

Jessica: [0:02] OK, good morning. As I said, today we're going to be presenting a corrosion webinar on corrosion protection in penstocks. We have Dave Tordonato, who's one of our materials engineers in our materials and corrosion laboratory here in Denver TSC.

[0:19] Dave has been at Reclamation for almost nine years now. He started in the coatings group and he's been cross-training and doing some design now on the cathodic protection side as well.

[0:29] Dave has his PhD from Mines and he has a whole list of certifications, including his professional engineering license, the NACE cathodic protection level three training, coating and specter level two training, and the SSPCS certification.

[0:48] David's also a member of the rope access team and has done a lot of penstock inspections in his time at Reclamation. I'm going to turn it over to him now and he will give this presentation. Thank you, Dave.

Dave Tordonato: [1:02] Thank you, Jessica. Thank you, all, for joining us this morning. As Jessica mentioned, we'll be discussing penstocks today, and how we can best go about our corrosion protection.

[1:15] For the webinar objectives today, I'll give you a brief introduction on penstocks, what they're used for in reclamation. We're going to do a review of corrosion, the process that we see.

[1:28] We're going to talk about our condition assessments. What do we do when we go out in the field, and what are we looking for when we do our inspections?

[1:40] We'll be discussing some of the common lining materials, both ones that were used in the past when a lot of our projects were built, and also the new materials that we're starting to specify in our rehabilitation projects.

[1:55] We'll be discussing some of the strategies involved with maintenance planning, and then how that feeds into our specification development and project management.

[2:06] Finally, I'll discuss some construction support aspects of project management.

[2:14] To give you an idea here, this photograph on the right is showing the discharge tubes. This is taken at Grand Coulee Dam in the wintertime. There's 12 discharge tubes. These are partially aboveground, as you can see here. The lower half is actually encased in concrete.

[2:35] This is just one example of what we're talking about here. We call these discharge tubes, but they function as penstocks as well. Water can be pumped from Roosevelt Lake into Banks Lake or six of these units are actually functioning as generating units allowing water to travel from Banks Lake back down to Roosevelt.

[3:00] When we talk about penstocks, we're talking about the pressure vessels that are used to convey water from the reservoir down through the turbine, the spiral case and out the draft tube into the river, terrace. Penstocks, especially in reclamation, can vary pretty widely, depending on the project.

[3:23] We've seen penstocks as small as 18, 24 inches on very small units, all the way up to 40-foot diameter on something like our Grand Coulee third power plant. In addition, they can vary a lot in length, too. Our shell thickness is going to depend a lot on pressure of the reservoir.

[3:45] It's going to also depend on diameter so it's common to see pipe shell thicknesses that vary along the length of the penstock. Penstocks are actually discussed and governed by our FIST manual. That's Facilities, Instructions, Standards, and Techniques. It's covered by volume 2.8.

[4:05] The inspection of penstocks and pressure conduits and, basically, this is our guidelines for how we inspect these things. It says that we need to be doing it every five years. I'll talk more about that but first let's go back up for a second and talk about corrosions. Why is it important to inspect this equipment here?

[4:31] Most of our penstocks are steel-lined and they're also coated. Whenever you have a metal and you've got the metal in an environment such as water or barrier such as soil, you have to worry about corrosion. Corrosion is electro-chemical reaction between the metal and an electrolyte. In order for corrosion to occur, we have to have four essential components to form that corrosion cell.

[5:01] This diagram on the lower left is illustrating that. You need a cathode, you need an anode, a metallic return path, and an electrolyte. Your anode is the area of the metal that's actually corroding here, you can see. It's giving up electrons.

[5:17] When that happens, those electrons flow to the cathode, which in the case of steel can be an additional part of the steel. If there's one part of the material that's corroding another part is not corroding. Then over time, if you have general corrosion, those sites can flip flop, and the anode then becomes the cathode, cathode becomes the anode.

[5:41] In order for that to occur, you need to have an electrolyte. It's either going to be water or it's going to be soil. The electrolyte provides a pathway for the ions to travel, and that would actually complete your corrosion cell, and here your corrosion circuit.

