RECLAMATION

Managing Water in the West

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This *Water Operation and Maintenance Bulletin* is published twice annually for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Bureau of Reclamation personnel and water user groups in operating and maintaining project facilities.

The *Water Operation and Maintenance Bulletin* and subject index may be accessed on the Internet at: **www.usbr.gov/assetmanagement**.

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For further information about the
Water Operation and Maintenance Bulletin, contact:

Ben Claggett, Managing Editor
Bureau of Reclamation
Technical Service Center (86-68260)
PO Box 25007, Denver, CO 80225-0007
Email: bclaggett@usbr.gov

***Cover photograph*:** Reclamation transferred works. Radial gate structure with intermittent immersion exposure.

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AQUALASTIC COSTS FOR CRACK REPAIR IN CONCRETE CANALS

by: Jay Swihart[1] and Allen Skaja[2]

Aqualastic is a polyuria coating that is spray applied to seal cracks in concrete canals. This article addresses the costs for Aqualastic repairs. Since 1998, the Yakima Field Office has used their own in-house crew and equipment to apply Aqualastic to numerous canals in the Pacific Northwest. Previous articles [1] in the O&M Bulletin have described the application process.

Applying Aqualastic to the entire canal prism would be cost prohibitive; therefore, the coating is only applied to cracks and joints that are severely leaking. The cracks can expand and contract without tearing the high elongation Aqualastic. Surface preparation consists of abrasive blasting approximately 6 inches on both sides of the crack. The coating is applied using high-pressure plural-component spray equipment to a total width of 6–8 inches, bridging the crack. Aqualastic is applied to an average thickness of 60 mils (1.5 millimeters). One "set" of product consists of a 55-gallon tote (drum) of Component "A" and a 55-gallon tote of Component "B." Using a Bureau of Reclamation crew, the average cost is $3.33 per linear foot or $5.13 per square foot. One gallon of Aqualastic will cover approximately 40 linear feet of crack. A five-man crew can typically repair 13,200 linear feet of crack in a 2-week period. Total costs are estimated at $44,000 for materials and labor during the 2-week period. These costs do not include any costs for the high-pressure plural-component spray equipment. If contracted out, the cost would be significantly higher (perhaps double).

Table 1.—Typical Aqualastic repair costs

Typical Aqualastic repair costs	~13,200 linear feet of crack
Total project cost	$44,000
Total cost per square foot	$5.13/square foot
Total cost per linear foot (8-inch wide)	$3.33/linear foot of crack
Materials (Aqualastic) cost	$16,500
Materials (Aqualastic) price per gallon	$50/gallon
Materials (Aqualastic) price per square foot	$2/square foot
Total square feet applied	8,800 square foot
Abrasive, supplies, fuel, etc.	$3,500
Abrasive, supplies, fuel, etc., per square foot	$0.40/square foot
Labor plus overhead	$24,000
Labor costs per square foot	$2.73/square foot

[1] Materials Engineer, Bureau of Reclamation, Materials Engineering and Research Laboratory, PO Box 25007, Denver, CO 80225, jswihart@usbr.gov, 303-445-2397.

[2] Chemist, Bureau of Reclamation, Materials Engineering and Research Laboratory, PO Box 25007, Denver, CO 80225, askaja@usbr.gov, 303-445-2396.

Figure 1.—Abrasive blasting is the preferred surface preparation method. Approximately 6 inches on both sides of the crack are sandblasted.

