion to your substrate.
32
1329,000 -- 1404,000
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 also need to resist the exposure environment. Whether it is atmospheric weather or if it is burial service, immersion service. It could be chemicals, abrasion impacts, as well as age resistance.
33
1404,000 -- 1440,000
The age resistance is basically to prevent cracking of the coating system. You also want something that is compatible with cathodic protection. Not all coating systems are compatible. The other thing you need to look at is ease of application. You may have the best coating system, but if it is difficult to apply, the contractor may have a very big challenge getting that applied correctly.
34

1440,000 – 1500,000
All those things you need to worry about in the coating system. 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.
35
1500,000 -- 1537,000
That is 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. The corrosion will just run right along that interface, and you will continue to have further and further delamination. That corrosion spot is going to expand. We have been doing research for quite a while.
36
1537,000 -- 1608,000
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. The other thing with corrosion is that barriers to electrolyte. If you have your electrolyte out here, it is going to want to migrate through your coating, through all coatings. Even the old cold coal tar enamel and vinyl resin.
37
1608,000 -- 1646,000
They are semipermeable membrane. That means water will get through eventually. It's just at what rate. Some of the coating systems, they incorporate suede-type pigments to help increase the path of that water or electrolyte getting through your coating system. That is very important. If you can have some sort of flake pigment, typically they're going to provide longer service life than without.
38
1646,000 -- 1718,000
Getting into the protective coatings, actual early 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. It could also be a hot application or a melt procedure.
39
1718,000 – 1806,000
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 protective film. The other type that Reclamation typically used was coal tar enamel. That is where they heated the coal tar up to about 400 or 500 degrees Fahrenheit and then mopped or troweled or used a dauber to apply the coal tar enamel to the infrastructure.
40
1806,000 -- 1825,000
Then thermosets, that means that there's going to be a chemical reaction that takes place during the curing process. They can be either two or more components, or they could also just be a single component, but react with the atmospheric conditions.
41
1825,000 – 1857,000
So like moisture-cured urethanes, they're 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 cross-link and cure.
42
1857,000 -- 1931,000
If it's a chemical-cure, such as an epoxy polyurethane, cold tar epoxies, something like that, there are two components, so you have to mix through 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, and it get shipped, the equipment gets shipped to the site, and they try to pull it out of the crate, and the coating is still wet.
43
1931,000 -- 2007,000
It's very important to have component A and component B mix together during the application process. What goes into a coating system? Or paint? There is a binder, there is a polymer, there's pigment and fillers, and then there's a 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.
44
2007,000 -- 2027,000
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 a hundred percent solids product, you may not have the solvents and diluents, but you have the binder and the pigments and fillers.
45
2027,000 -- 2051,000
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 solvents. That's the difference between a stain and a coating system.
46
2051,000 -- 2115,000
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. You have a high film build type coating systems, which are those coal tar enamels, you can have polyurethane or an epoxy.
47
2115,000 -- 2144,000
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've got to look at the polymer chemistry and 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.
48
2144,000 -- 2219,000
Another thing, like I said at the end about the flake pigments, they seem to really increase that path of water permeation. If aluminum, glass, there's micaceous iron oxide, the old coal tar enamel systems used mica, a mineral that's mined, and then they put that into the system.
49
2219,000 -- 2244,000

The other types of coating systems are sacrificial. 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. The zinc-rich primers are an example of that, as well as metalizing or galvanizing.
50
2244,000 -- 2307,000
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 worked, was that they actually were slightly soluble in water, and they can passivate your steel at any defects.
51
2307,000 -- 2350,000
Like I said, they're no longer used, and the basic reason was because of the health hazard. Getting a little more further depth into the barrier coatings, vinyl resin and coal tar enamel have been the historical coatings used in Reclamation. Vinyl, it consisted of vinyl chlorate and vinyl acetate. Think of PVC pipe, it's very water impermeable. It's because of the vinyl chlorate polymer that creates that.
52
2350,000 -- 2419,000
The vinyl acetate was just so they could actually get it into solutions easier, these coating systems still contain about only 20 percent solid, so it's 80 percent solvent, and high VOCs. The coating system itself was very polar, it prevented- it minimized that water permeation through that coating system.
53
2419,000 -- 2442,000
Same thing with coal tar enamel. That had a lot of aromatic rings, so you ended up getting ring stacking, and those aromatic rings themselves are very polar and prevent water permeation. It's basically a bunch of benzene rings that are stacked on each other.
54
2442,000 -- 2516,000
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. Then, again, that combines some of that coal tar pitch with an epoxy system so it makes it very polar, it gives it a fairly good service life as long as it was applied correctly.
55
2516,000 -- 2550,000
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 cross-links that coating system. Those are the basic barrier properties, barrier coating systems we can use, or have used in the past. Again, showing you the flake pigments.
56
2550,000 -- 2635,000
Now, sacrificial. Sacrificial coating systems, basically there's four types. There's organic zinc-rich coatings, inorganic zinc-rich coatings, galvanizing and then metalizing. Basically, it's just trying to minimize the corrosion rate by having a pigment sacrifice itself. 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. We have to have a negative shift.