Jessica: [6:04] Before we get into that for just one minute. Everyone who's on the phone, can you please make sure that your microphones are muted. We do hear a few people speaking in the background. Please make sure your computer microphones or your phone is muted for the duration of the presentation. Thank you.

Dave: [6:26] That's a brief introduction for corrosion. Now, there's many different types of corrosion that we see. For penstocks, I've narrowed it down to just four of the most common forms that we see here. The first is going to be the uniform or general attack. Second, we have crevice corrosion. We can also see pitting corrosion and then finally, erosion corrosion.

[6:52] Now, in general, with all of these different types, creating a barrier between the metal and the electrolyte, i.e., a coating, is usually the best way to prevent that corrosion from forming. We also want to try to avoid the use of dissimilar metals.

[7:08] Cathodic protection is something that we use a lot but in penstocks, it's less effective. The reason for that is that anytime you have flowing water, it's acting as a mechanism for depolarizing your structure. Cathodic protection polarizes the structure to prevent corrosion or slow it down to the point where the rate is undetectable.

[7:33] You're fighting that polarization when you have flowing water that's removing it, and because the flow rates are so high, it makes it really difficult to use CPE in this case.

[7:48] That first type of corrosion I mentioned is general corrosion, and you can see an example of that here. The Statue of Liberty, this was a bronze statue. It's completely covered in green, so that's got a nice little patina on it. That's general corrosion, anytime you've got something that's occurring across the broad surface of it.

[8:09] An example in reclamation, Nevada spillway that we see here is uncoated. You're going to experience general corrosion over that entire surface. General corrosion by weight is going to actually take away the most metal over time.

[8:28] One way to deal with that is to pick an alloy that's going to resist it. If you pick something that's more resistant to corrosion, you're going to slow down that corrosion rate. Again, protective coatings are a good solution here, cathodic protection, depending on your actual exposure environment.

[8:46] Then another thing that's done commonly is to specify a corrosion allowance, and that's done in the design process. If you know that something is going to corrode, you can design it to be thicker to allow that corrosion to occur before to give you a longer time before you have to actually mitigate it.

[9:06] The next type of corrosion is localized. In fact, the rest of them are localized corrosion. This is an example that occurs when you have anything like a manway, or expansion joint. If you've got any kind of a plate that's welded to the structure, but then you have skip welds that allow water to get inside that, that's going to give you a chance to form crevice corrosion.

[9:33] In penstocks, we would see this typically in the expansion joints or in piping supports. This can be a design issue. In a lot of cases, you can try to eliminate crevices. For example, this photograph in the lower right here showing skip welding.

[9:51] We try to avoid if we can in the design phase using skip welds just because it does give that opportunity for that type of corrosion to occur. Instead, we would want to see welds that are complete across this entire joint if possible.

[10:07] Another thing we can do is to try to use caulking to seal up any crevices to help prevent moisture from getting in there. Once it does, it's really difficult to protect that crevice.

[10:21] Pitting is another form of corrosion, another localized attack on the surface. By total volume or total weight of metal, pitting is a lot less than general corrosion. However, it can be far more devastating just depending on the situation you have.

[10:41] You can imagine if you get a small pit in here, you're not actually losing that much metal by weight, but you can perforate that shell pretty quickly depending on your environment. When does pitting occur? When do we have to worry about this? This is going to be largely a function of your material and also your environment.

[11:03] If you have situations with stainless steel, which we don't typically see for penstocks, but in general if you have a passive airing material like a stainless steel and that passive airing layer is interrupted, then you can experience pitting. In some cases, water chemistry can also promote pitting.

[11:22] In penstocks, what we would typically see is situations where you have what are called holidays or breaks in your coating. That's going to promote pitting in areas where you have a breach in protection.

[11:35] Pitting corrosion is something to take seriously. We need to make sure when we do any kind of inspections that we're looking out for these pittings. You're not really going to see an overall decrease in your wall thickness like you would for general corrosion, but you might see a failure before you would notice it in your wall thickness decrease.

[12:00] Erosion corrosion is the fourth one that I mentioned here. I put this one in for penstocks, because depending on the project, you may have a situation where you have turbulence. You may have a situation where you have suspended particulates in the water. We call that a slurry.