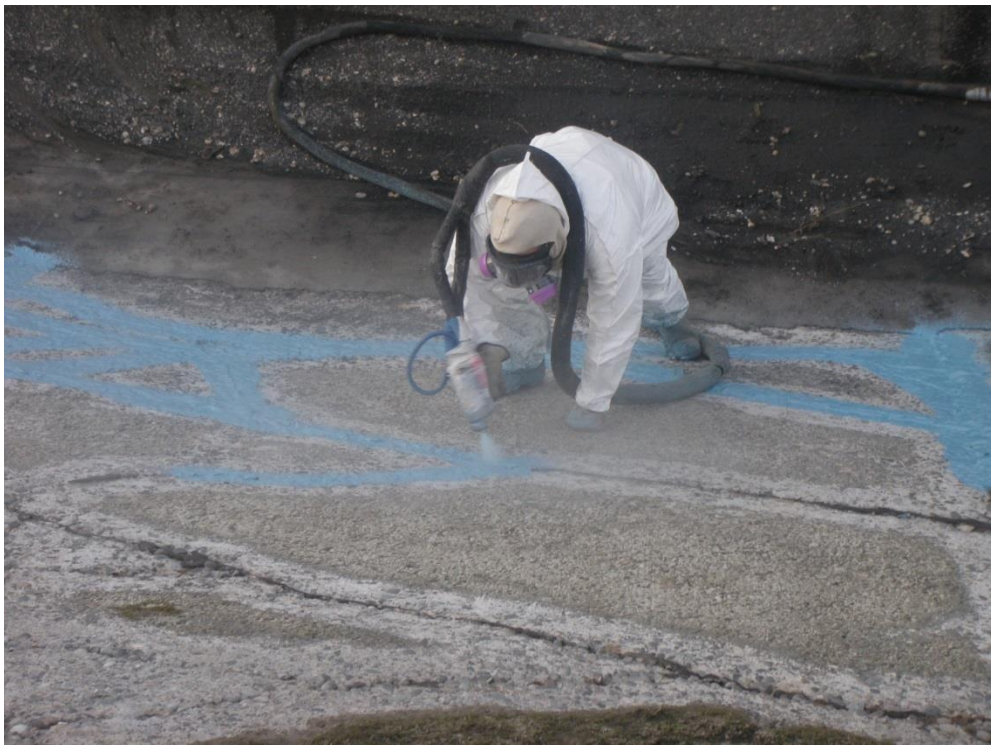

Figure 2.—Aqualastic is spray applied approximately 6–8 inches wide, leaving some abrasive-blasted surface exposed on each side.

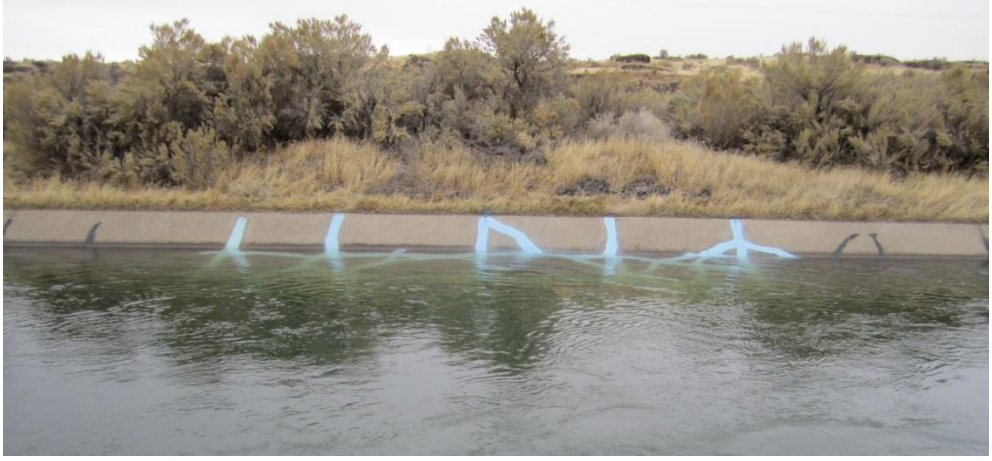

Figure 3.—Typical canal repair using Aqualastic can significantly reduce water loss and seepage.

References:

[1] Bureau of Reclamation. 2012. "Sealing Concrete Canal Lining Using Aqualastic Material." Pages 13–15 *in* Water Operation and Maintenance Bulletin No. 228.

Contact Information:

Aaron Galayde, Bureau of Reclamation, Yakima Office
agalayde@usbr.gov; 509-575-5848 x245

Jay Swihart, Bureau of Reclamation, Technical Service Center
jswihart@usbr.gov; 303-445-2397

Allen Skaja, Bureau of Reclamation, Technical Service Center
askaja@usbr.gov; 303-445-2396

COATING MAINTENANCE PLANNING TO ENSURE RELIABLE WATER AND POWER DELIVERY

by: Bobbi Jo E. Merten[1], Rick Pepin[1], David S. Tordonato[1], and Allen D. Skaja[1]

Introduction

The Bureau of Reclamation (Reclamation) is responsible for delivering raw water and power to the Western 17 States. Reclamation infrastructure provides irrigation water to 25 percent of the Nation's fruit crop and 60 percent of the Nation's vegetables. This water also reaches 31 million people for municipal, residential, and industrial uses. In addition, Reclamation contributes to 17 percent of the Nation's hydropower through 53 owned and operated hydroelectric powerplants, including Grand Coulee, Washington (figure 1); Hoover, Nevada; and Buffalo Bill, Wyoming. It is vital to ensure this water and power delivery is continued and reliable.