57
2635,000 -- 2719,000
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 0.1 to 0.11, so there's just that potential shift. Or when we talk about organic zinc-rich primers, that means that the binder itself is organic. It's either an epoxy, a moisture-cured urethane, possibly vinyl, the Corps of Engineers used a vinyl zinc-rich coating system.
58
2719,000 -- 2757,000
When we talk about inorganic, that means that it's the bond is inorganic in nature, it's not carbon based. It's ethyl silicate, or an ethyl silicate-phosphate type chemical reaction. Again, the inorganics are primarily a moisture-cured system. I think there's some that might be carbon dioxide-based curing mechanisms. There's typically a one or two component system.
59
2757,000 -- 2835,000
Now when we talk about thermoplastics, and why do thermoplastics work? There is no cross-linking 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.
60
2835,000 -- 2902,000
If we look here, this is just a demonstration of what I mean by crystallinity. That's the polymer chains themselves that are aligning within that material. The crystallinity is what provides that permeability. It decreases that permeability rate when the crystallinity increases.
61
2902,000 -- 2939,000
There is no chemical reactions that are taking place, it's polymer chain alignment. All these materials are pre-polymerized. Like I said there's multiple types, so you can have solvent evaporation or melt, or heating of the material. Typically, these are the most flexible type of coating systems. They're not very rigid, and you get better impact resistance because of it.
62
2939,000 -- 3004,000
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.
63
3004,000 -- 3033,000
When we look at thermoset systems, now remember, this is where they have a chemical reaction that takes place so you're increasing your cross-link density. When you increase your cross-link 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 cross-link density, it actually becomes more brittle.
64
3033,000 -- 3046,000

This is the trade-off, so you can have a more open structure, but then you're going to have a higher permeability rate in order to have a little more flexibility.
65
3046,000 -- 3108,000
This is one of the reasons that most epoxies are very brittle or cannot take large impact damage. These are typically a two or three component system, or else they react with the oxygen or moisture in the atmosphere.
66
3108,000 -- 3132,000
These are crosslinked systems, and they can't be melted and reformed compared to with a thermoplastic system. You can melt and reheat thermoplastic coatings. It's a little bit easier to repair a thermoplastic coating compared to a thermoset.
67
3132,000 -- 3151,000
With a thermoset, in order to do a repair, you actually have to abrade that surface. You're relying on that mechanical interlocking in order to form adhesion between the old system and the new system.
68
3151,000 -- 3217,000
If common thermoset coatings, epoxies, polyurethane, polyurea, polyaspartic, polysiloxane, silicates, alkyds, phenolics, vinyl esters, polyesters, moisture cured urethanes...There's a long list of different coatings' chemistries that are thermoset coatings.
69
3217,000 - 3220,000
[pause]
70
3220,000 - 3240,000
Boy. I talk way too much, I guess. In modern day...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, the UV light.
71
3240,000 - 3300,000
Aliphatic polyurethanes, alkyds, siloxanes, acrylics, siliconic alkyds. Those type of coating systems are good for atmospheric exposure, but they're not good for water immersion service. They don't have the hydrophobicity to minimize that water permeation.
72
3300,000 - 3327,000
We've got zinc-rich coatings. They're typically used for minimal water contact or high humidity, atmospheric exposure such as bridges, I-beams, etc. We do not typically use these in conjunction with an external cathodic protection system. We see it causes a lot of blistering randomly throughout the coating system.
73
3327,000 - 3358,000
Moisture cured urethanes and siloxanes. Sometimes they are good for atmospheric and immersion service. It depends on the formulation, actually. They are moisture cured, so it requires humidity to cure. This might be a limitation especially out here in the arid west when we have