[12:17] When you do that, you're going to accelerate your corrosion process. Typically, what happens in normal corrosion is you have that iron oxide formation which actually slows down the corrosion reaction because it's acting as a barrier.

[12:36] When you have erosion corrosion, you're continuously removing any kind of rust or iron oxide formation. That's helping to continually renew that fresh surface which is just going to corrode that much faster. Erosion corrosion can serve to speed up the corrosion process and reload very high corrosion rates.

[12:57] Some additional corrosion forms that fall under this category would be like cavitation, high velocity and abrasion, which I alluded to. I've seen this in a couple of situations where you have a girth weld and penstocks, and then just downstream of that girth weld, you see corrosion or additional damage that's occurring there.

[13:18] That can actually wear right through your coating as well unless you have a coating specifically designed to withstand cavitation or erosion. With that being said, what do we need to be inspecting for in our penstocks?

[13:37] I mentioned the FIST manual earlier. That gives us some guidelines here. For five-year inspections. The FIST manual is basically calling out that we need to do an initial assessment. This is a lot of text here. I've highlighted the blue text to show what we do for corrosion. There's some additional requirements that FIST requires as well.

[13:59] What we're looking at is a general assessment. This would be a visual assessment looking at the welds, bolts rivets, expansion joints in addition to the pipe shell. Then, we would also be looking to do shelf

thickness measurements. That's done using a nondestructive evaluation technique which is usually ultrasonic thickness testing.

[14:23] If we do find anything wrong, then they would do a more detailed assessment using ultrasonic thickness or other NDE techniques. Those would be for a specific items of concern. Finally, after we take those readings, we take the visual, we would want to have assigned personnel evaluate the data obtained during that inspection.

[14:46] We have engineers here at the TSC that specialize in this. Our mechanical engineers do a lot of ultrasonic thickness testing. They do stress analysis. They determine if the penstock is still within its operating acceptance criteria.

[15:09] For coatings inspections here, this flow chart is showing our general approach to how we would look at the coatings. We would do an initial coatings condition assessment to determine the overall condition.

[15:24] From that assessment, we would say are any repairs needed in the coating. No, we would defer coating maintenance obviously to a later time. If there are repairs needed, how severe are they? Do we need to schedule a recoat? Well, if a recoat is not needed, we might be able to get by with spot repairing.

[15:45] I'll talk more about that in a few slides, but that would involve a more detailed inspection where we'll actually go through and log all the damage and then figure out the square footage and the distribution of that damage.

[16:02] If there are large sections then that need to be repaired, we would be looking at doing zone repairing versus spot repairing. Those are two different approaches for a localized repair which is in contrast to doing a full recoat of the penstock.

[16:23] When we go and do an inspection, we take safety very seriously. What is involved in a safe inspection of penstocks? First of all, we want to see certifications, things like fall protection or, more likely, rope access are going to be required.

[16:41] A lot of these penstocks are steep enough to require a two-rope system to access them. Anytime you need to have a rope to hold you in place, you need to have a two-rope system which is in contrast to just using a fall protection or a one-rope system. That's one aspect of it.

[17:00] Again, with a penstock, you're also looking at confined space, often a permanent required confined space. We will do air sampling. There's a whole bunch of other requirements that go along with doing anything in confined spaces.

[17:16] Lockout-tagout is another thing that we need to be considerate of. We also nowadays lock up tag on a lot of our facilities. It is referred to as the Hazardous Energy Control Program. Prior to doing any of these inspections, the inspector needs to be certified in all three of these categories.

[17:38] Once the certifications are obtained, we also need to have a job hazard analysis. That would include providing the appropriate PPE, things like safety shoes or felt waders. A lot of times, these penstocks have significant leakage occurring past the gates.

[17:58] In order to stay warm and dry, you're either going to have to have waterproof pants or waders involved. Felt shoes can help provide extra traction. Oftentimes, the coating can be very slippery and so that's something to be aware of as well.

[18:13] Hearing protection and other PPE may be required. We also need effective lighting and backup lighting. We use pretty bright lights. We carry head lamps.

[18:25] We like to see, at least, about 700 lumens to get really effective lighting during the inspection process. We're going to need radio communications and a person that's stationed outside of the pipe, just in case. We would need a rescue plan, just to make sure we know how to get somebody out if we need to.