The successful operation of Reclamation's very large and complex infrastructure requires careful coating maintenance planning. Reclamation's assets include small to extremely large facilities (figure 1) and hard to access areas, such as confined spaces, remote locations, and rough and steep terrain (figure 2), and they receive exposure conditions of atmospheric, immersion, or intermittent immersion (figure 3). Each scenario affects the maintenance plan, and often creative solutions are required to arrive at a cost-effective approach.

Within this article, we describe the strategies undertaken by Reclamation's facility personnel and coating specialists to inspect, repair, and replace coated infrastructure. The focus is restricted to hydropower facilities but translates well to other infrastructure. We conclude with an outline of basic details to consider when developing one's own coatings maintenance strategy.

Maintenance Planning

Maintenance planning for hydropower facilities and water transmission equipment originates from an understanding of the basic components and routines of these facilities. The coated metalwork begins at the intake gates or trash racks, generally within a reservoir behind a large dam. The water is carried from this reservoir to the powerplant via one or more penstock pipelines. The length of these pipes ranges from a few hundred feet to a few thousand feet. (In other cases, water can be carried through the dam via outlet works pipelines.) Figures 1

[1] U.S. Department of the Interior, Bureau of Reclamation, Denver, CO 80225.

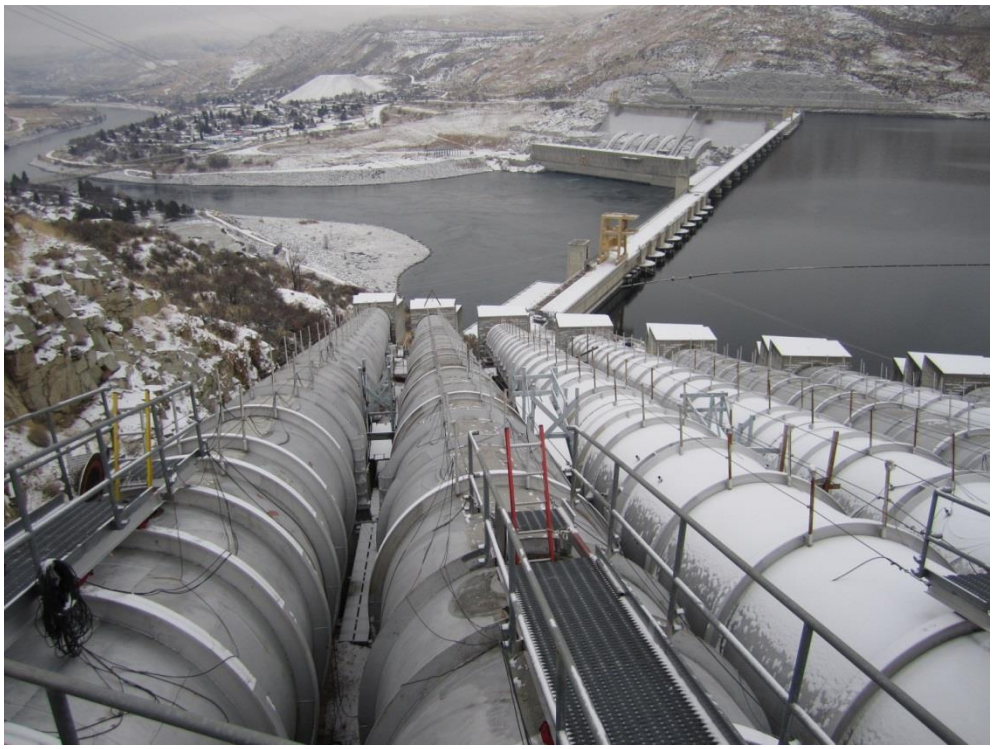

Figure 1.—Grand Coulee Dam, Washington, and John W. Keys III Pump-Generating Plant aboveground penstock/discharge tubes.