humidity levels around 10 to 15 percent. You've got to keep that in mind when you're using those products.
74
3358,000 - 3433,000
Fusion bonded epoxies and nylon...Sorry, fusion bonded epoxies are good for buried and immersion service, but it's usually only for small parts or small diameter pipes because they have to fit into an industrial oven. Again, they're not designed for atmospheric exposure. Nylon, Teflon, PVDF. Again, they're melt-applied so they require an industrial oven.
75
3433,000 - 3508,000
Polyurethanes, 100 percent solid epoxies, aromatic polyurethanes. These are designed for water immersion service. It requires specialized equipment, but polyureas, we typically only use them for repairing cracks in canals because it requires a really, really aggressive profile, a quarter inch profile in order to get good, adequate adhesion.
76
3508,000 - 3527,000
The last is vinyl resin. They're excellent for immersion service and atmospheric. Some of the case histories that we've seen. For cavitation resistance, I know we typically, in Reclamation, use stainless steel weld overlays.
77
3527,000 - 3605,000
There's this other product that works really well. It's from Enecon—Flexiclad Duratough DL. This is a polymeric material that's elastomeric. It actually withstands cavitation fairly well. We've got many years' experience with that at Yellowtail. Elephant Butte, and Durango Pumping Plant, this was erosion resistance of pumps, and, I believe, it was at the wicket gates at Elephant Butte.
78
3605,000 - 3639,000
This is a 3M Thortex, Cerami-Tech FG, very erosion resistant as well as the Belzona Ceramic S Metal. For zebra and quagga mussel control, we've been doing research since 2008. The 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 three years of service-life so far.
79
3639,000 - 3715,000
Denver Water. They are one of the first applicators of the aromatic polyurethane, the rigid polyurethanes. That coating system, we got to do an inspection about two years ago. 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.
80
3715,000 - 3755,000
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.
81
3733,000 - 3757,000
We're reintroducing vinyl resins to Reclamation. It's been a coating system that Reclamation used for a long, long time. 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.
82
3757,000 – 3823,000
They're easily repaired. If you mess up like I have done in the past, you can just re-dissolve that resin using a solvent wipe, using a ketone solvent. They also have an indefinite overcoat window. There's no proprietary chemicals. These are all formulation driven specifications from the Corps of Engineers.
83
3823,000 – 3859,000
Where we can use these, it has to be classified as "impacted immersion coating system." The definition of high-impact is that 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.
84
3859,000 – 3940,000
Basically, we can use these coating systems under certain conditions. If we just have straight water immersion, and there's no impact, we cannot specify these materials. But, if we have log impact or sediment impact we can use these products. Inside scroll cases... Right here is a photo of a big tree that's hung up on the TCD structure at Shasta Dam. We're just trying to remove that debris.
85
3940,000 – 4013,000
The Corps of Engineer formulations are right here. I'm not going to get too involved in detail on that. The biggest takeaway here is where we can use these coating systems. It's on radial gates, trash racks, drum gates, turbine runners, penstocks, draft tubes, surge tanks, etc. We have specifications developed, and we've been using them for about six months.
86
4013,000 –4041,000
Some incompatibility 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 resins. The other incompatibility is using epoxy filler materials. Sometimes we use those to fill pits, crevices, and such.
87
4041,000 – 4109,000
One concern is that these contain a high amount of solvents so they're flammable. There's a huge flammability issue as well as you want to use supplied air respirators when you're applying these coating systems unless you have environmental controls like a spray booth. In confined spaces, you definitely want to wear supplied air.
88
4109,000 – 4111,000
I'm so far behind.
89
4111,000 – 4112,000
That's OK.
90