[18:48] Finally, is there going to be any coating sampling for hazardous materials? If so, we may need to follow additional requirements for that. Things like a dust mask or a respirator to avoid breathing that in, and gloves.

[19:05] This slide again is showing some potential conditions you may experience during an inspection. We've got pipes that are partially filled, either with sand or water, usually we have something on the invert that can be a slippery condition there.

[19:23] We would have again spray past the head-gate. Potentially low visibility. We've seen situations in penstocks where you have mist that makes it difficult to see.

[19:34] There may be a thin layer of silt or bio-film that obstructs the actual coating and it may need to be removed prior to inspection. We've taken brushes in there, or you can clean it off with a rag or something to actually see the coating and make sure you know what you're inspecting.

[19:56] The substrate may be damaged, corroded, or deformed. I've seen that in pipes too, so be looking for any kind of dents that may be present if the pipe is above ground. The linings that we would typically see on some of these older structures include primarily coal tar enamel.

[20:18] Coal tar epoxies have been used in the past as well, vinyls in some cases. If it's a new pipe or it's been recoated, we would expect to see either an epoxy or a polyurethane liner inside there.

[20:36] If we're doing a detailed inspection, we may be doing additional things. Pipe-shell assessment would include ultrasonic thickness testing. We go in and we do thickness readings in the pipe. Typically, we take about 5-10 gauge readings per pipe segment, or maybe about every 10 feet or so. We're going to be looking for any bulging or deformations. That's all part of the pipe-shell assessment.

[21:03] For the liner itself, we want to document what material it is. Usually, it's pretty easy to tell if it's coal tar. It's a very thick material, but we would document the actual dry-film thickness. This is important if we're going to put a specification together, because the contractor needs to know how much material is going to be removed.

[21:25] We also need to do a systematic visual inspection. This would include looking for things like spalls, cracking, spot rusting of the lining. We would either rate the condition on a subjective scale such as

excellent, good, fair or poor, or we would do a rust rating in accordance with ASTM D610.

[21:49] In the past, we've used just a percent of the total area if it's a spot rust that we're seeing, or we could do an approximate area of total damage if there's discrete areas of coating missing. The important thing is, we just need to document it in some way that's systematic so that it can be repeated.

[22:12] Exterior coatings as well. We would also, if there's any kind of exposed portion of the pipe, we would want to look at that. Those exterior coatings degrade over time as well.

[22:23] Finally, we would be looking at a visual inspection of any pipe penetrations, drains, expansion joints, steffinare supports, and other appurtenances. Sometimes these can get lost. Drains are pretty important. They hold the full pressure of the penstock. You can recoat your penstock, but if you've still got drains that are pretty much corroded through, you're going to have leakage problems.

[22:49] We want to make sure we don't overlook those smaller items as well.

[22:56] This slide is showing an example inspection log, and this is more just to show rough guidelines of what we would classify the coating condition as. On the left here, we see coatings rankings that range between excellent all the way down to severe.

[23:15] A description that would accompany that, an excellent coating would be nearly perfect, or in the applied condition. The square footage...the associated amount of damage that we would expect to see for an excellent coating would be less than one square foot per thousand square feet, or, as a percentage, that would be less than .1 percent.

[23:37] You can see that it goes down from there. A bunch of small areas that are damaged, we might see one to five feet per thousand or about .1 to .5 percent of the total area.

[23:52] When you start getting down in this range here, that's when we're starting to think about a liner that's going to need to be replaced. Anywhere in the 5-10 percent range is considered poor. Anything over 10 percent is considered severe. This would definitely be a situation where we would be looking to start planning for a recoat or a reline.

[24:21] This chart shows the example that we've taken from an inspection that was done as a detailed inspection for spot repairing. You can see here that it's broken down by pipe segment. Each pipe segment is 20 feet in this case, and we've got it separated by position.

[24:42] In this case, it was done on a coal tar enamel liner. A lot of times with coal tar, what we're looking at also is cracking. We've got that separated out into a separate category.

[24:56] Cracking tends to be a more systematic degradation of the material, whereas damage spots can be individual and random. In here we've got damage on...For example, the spring line we've got three spots that are less than an inch, about half an inch.