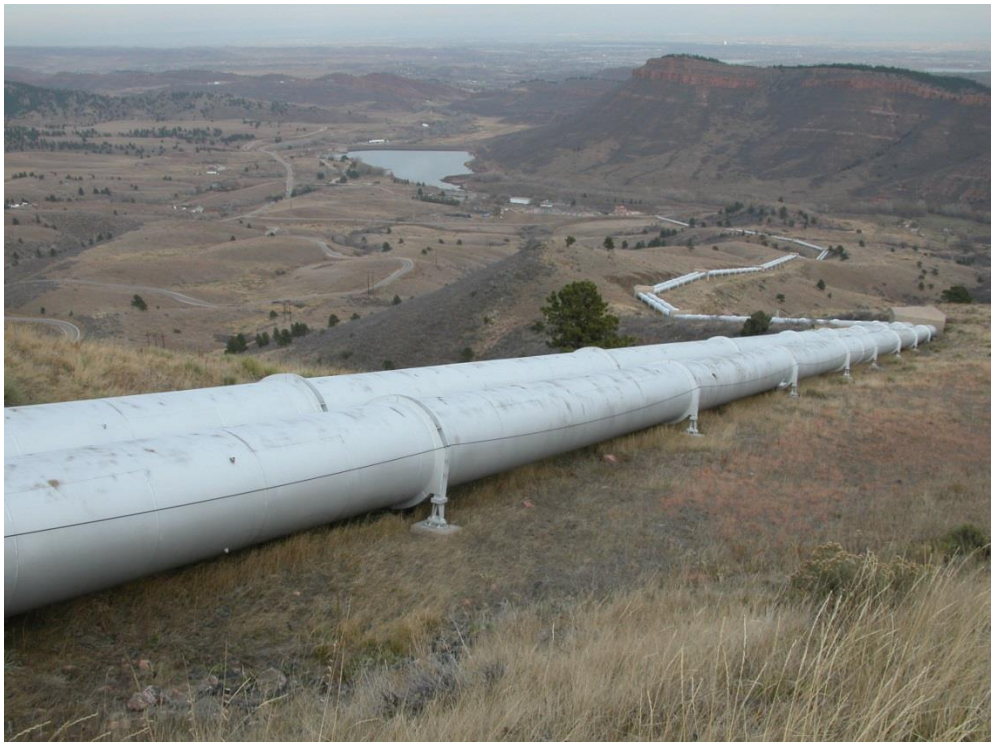

Figure 2.—Flatiron Penstocks, Loveland, Colorado, approximately 6,000 feet long and 1,000 foot drop in elevation.

Figure 3.—Reclamation transferred works. Radial gate structure with intermittent immersion exposure.

and 2 provide photos of short and long aboveground pipe, respectively. Figure 4 is an inspection photo of the interior sidewall for an 8.5-foot-diameter below ground pipe. The penstock water flows into the scroll case (figure 5), which directs the water through the power-generating turbine runner. It then flows into a draft tube (figure 6) beneath the turbine unit where it is discharged to the river downstream from the dam.

So much of Reclamation's water is delivered for agricultural irrigation practices that maintenance schedules coincide with this cycle, leading to maintenance outages that occur during the winter months. However, a lower volume of water delivery may still be required to meet regulatory obligations, which typically results in construction operations being limited to repairs on one unit at a time—or several in the case of facilities with many units.

Coating Inspections

Maintenance decisions often rely heavily on observations made during coatings inspections. Reclamation facility personnel perform periodic inspections of the infrastructure. For the waterway and other limited-access areas, this detailed inspection is often restricted to the facility's annually scheduled outage. The goal of the inspection is to assess the general condition of the coatings by visual techniques. If corrosion, cracking, or blistering is detected, photographs and written comments are used to document the location and extent of the damage.

Figure 4.—Interior surface of an 8.5-foot-diameter penstock, coated with coal tar enamel, showing severe cracking.

Figure 5.—Scroll case, stay vanes, and wicket gates with previous spot repairs.

Figure 6.—Turbine runner and draft tube with coating and cavitation damage.