4112,000 – 4146,000
Do we want to keep going? OK. Coating application is many and different techniques, guns, equipment that are available. You need to look at your MSDS's and application sheets and follow those to a T. You need to be concerned about environmental effects. If you're applying coatings in low temperature or in high humidity, what are the effects? You could have amine blushing if you're using an epoxy coating system.
91
4146,000 –4224,000
Other things you need to be concerned about are your re-coat windows, your downtime, your cure time. All of these will affect your coating application, your temperatures. 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.
92
4224,000 –4251,000
Surface preparation. 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 coating application sites, some of the hazards you have...isocyanates, amines, solvents, flammability, high pressure lines…again fall protection, hearing protection.
93
4251,000 – 4315,000
One thing we don’t want to see ever again is a fire in a penstock. This was an Xcel Energy plant where they were re-coating. The cabinetry fire broke out, and five people perished within that penstock. We want to be very careful about allowing solvents and equipment inside a penstock.
94
4315,000 – 4353,000
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. When we're looking at it, we want a very aggressive roughness, they call that profile. The larger your profile, the more surface area your coating has to adhere to. And then your surface cleanliness. A white metal glass is better than a near-white versus a commercial glass.
95
4353,000 – 4429,000
Your chemical bonding. That's covalent bonding or a hydrogen bonding. Of course, a covalent bond is stronger than a hydrogen bond. If you look at an epoxy chemical reaction here, you're opening up this epoxy ring which is going to form hydrogen bonding through your OH- group, but it also forms a covalent bond to your iron. That's why epoxies are typically used in industrial maintenance coatings because they form a covalent bond.
96
4429,000 – 4437,000
Your wetting properties. You need to be able to wet off that substrate as well as form a continuous film.
97
4437,000 – 4505,000
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. We've got to be very cautious as to what products we actually use.
98
4505,000 – 4526,000
What you would like to see if you're going to have 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, you're concrete has a poor tensile adhesion, and you could have the substrate failure. That's another thing you do not want to see.
99
4526,000 – 4545,000
Of course, the best means of getting the surface profile that you desire is abrasive blasting. It is the most economical and effective. It's very important to have a good mechanical bond.
100
4545,000 -- 4620,000
Here's some power-tool cleaning methods. We always use scalers, chisels, or a needle gun, but there's many different types. This is a fairly new product, probably within the past 10 years it came on the market. It's called a bristle blaster. It actually imparts a surface profile similar to abrasive blasting into your steel. That's a very good tool. Don't use it on a lot of surface area, because it is very slow.
101
4620,000 – 4639,000
Water jetting and wet abrasive blasting. These are methods to remove chlorides as well as minimize the dust that's generated. Water jetting is a very useful technique for removing coal tar enamel.
102
4639,000 --- 4709,000
Another key thing to worry about is your surface cleanliness or the level of dust on your surface. You do not want to have something like this, because your paints will only adhere to the dust particulates rather than your steel surface. We want to be up in this area of surface cleanliness from dust.
103
4709,000 – 4737,000
The next thing I want to talk about is there are many different types of application methods. For stripe coating it is very, very important to brush apply your stripe coats, because if you do not you can end up with voids in corners and crevices. If that happens, you're going to have an immediate point of failure.
104
4737,000 – 4752,000
As your coating shrinks and cures and the solvent evaporates, it's going to crack that coating system right there. It's very important to brush apply and work that coating system in to those crevices.
105
4752,000 – 4757,000
I am so far behind time. Do we want to keep going? OK.
106
4757,000 – 4800,000
I think that's OK, you can skip. Go ahead. Otherwise...
107

4800,000 – 4819,000
I'll just 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. It only goes through about a quart of material, so it's really good for, maybe, spot repairs.
108
4819,000 – 4850,000
This is plural component equipment. You've got your pump and your fusion gun. You have two different lines that hook up right here so you don't mix the materials prior to application. It mixes right in this little chamber. That's your only cleanup area. Whereas the airless system you usually mix the coating system together and push that material in through one line.
109
4850,000 – 4915,000
This is a cartridge gun, again, for plural component coating systems for application on small structures. You have component A and component B. It pushes these plungers through the cartridge. It pushes the material out through a static mixer which mixes your coating and then out through the nozzle, right here, to atomize your coating system.
110
4915,000 – 4944,000
The other application method that is starting to really take place for penstock lining as well as pipelines is a robotic application system. This was used in these three penstocks. There's pretty steep grades, and it's just spinning, rotating the head, and applying the coating system.
111
4944,000 – 5005,000
One concern I have about this technique is, see all these riveted structures? There's not stripe coating prior to application. There could potentially be a lot of voids as well as remedial work because it may not have bridged those rivets or those crevices.
112
5005,000 – 5033,000
I'm going to skip this particular slide, but one of the things I need to talk about with curing is if you had an amine cured product -- in an epoxy amine system, there is this potential for amine blush at low temperatures and high humidity because there is a secondary reaction that takes place that reacts with your amine.
113
5033,000 – 5108,000
The other thing to worry about with low temperature cure, it affects your cure rate. It's going to take much, much longer for that coating to make a complete cure than if it was applied at a warmer temperature. 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.
112
5108,000 – 5123,000
This is one of my last slides here. The Coatings laboratory has gone through some renovations this past couple years, and we just got a new spray booth. That's right here on the left.
113
5123,000 – 5150,000

While I was waiting the two years to get this new spray booth, we actually built a cavitation testing apparatus to evaluate coatings and materials for cavitation resistance. We're going to do a three-day class in Denver, a Coatings and Corrosion class. We're still to-be-determined on the dates.
114
5150,000 – 5216,000
The Corrosion webinars are offered twice a year, February to March or June and July. Email Jessica Torrey any ideas that you have. This is our team of people right now for Corrosion and Coatings needs. Contact any one of us, and we can direct you in the right direction.

p.