[25:14] Overall, we would go and tally up the amount of damage here, and we would round that up to the nearest square foot for each repair spot.

That's typically how the contracts are written. We want to have a realistic estimate of what the contracts...what the pay items for the contract would be. This is how we would break it down if the job is a spot-repair or a zone-repair job.

[25:43] What linings do we typically see? I mentioned earlier that coal tar enamel is one that is commonly used. What is coal tar enamel? This material has been used in reclamation since the 1930s. It was put on...Hoover Dam, I believe, was one of the first applications of coal tar enamel. It's actually hot-applied material.

[26:04] They take it, put it in a kettle, heat it up and melt it, and then they either hand-daub it, mop it on, or if it's done in a shop, they can spin-coat it on. The method that they use to apply it will actually be obvious when you go in these pipes and look at it.

[26:22] These photographs here are examples showing that hand-daubed coal tar enamel. This is looking up at a pipe crown here. You can see the pattern that was used when the material was applied. It solidifies in place, and it still has the original pattern.

[26:38] On the bottom or...I guess this was taken near the bottom or the invert...This is a piezometer tap here, and then around that you can see evidence of the original application. These are kind of drips where the coal tar dripped down from the ceiling. That's very common.

[26:56] Sometimes it's difficult even to get a good spot to take a UT reading, depending on the size of your transducer, because the coal tar is spattered everywhere. That's common.

[27:11] This material is applied very thick too. It can be up to 120 mils or more in some cases. Something to be aware of with coal tar...Why don't we use it anymore? Because it's actually toxic. The polyaromatic hydrocarbons in there are a health hazard, but the material is very long lasting.

[27:32] It's not very good for you, but it lasts a really long time, which is kind of similar to what we see in a lot of our old coating materials, unfortunately.

[27:43] One thing about coal tar, though, is that it can dry and become brittle over time, especially if your pipe is aboveground and it's allowed to heat up, if it stays dry for an extended period of time. You can see this embrittlement occurring over time.

[27:59] That's your typical failure mode that you can be looking for. Whenever you go and do coal tar enamel inspection, we would see cracking, spalling or pinhole rusting.

[28:09] We call the cracking alligator cracking because it can resemble, actually what it looks like an alligator. This is an example here showing the alligator cracking. This is mostly orientated in the direction of the flow.

[28:23] Sometimes if it's really bad alligator cracking, we would expect to see this occurring in two directions as well. That is just one example. Eventually, if you let that progress, it's going to look like what we see here in the upper right. That's an example of a pipe that stays unwatered for an extended period of time.

[28:43] That material gets hot, gets brittle and over time, it actually disbonds from your surface there. The upper half of this pipe that sees the sun obviously has even more degradation than bottom half. This is just showing extreme case of coal tar enamel failure.

[29:04] You also might see defects that start to originate at things like rivets or joints. This is common. This is another example showing an expansion joint here where the coal tar is starting to fail. This is just a local example, localized failure point here, something that could be repaired.

[29:26] Vinyl materials, this is another common material that was used. It was very popular by the Corps of Engineers and Reclamation used it in certain situations where coal tar enamel wasn't as feasible. In places where the temperature was expected to be very cold. They knew coal tar wasn't going to last very long.

[29:48] Vinyl is another material that lasts a very long time. In contrast to coal tar however, the thickness of vinyl is typically only in the 12 mil range. You would expect this to be much thinner. It's still last a long time, but its failure mode is going to be much different.

[30:06] Instead of becoming brittle over time, vinyl's actually going to blister as eventually the electrolyte can permeate through the material and start to corrode the substrate. That's how this would fail.

[30:26] OK. Now that we know what materials we're typically looking for and what we're doing for our inspections, once we have a good idea of the condition, then we've got some different options here. These options would range in complexity. Basically, for no painting, all the way to a structural liner.

[30:48] If you've got a situation where your coating is really in good condition, you may not do anything. In contrast, if you've got a situation where equipment is so old and you're planning a decommission, you may not do anything as well.

[31:04] Or if it's pretty much on the borderline between spot repairing it or totally removing it and recoating it, you may just defer that maintenance, and then skip ahead to the option number four here.

