While it remains axiomatic that good surface preparation is critical to the success of a coating application, for overcoating applications it is equally crucial to select overcoating systems with utmost care, paying particular attention to their chemistry, physical properties, performance history, and intended service environment.

This article describes key technical attributes of an innovative high ratio calcium sulfonate alkyd (HRCSA) overcoat system, and how these attributes allowed for the successful overcoating of a lead-based alkyd paint system on a penstock exterior at a Canadian hydroelectric facility, using only 5,000 psi pressure washing for surface preparation.

The case history provided outlines how the coating system also lent itself well in helping to solve different crevice corrosion issues.

Background on Overcoating

Defined by some as “spot cleaning and priming degraded areas, cleaning intact paint, and applying a lead-free system over the existing system,” overcoating has many benefits.1 This is especially true when the coating systems have been chosen judiciously and applied properly with full time inspection.

Cost reductions associated with less surface preparation and containment requirements, together with less hazardous waste disposal, are primary driving forces behind

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This article is based on a paper given at PACE 2009, held February 15–18 in New Orleans, LA. The paper was the winner of the 2009 SSPC Presidential Lecture Award.
The overcoating of structures previously protected by lead-based paint. In some cases, full-scale refurbishment of existing lead-based paint is undertaken, whereas in other cases, only the most deteriorated areas on a structure are treated. This latter practice is known as zone painting.

To date, overcoating is most commonly associated with bridge painting projects, and numerous examples of such have validated the overcoating approach as a viable option to full-scale abrasive blasting and full containment. However, to ensure success and avoid premature coating failures on less than ideally prepared substrates, the following key requirements must be met.

First, careful scrutiny of candidate overcoating systems is of the utmost importance. Failure to pay sufficient attention to critical coating properties germane to overcoating will make the success of overcoating unpredictable. Coating applications carried out in cold climates can make the odds of success even worse. Second, the structure to be coated and the existing coating system must be rigorously inspected to ensure the suitability of overcoating. Third, definitive specifications must be written. Fourth, when the refurbishment coating application is carried out, proper inspection of the coating work cannot be overemphasized.

**Desired Attributes of Overcoating Systems**

So what does the received wisdom say are the highest performing overcoat systems? Epoxies? Moisture-cured urethanes? Acrylic latexes? Interestingly, some twenty-five years ago, to ascertain what coating professionals considered the most desirable attributes of prospective overcoat systems (for overcoating lead-based paint), SSPC conducted a survey of 200 coating companies that referenced some 49 coatings in total.¹

The survey results were intriguing and partially summarized elsewhere.² “Epoxies accounted for about half the overcoating systems used. According to the survey, four dominant mechanisms gave good overcoating performance. They were, in order of descending importance: a) tenacious adhesion, b) good ability to wet and/or penetrate the surface, and c) benign influence on the existing coating, including compatibility and imparting minimal stresses from solvent lifting or cure, and d) barrier properties for corrosion protection. Other, less-cited overcoating attributes of coating materials in the survey included flexibility, moisture tolerance, rust tolerance, and rust inhibition.”²

Today, however, the authors contend that it is an arguably different story because of a fundamental change of perspective. Viewing an overcoating project first and foremost from the standpoint of corrosion resistance of structure critical connections, bearings, and anchor bolts—and then and only then the coating of adjacent flat surfaces on the structure—a revisionist picture emerges of the most desirable overcoating system (Table 1).