Figures 4–6 provided examples of coating systems demonstrating the need of maintenance. In order, they show an embrittled coal tar enamel coating at the end of its useful service life, a spot-repaired coating system with visible corrosion of the leading edge of stay vanes, and a delaminated epoxy (turbine runner blade tips) adjacent to coal tar enamel overcoated with degraded paint (below turbine runner)—both experiencing cavitation damage. These examples also give insight to the complexity of existing systems and coating conditions at Reclamation facilities.

Reclamation's Technical Service Center (TSC) provides coating specialists to field locations at the request or need of its facility managers. The inspection team should include facility staff in addition to the TSC coating specialist in order to combine the knowledge and experience of each party. The joint effort results in the most comprehensive analysis. A balanced inspection determines the following:

- Infrastructure history and specifications—previous repair records, problem areas, and construction challenges or limitations

- Condition evaluations—visual defects, film and ultrasonic thickness testing, and hazardous materials testing

- Engineering options and recommendations—spot repair, overcoat, and recoat

The results and recommendations of any TSC inspection are provided to the facility owner in an official report. A good inspection report incorporates the facility owner's perspective into this process in order to ensure the recommendations are feasible. For example, spot repairs may be recommended for severely corroding areas when it is known that funding cannot be secured to perform total coating replacement in the near future.

Maintenance Options

The purpose of most coating inspections is to assess the condition of existing coatings and to make maintenance recommendations. Many factors affect the service life of a coating system, which include the type of coating, type and quality of surface preparation, service environment, number of coats and film thickness, and previous maintenance activities.

Prior to the 1970s, lead, coal tar, polychlorinated biphenyls (PCBs), and asbestos were used extensively in industrial coatings. Instances of these coatings remain common throughout Reclamation's inventory (e.g., Hoover Dam penstocks have retained their original coal tar enamel coatings for nearly 80 years). It is customary to include hazardous materials testing during any inspection, especially when maintenance actions are likely to follow. A certified laboratory performs this testing, and the results are used to ensure that containment and disposal are carried out according to applicable hazardous materials regulations. Oftentimes, the confirmation of hazardous materials in the existing coating impacts the decisionmaking process for coating maintenance.

Coating maintenance recommendations can be divided into four main categories: (1) deferral of maintenance, (2) spot repair, (3) spot repair with full overcoat, and (4) complete coating removal and replacement. Each of these options is progressively more complex and requires increasingly more work, all at additional costs. Correspondingly, each option also offers greater long-term protection to the structure.

Deferral of Maintenance

Coating maintenance is deferred for an existing coating system in good condition, a structure with limited service life, or when there is some other benefit to postponing the work. It becomes costly to defer coating maintenance where extensive corrosion is present because the level of surface preparation required increases correspondingly. Eventually, total removal will be the only remaining option.

A structure corroding extensively, but structurally sound, may have deferred maintenance because the highest level of surface preparation (abrasive blast

cleaning) is already needed, whether performed today or several years from now. The strategy in this case becomes to allocate the money to repair coatings on other structures that are not so badly deteriorated in order to prevent the coating degradation from reaching the point that total removal is the only option for those structures as well.

Spot Repairs

Spot repairs, as the name suggests, limit surface preparation and coating application only to the individual locations of corrosion or coating breakdown. The goal is to repair the existing coating film only where it is needed, stopping the propagation of corrosion and coating breakdown. Coatings in any condition may be spot repaired, but it is only practical when the coating damage is minor and somewhat isolated and covers a small percentage of the total surface area. Surface preparation should proceed 1–2 inches beyond the perimeter of the intact coating to give a feathered edge.

A disadvantage to this approach is aesthetics. Oftentimes, the repairs are clearly visible. A variation of this type of localized repair includes zone or area repairs. Here, surface preparation and coating application is performed over a larger area that exhibits more concentrated levels of damage. For example, severe cracking is observed on 40 linear feet of penstock interior coating while the remaining 400 linear feet is in excellent condition.

The total spot repair area is estimated during the inspection. Photographs of representative coating conditions can be further analyzed during report preparation, and the total coated area (intact and degraded) is calculated using Reclamation's construction drawings. The rule of thumb is to use spot repair when the area is 15 percent or less than the total surface area. As a caution, the spot repair area could be significantly underestimated for surfaces covered in mud or dirt, in the absence of adequate lighting, or when inspected from a distance; this may result in expensive contract modifications during construction. This rule of thumb is somewhat flexible however, and therefore, conditions such as hazardous materials, restricted location, and projects with difficult accesses, cause even higher percentages (greater than 15 percent) to be economically feasible.