[31:20] If you do have just a little bit of damage scattered in the pipe, spot repairing is a decent option for that. The example here is showing a valve that's been spot repaired multiple times. You can see the different colors here and this was a vinyl coating. Vinyl's a pretty easy material to spot repair.

[31:39] That can be an economical approach. If you've got a lot of damage clustered in a single area then you might consider doing a zone repair on that. If the material's over about 10 or 15 percent by area corroded, then the total removal and recoat starts to become the most economical option.

[32:01] There's some caveats associated with that. You have to look at why the material is needing to be repaired. Is it mechanically damaged in some cases, or is it more of a systematic degradation where if you repair the 10 percent, then you're going to be back doing the same repairs to a different part of the pipe in another five years?

[32:23] It's worth considering what the reason for the repairs, as well the underlying cause of the damage.

[32:30] Talk a little bit more detail about each of these options here. Deferral of maintenance mentioned if the coating is in good condition here, we can defer that maintenance. If full recoat is almost required or full recoat is required, but we want to allocate the funds to do other things, such as fixing leaks, shown here.

[32:54] In order to do any kind of coatings maintenance, you're going to want to fix anything pre-existing conditions. Things like joint-leaks, or seepage prior to doing any kind of coatings maintenance on the pipe.

[33:08] Spot repairs. One key aspect of doing spot repairs is documentation of the area. You want to make sure that we're covering the entire area that needs to be repaired and documenting the square footage and so forth.

[33:24] Another thing I wanted to mention here on this slide, you've got two people that are laying out the area and measuring it. They're doing a zone repair here because they've got three areas that are clustered in a small area.

[33:36] But if each one of these spots was taken on its own, you would probably want to measure a healthy boundary around that, a perimeter. What we would call a margin to make sure that we're getting all of the compromised coal tar out of there. We want to make sure we get to good material before we do our spot repair.

[33:59] We typically take an inch or two around that as well. When you do a spot repairs on coal tar enamel, there's a little bit of a trick to that.

[34:11] Because of the nature of the material, coal tar enamel by itself is a pretty weak material. It's only adhering to the surface by about 300psi. If you put anything on there that has a solvent has a tendency to weaken that coal tar and soften it even more, and that increases the likelihood of a premature failure of your spot repair.

[34:36] Allen Skaja, one of our coating's experts in the group did some research on this a few years ago. He found that using 100 percent solids epoxy to repair the coal tar is actually the best option there contrary to what he had actually been told previously. What we would do is 100 percent solids epoxy material, we would want to go ahead and do some surface preparation to the substrate.

[35:02] This is the material that needs to be repaired here, we would take that, overlap the repair material onto the coal tar. Prior to doing that, we want to make sure we have a clean metal surface to apply that repair material to.

[35:18] This is usually done with an abrasive blast. SSPC, the Society for Protective Coatings has some standards for that. SP5 is the white metal blast. That's the highest standard of cleanliness for your metal surface.

[35:34] If you can't do an abrasive blast, then SP11 is the power tool cleaning. The essential thing here is that we want to see a clean metal substrate prior to coating with a good solid anchor profile, something for the coating to actually adhere to.

[35:51] Then, in the case of a spot repair, what we would want to see is that we have a nice beveled edge for your coal tar, and then a slightly rough and/or braided surface for your repair material to adhere to as well. You have to be careful here with this because coal tar is a soft, and can be a brittle material.

[36:12] In some cases if you're getting too aggressive with your surface preparation, you can start to unravel this coal tar. We wanted to see, kind of, a sweet blast, or a light abrasion of that, to give the repair materials something to adhere to.

[36:28] Finally, you would want to see a double edge for your repair material. Something to give the water a smooth surface to flow over.

[36:37] There's a little bit of an art to performing these spot repairs. As you can see, that's why we say if there's anything more than about 10 or 15 percent, it gets expensive really quickly when they have to start doing this kind of preparation for every spot you can imagine.

[36:57] Total removal and recoat, throwing that number out again, is the same 15 percent. It's a rule of thumb. It's going to depend a lot on, as I said before, what the overall cause of the degradation is. Again, coal tar enamel is going to be a thick material. It's not easy to get off by itself.