**Table 1: Characteristics that Assist with Optimum Functioning of an Overcoat System**²

<table>
<thead>
<tr>
<th>Desired Attribute</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide compatibility</td>
<td>Generically different coatings (especially alkyds)</td>
</tr>
<tr>
<td>Good performance</td>
<td>Overhand, power tool, and water-jetted surfaces</td>
</tr>
<tr>
<td>Proven long-term flexibility</td>
<td>Active chemistry</td>
</tr>
<tr>
<td>Proven long term success</td>
<td>Structural connections</td>
</tr>
<tr>
<td>Significant penetration</td>
<td>Voids and surface imperfections of the old coating</td>
</tr>
<tr>
<td>Delivery of rust inhibitors</td>
<td>Structure critical connections</td>
</tr>
<tr>
<td>Mitigate corrosion</td>
<td>Frozen bearings</td>
</tr>
<tr>
<td>Penetrant material</td>
<td>Has sufficiently high pH to neutralize acidity in pack rust</td>
</tr>
<tr>
<td>High degree of wetting, adhesion, and capillary action</td>
<td>Low viscosity—notably in crevices</td>
</tr>
<tr>
<td>High volume solids and, preferably, 100% solids (solvent free)</td>
<td>No lifting of old coating edges</td>
</tr>
<tr>
<td>Good barrier properties</td>
<td></td>
</tr>
<tr>
<td>Penetrant sealer, unpigmented: zero or low shrinkage during cure</td>
<td></td>
</tr>
<tr>
<td>Penetrant sealer remains wet for a prolonged period prior to cure</td>
<td></td>
</tr>
<tr>
<td>Moisture-tolerant and able to displace or react with water; carefully balanced rate of cure</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td></td>
</tr>
<tr>
<td>Low-temperature cure</td>
<td></td>
</tr>
<tr>
<td>Optimal application (brush, roller and spray) and flow characteristics</td>
<td></td>
</tr>
<tr>
<td>Minimal stress at the substrate-coating interface</td>
<td></td>
</tr>
<tr>
<td>Resistance to hygrothermal stress</td>
<td></td>
</tr>
<tr>
<td>Capability of rust consolidation: rust inhibition</td>
<td></td>
</tr>
<tr>
<td>Low dft</td>
<td></td>
</tr>
<tr>
<td>Ultraviolet resistance</td>
<td></td>
</tr>
<tr>
<td>Applicator and environmental friendliness</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 2: Generalized formula of HRCSA coatings**¹⁰

\[
(R-Ar - SO_3)^2 M \cdot x (MA) \\
R = \text{alkyl side chains 12 to 20 carbons} \\
M = \text{Ca}^{2+} \text{ or Mg}^{2+} \text{ or Ba}^{2+} \ \\
A = \text{CO}_3^{2-} \ \\
x = 10 \text{ to } 20
\]
In many applications, overcoat systems should be low-viscosity and high-wetting systems able to remain flexible, give long-term corrosion mitigation in crevice corroded joints, mitigate corrosion frozen bearings, and provide the normal expectation that they will remain tightly adhered to aged coatings. Hare has also stressed the importance of low-viscosity and high wetting properties of overcoating systems.

A New Overcoating Paradigm

A new overcoating paradigm is offered here, one in which corrosion control considerations are more prominent than decisions involving coating film attributes per se. This paradigm is especially relevant given the unfortunate spectacle of failed bridges, in which the public focus has been turned to structure critical connections. What is the present front-runner in the contest for best overcoating of flat surfaces and for best dealing with severe corrosion in joints and connections?

The answer is HRCSA coatings. To the layman, HRCSA sounds “out there.” In reality, its claim to fame is that the technology is “in there.” In there—quite literally. How so? Look at an old bridge. The careful eye is drawn invariably to steel plate bent out of shape in a few places (from pressure exerted by pack rust formation) and to the tell tale rust stains and streaks emanating from hundreds of crevice corroded joints where little or no anticorrosive protection is “inside.” The observation leads you to wonder just how badly the bridge is compromised and what possible safety ramifications result from substantially weakened structural connections.

Of course, not only bridges have such weighty issues. For instance, the critical zones of ships, cranes, and all manner of hydroelectric infrastructure present engineers and coating professionals with similar challenges and thus highlight the need to evaluate the performance variability of different coating systems.

From a corrosion engineer’s vantage point of an overcoating project, an active rather than a passive coating is wanted “in there” in an inaccessible connection, where a well-chosen coating remains indefinitely active, inhibits, and stultifies corrosion, hence preventing pack rust formation (Table 2). The secondary consideration for overcoating selection is a long lasting and well-adhered anticorrosive overcoat finish compatible with pre-existing coatings on the flat surfaces. Clearly, the dynamics of what transpires in a crevice corroded joint, as typified by back to back plates and rivets, is of critical concern.

Addressing the microenvironment associated with crevice corrosion is therefore of paramount importance. The authors anticipate that this contention will be borne out as new legislation is enacted to deal with deteriorating infrastructure.

There is a particularly helpful caveat emptor question for each specification authority to ask before signing off on an overcoating system. “Are we about to use a coating system that we know from a chemical standpoint cannot work satisfactorily or give long-term performance in corroded joints and connections?”

The HRCSA system used for overcoating is elegantly simple, consisting of a wet-on-wet approach of an easy-to-apply, single-component material. First, care must be taken to remove soluble salts and water from properly cleaned complex geometries such as joints and connections.

Second, a low viscosity and high lubricity, surface-tolerant HRCSA penetrant is applied to those joints and connec-
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Overcoating Penstocks at Hydroelectric Facilities

Enter the realm of hydroelectric facilities, where miles and miles of above-ground penstocks painted with gradually deteriorating lead-based paint, or bituminous coatings, abound in British Columbia, Canada. Some penstocks are in remote locations, on steep mountain slopes, and in regions that experience huge temperature variations in both summer and winter and can inflict pronounced hygrothermal stress on a protective coating system.