Spot repairs make sense when the coating damage is isolated to specific locations such as areas that have received mechanical damage. A zone repair that involves coating rehabilitation of larger, well-defined portions of a structure such as a pipe invert or the waterline of a gate, which may receive more damage than other areas, can significantly extend the life of a coatings system that is otherwise in good condition. In these situations, the coating is considered to be in serviceable condition.

The cause of coating degradation should be a primary consideration. Degradation that is either widespread and/or randomly distributed should be approached with caution when considering spot repairs as an option even when the damage represents a small fraction of the total area. If the coating is nearing the end of its useful service life, the damage is likely to progress in areas that are not targeted for repairs, and spot repairs may just be a short-term solution. This may still be a practical approach when it is necessary to temporarily preserve the structure until more comprehensive maintenance can be performed.

Spot Repair with Full Overcoat(s)

The application of a full overcoat serves two primary purposes: (1) the fresh coat provides additional barrier protection and (2) it helps to seal minor defects that are not apparent when conducting inspections or spot repairs. It also offers an improved appearance compared to spot repairs but also adds complexity and cost to the overall project. The complexity increases because a contractor must now gain access to all areas of the structure to apply the full coat. The existing surface must also be thoroughly cleaned (i.e., power washed) to remove chalk and surface debris.

This strategy is also used when the amount of visible corrosion and coating deterioration covers less than 15 percent of the surface but has the same cautions and flexibility described in the "Spot Repairs" section. The adhesion of the existing coating to the substrate must be intact; otherwise, the stresses imparted by the overcoat can cause disbonding of the existing system, especially under freeze-thaw conditions. The compatibility of overcoats is examined using one or more test patch areas prior to construction. In some cases, two full overcoats are applied, keeping in mind that the total number of overcoats may be limited due to additional weight and stress. Unfortunately, overcoats are not typically considered as an option for immersion service.

Total Removal and Replacement

Total removal and replacement is the most comprehensive option for coatings maintenance. It is the most costly option (especially when removing existing coatings containing hazardous materials), but it offers the greatest opportunity for long-term protection. All mill scale, rust, and paint are completely removed, and a new system with a new design life is applied. Coatings containing hazardous materials are removed at the same time, alleviating future concerns and responsibilities. This method also provides the most pleasing appearance.

The Ideal Maintenance Cycle

When total removal and replacement is performed, a new maintenance cycle begins. As the coatings age and weather, isolated spot repairs will be required. Several rounds of spot repairs may be made to the individual structure until the first full overcoat is necessary. More spot repairs and additional overcoats may again follow until extensive corrosion develops, significant coating breakdown occurs, or the mechanical properties of the coatings (e.g., the adhesion) degrade to the point where additional work (spot touch-up or overcoating) is no longer practical. At this time, complete removal and replacement may again be required, but only after the maximum effective life of the original coating system has been extended through the planned maintenance activities.

The Progression of Coatings Maintenance Projects

A coatings maintenance project can range from a small area of spot repairs that is easy to access to total removal and replacement with all the worst-case scenarios: complex infrastructure, hazardous materials, confined space, remote location, etc. The following sections are dedicated to the process of performing contracted coatings maintenance.

Scope Definition

TSC coating specialists work with infrastructure managers to define the project scope, which often requires several refinements to incorporate items that are not straightforward. Recommendations within inspection reports typically serve as a starting point for this task. The goal is to provide a scope that is as clear and comprehensive as possible before beginning the project specification work.

Coating Specifications

Coatings specifications will serve as the official and legal directive for the contractor during construction. A complex coatings project may involve several engineering disciplines to write specification sections, especially when structural and or related work is to be included. Cavitation weld repairs must occur prior to recoating when needed. Another example is to include the repair or replacement of mechanical components such as valves. The specifications package may require several reviews as well as value engineering or similar studies prior to finalization.

Construction Support

Once the specification has gone out for bid and a contract is awarded, the TSC coating specialists assist with compliance of the contractor's contractual obligations, which includes the review and response to contractor submittals for coating products, applicator qualifications, etc. The infrastructure managers have a representative onsite during construction to fulfill inspection and oversight roles. It is important that all parties know and understand their responsibilities prior to work commencing and that the procedures for addressing any complications that arise are mutually agreed upon.