[37:19] What's typically done is a high-pressure water jetting to remove it and that's due to the thickness. After we do that removal process, then we would go back through and do an abrasive blast to prepare the metal to receive the new liner. The advantage of doing this is that it restarts your maintenance cycle from day one.

[37:42] The maintenance cycle. An ideal maintenance cycle, let's talk about that for a little bit. There's was a paper in NACE, this was done in 2008, that's pretty conservative here. This is showing a 22-year maintenance cycle.

[37:56] Now, you're probably aware that a lot of our structures are much older than that and haven't had any maintenance done, or at least not a full recoat to this point.

[38:05] The newer materials are not going to last quite as long as our legacy materials, which are coal tar and vinyl. However, there are things that we can do to try to extend their service life.

[38:17] Picking a good product is first and foremost the number one thing. Making sure that we get a good project is another. I'll talk more about that.

[38:27] Our surface preparation is the key in maximizing our overall life span. For a maintenance cycle, what we would typically see, or what we would expect to do, would be an initial painting followed by spot repairs. Depending on the service condition, they may occur as soon as 8 or 12 years afterwards.

[38:48] If it's something on the exterior of the pipe and it's not an immersion, we can get away with doing an overcoat on it. We do not recommend the overcoat option if the product is in immersion. That's due to the concerns with the adhesion.

[39:06] Finally, once that coating degrades to the point where additional repairs are no longer practical, we would have to start over again with another reline.

[39:18] Once we know what we want to do in terms of spot repairs, zone repairs, or relines, the typical progression of the project would be defining the scope. In order to do that, we need to know, are there other pieces of equipment that would make sense to coat during the penstock relining? Things like scroll cases or draft tubes might also be considered to be included in the project.

[39:44] We may also want to address those filling lines or drain lines.

[39:50] What items need to be protected or treated separately? Piezometer taps. We want to make sure the contractor's aware of any instrumentation that's present in the pipe. We want to make sure that that gets protected and not coated. Those are things to be aware of.

[40:06] Writing a coating specification. We have guide specs available. The TSC is also available to write specifications, but we provide guide specs for regional use as well. We can be contracted. We can also serve as providing a peer-review service for specifications that are being written. There is a number of different ways to approach the actual specification process.

[40:31] Then construction support. We want to make sure we have good quality assurance for any of these projects. NACE has a really good program. It's called the certified inspection program, or coatings inspection program -- I apologize -- and there's three different levels of that.

[40:48] We would want to see somebody who has a NACE certification to be on site, making sure that everything is done in accordance with our specifications.

[41:00] System considerations for the project and specifications. We would want to look at outages and timeframe for accomplishing the work. How quickly does it need to be done? We want to look at if there's any ribbons or any other things in place that may interfere with the coating process or may require stripe coating.

[41:22] Stripe coating is something that we would do any time we have edges because those edges tend to be places where the coating is the thinnest due to surface tension. Applying a stripe coat can help prevent premature failures at any kind of edges or corners.

[41:40] We need to identify any couplings, contraction joints, and things like that as well. While we're at it, do those expansion joints need work? Are they leaking? Do they need to be repacked? That might also be something to consider, including in the specification.

[41:56] As far as logistics goes, looking at areas to stage all the equipment in, that's going to be important for the contractor to know, so we want to include that information.

[42:06] Manhole spacing. Contractor, depending on what product they're applying, has restrictions on how far they can go between manholes. It's going to be important to note to the contractor how far apart these manholes are. If they're more than 500 feet, they may need to take a different approach to what they're planning to do.

[42:29] Isolation and dewatering requirements. This can be an issue too because a lot of times those head gates do leak. We want to make sure the contractor is aware that they may need to come in and provide some additional protection against leakage.

[42:47] We have the gate down, but they may also need to build a cofferdam and pump that water out so that we have the surface staying dry throughout the project.

[42:57] Temporary utilities. Things like air, power, and water, are those available for the contractor? Do they need to provide their own?

[43:04] Surface preparation. What methods does contractor need to do? High-pressure water jetting is necessary for coal tar enamel, in addition to abrasive blasting.

[43:17] Soluble salt testing. That's something that we would also consider. New coatings require a very clean surface, and there can be non-visible contaminants on that surface, things like chlorides and sulfates.