Typical Coatings Maintenance Challenges for Reclamation

As with any sector of use, coatings maintenance at Reclamation facilities has overarching challenges that must be handled as best as possible. Below are some of the most prominent considerations:

- Coatings maintenance typically occurs in the winter to accommodate water delivery schedules. Coatings products appropriate for anticipated weather conditions must be selected.

- Coatings maintenance within dam structures often occurs in high humidity, and amine blush is a potential concern with epoxy coatings.

- Quick curing and underwater cure coatings are growing in demand as water delivery schedules become less flexible. For instance, Reclamation has canals that are not dewatered, and coating materials are desired for underwater crack repairs. In addition, critical infrastructure such as the Folsom North Fork Pipeline recently received work in which the maximum inoperable time for some valves was 24 hours. These situations greatly impact surface preparation techniques.

- Some of Reclamation's waterways have firm requirements for coating toxicities and volatile organic compound compliance. A coating for potable water is one common request. Fish hatcheries are another example of a sensitive system—here, zinc-containing coatings must be avoided.

Developing a Coatings Maintenance Strategy

Organizations have mutual challenges when it comes to coatings maintenance plans. For instance, it is tempting to overlook architectural coatings, especially since the reliability of other systems—hydroelectric power and water delivery in

this case—are public priorities. Similarly, the old coating systems (coal tar enamel, lead, and vinyl) offered substantial service lifetimes compared to the modern coatings replacing them. The new maintenance cycles may occur at much shorter timescales for Reclamation facilities, and this makes it all the more important to develop and institute a maintenance program.

Prior to an initial coatings inspection, it is important to review records regarding the coatings system type, age, and previous maintenance. In some cases, maintenance records are not available or non-existent. Utilize as many resources as reasonable, and keep in mind that some of the most valuable information may come from personnel experienced with that infrastructure, although increasing staff turnover poses a challenge. It is essential to carefully document key details in the inspection records for future use by an organization.

Provided here are several key questions that will assist in developing a good maintenance strategy:

- What is the funding source for coatings maintenance, and what are the budgeting capabilities for regular coatings inspections, repair work, and replacement? The answer to this question forms the basic structure of an organization's maintenance strategy. When possible, small and regular contributions to coatings inspections and spot repairs can effectively delay a complete replacement for years to decades.

- What type of infrastructure requires protection? Is there a single substrate type such as steel, aluminum, concrete, wood, or other? Most facilities are complex and are likely to have several types of surfaces that are coated.

- What exposure(s) does the coated infrastructure receive? Common exposures are atmospheric (with or without ultraviolet rays), immersion, or buried as well as intermittent immersion and chemical.

- Are there special construction needs to consider? How accessible is the coating infrastructure, and can it be recoated without interrupting operations? Does the present coating contain hazardous materials? Projects requiring compliance for hazardous materials, confined spaces, or dedication to outage windows can result in overall construction costs for a replacement coatings project that are overwhelming compared to the cost of the coating material itself.

Summary

Reclamation owns and operates a large and complex network of water infrastructure, including dams, hydroelectric powerplants, canals, pipelines, and ancillary equipment. Like many organizations, Reclamation faces challenges associated with maintenance and upkeep of aging infrastructure, much of which was designed and built in the early- to mid-20th century. Budget constraints, environmental restrictions, escalating maintenance costs, and operational demands are all challenges that are typical of what many facility owners face today. In the past, coatings were able to provide a relatively long service life with minimal upkeep. Modern coatings are not expected to have the same lifespan. Life extension of aging equipment is achieved by determining the most cost-effective course of action, which may include spot repairs, overcoating, or a complete recoat. The decision will depend on the needs to the facility manager, the funds available, and other factors such as the presence of hazardous materials, accessibility, etc. A proactive approach, including planning and budgeting for future coatings maintenance activities and inspections, is crucial to a successful coatings maintenance program.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

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Regional Bureau of Reclamation contacts are listed below:

Scott Boelman, Great Plains Region

Salvador Martinez, Mid-Pacific Region

James Dean, Pacific Northwest Region

Nathaniel Gee, Lower Colorado Region

Rick Scott, Upper Colorado Region