[43:30] If those are present, that actually acts to promote osmotic blistering, which is something that can prematurely cause the coating to fail. We would want to, at the bare minimum, at least test in several spots to make sure that our metal is free of any of those contaminants.

[43:48] If it comes out positive, they may need to wash that pipe. If they're doing high-pressure water jetting already, that's probably a pretty good indication that they're going to at least remove most of that soluble salt.

[44:03] Substrate condition. If the coating's then in a degradative state for a very long time, you may actually have some pitting in there that needs to be filled or welded, in some cases. We want to make sure the contractor is aware of any additional remediation of the substrate that may need to be done prior to coating.

[44:28] I have here cathodic protection. Is it feasible? We talked about this at the beginning of the presentation. There's certain situations where you may want to consider cathodic protection. In general, if you've really high flow rates, it's probably going to be not very economical to operate it.

[44:45] If the pipe stays full of water in a stagnant condition for an extended period of time, then cathodic protection can provide some protection during that process. If it's flowing constantly, it's probably not going to help too much.

[45:02] Other items to include in the specification would be hazardous materials test results. It's important to know the concentration of hazardous materials. The contractor needs to have that in order for them to prepare a good bid for the project.

[45:20] Ideally, we should have sampling results for whatever they're doing coatings work. We would want to make sure that we test that for anything like heavy metals, PCBs, possibly asbestos, and then coal tar itself, so polyaromatic hydrocarbons.

[45:41] Those are the main things that we would want to see in the hazardous materials test section. We have folks here at the TSC that specialize in writing those specifications as well.

[45:54] Other things that are nice to include are relevant photographs that show the project and existing conditions, anything the contractor might need to be aware of and then drawing the show access. What's the access like for the project?

[46:10] One other thing I'd like to mention here is robotic application. This is a newer technology that's coming online now that allows for a more automated process for both surface preparation and coatings application.

[46:27] We've got a couple projects that we've seen this done on and the production rates are very good so that can result in a good product for a lower cost. We're really encouraged by this potential development in future projects, as well. I wanted to put that out there and make you guys aware of that.

[46:53] As far as replacement, the actual materials that we would replace with, typically what we're looking at right now is 100 percent solids epoxies. These typically are getting applied at 50-plus mils in thickness.

[47:07] Our Materials Lab has been evaluating a variety of different coatings to try and figure out which ones are going to last the longest. That's our main goal, is minimizing our overall lifecycle cost here.

[47:21] What we do here in the lab is inversion testing. We do prohesion testing, which is a cyclic test that alternates between accelerated weathering, UV-cabinet, and assault spray. That's a really good, aggressive test. We look at its rust creep. How much rust is creeping up under that coating when you start with just a scribe there, part of the coating that's damaged?

[47:49] We also look at things like impact-resistance, abrasion resistance, erosion resistance, cathodic disbondment, wet adhesion, and dry adhesion. We've started doing wet adhesion more now because we realized that the coating actual does lose some adhesion after it's been immersed for a period of time so we're looking at both initial and wet adhesion.

[48:16] The last thing I want to touch on here is the construction support. We've got the contractor, who would typically have his own inspector, preferably a third-party inspector. They're going to do all the testing and reporting that we require in our specifications, things like dry film thickness testing, surface cleanliness, testing of the profile.

[48:42] In addition to that, what's nice to have also is a government inspector, somebody who represents the owner or the government in this case. That's typically a Reclamation employee. What that person would also be responsible for is observing all of those tests.

[49:01] They may conduct some tests on their own just to verify it but the goal here is to make sure that we're getting a good product because we do put a lot of money into recoatings. If you don't have a good surface prep, then you can have a premature failure. It's a very small cost to add an inspector to the project but it can greatly increase the

likelihood that you're going to end up with a satisfactory product in the end.

[49:32] The roles for the inspector, basically observing, then they're testing and verifying the contractors results to verify specification conformance. That's to ensure that you did a high quality job.

[49:50] That is pretty much the end of the presentation. I got the last slide here showing our coatings and corrosion team. I got good group of people and any one of them would be able to assist with coatings and corrosion questions, if you have any. We can take some questions now, I think we've got a few minutes.

Jessica: [50:09] Yeah, thank you, Dave...