Overcoating can extend the service life of a penstock while avoiding the costs associated with abrasive blasting and full coating removal. In addition to considering initial and life cycle costs of the coating system to be applied, another critical maintenance issue is worker safety during surface preparation and coating application. In this regard, coatings that are easy to use, environmentally friendly, and save 30–50% on surface preparation costs are very attractive.

One of many penstocks considered for overcoating is located at Bridge River in British Columbia, Canada. Given the expense of abrasive blasting and full containment of lead-based paint, overcoat system selection became an issue. The overcoating system would need to address the flat surfaces and structure critical connections and to afford a potential 25-year service life.

The Bridge River penstock was approximately 10 ft in diameter and supported on concrete saddles. To accommodate the large amount of expansion and contraction caused by the dramatic temperature variations and the high flow of water in the penstock, asbestos pads impregnated with graphite were used as a buffer between the concrete pads and the steel penstock itself, thereby allowing movement of the steel structure.

A significant head start to the project was gained because the utility owner had been proactive, conducting accelerated in-house laboratory testing of coating systems applied over a variety of aged coatings and abrasive blasted steel. The owner had also field tested an assortment of maintenance coatings and identified the promising ones, including calcium sulfonate alkyds, epoxies, and urethanes.

Significantly, the utility had a well-deserved and first-rate reputation for coating success due to rigorous coating inspection by the in-house coating inspectors. In addition, the utility owners were aware of the good long term performance of a particular HRCSA that had ranked either in the top decile, or #1, in several independent laboratory tests undertaken by its own laboratories. The same coating also had a known history of success in Canada, either on large-scale overcoating projects or refurbishment projects in which abrasive blasting had been followed by a single-coat application of the HRCSA coating.

Critically, the same HRCSA had performed well for the utility itself, both on its own bridge overcoating project (lead-based paint substrate; overcoat applied two years before) and several earlier
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High Ratio Calcium Sulfonate Alkyd Technology

HRCSAs are easy-to-use, single-component coatings that cure by air oxidation, much like regular alkyd paint. However, unlike typical alkyds, HRCSAs are softer films that remain both active and flexible while they continuously release their corrosion inhibitors at the coating/metal interface. In this way, HRCSAs possess both barrier properties against the ingress of corrosive materials and corrosion inhibitive properties.

While the coatings industry is more familiar with other generic types of coatings such as alkyds, latexes, zinches, epoxies, urethanes (2 pack, polyaspartic and moisture-cured) the HRCSA coatings are a rather interesting and somewhat lesser known coatings type. Although HRCSAs have the word “alkyd” in their description, chemically, they are actually much different than alkyds.

As shown in Fig. 2 on p. 19, the essential formula of an HRCSA coating is (R-Ar-SO3)2-M.x (MA), and the chemistry helps explain the efficacy of the coating type. The coating is made up of a non-polar alkylate (the R group with alkyl side chains containing 12 to 20 carbon atoms); a complex of calcium (M) sulfonate (SO₃) and basic calcium (M) carbonate (A); one or more alkyds with which the sulfonate copolymerizes; drying oils; and an array of additives and anticorrosive pigments. The benzene ring (Ar) attached to the acidic sulfonate group gives the coating considerable polarity and ability to wet out surfaces. The carbonate is basic and inhibits corrosion. Platelets of the complex sulfonate-
carbonate crystals present a more tortuous path for the ingress of corrosive materials and also confer extra film strength (Fig. 8).10, 11 How’s that for beauty and simplicity in action!

As with any formulation, the nature of the ingredients and how they are assembled determines the level of in-service performance. On the one hand, the presence of calcium carbonate as hexagonal plate-like calcite crystals in an artificially grown sulfonate-carbonate lattice gives the HRCSA coating substantially better performance than a sulfonate-low cost amorphous calcium carbonate admixture in a non-HRCSA. On the other hand, the selection of the non-polar alkylate is extremely important to the performance of the final coating.

What does the designation “high ratio” mean? It refers to the formulation having a high percentage of active sulfonate balanced with the right amount and type of artificially grown basic calcium carbonate. The ratio of active sulfonate to the Total Base Number basic carbonate (total base number TBN) is very important. For optimum performance, the ratio should be between 90 and 105 TBN (Total Base Number) and a minimum 9.5 to 11% active sulfonate. Calcium sulfonate alkyd coatings with lower active sulfonate percentages (3–5%), or high TBN numbers (200–300) are markedly lower in performance characteristics.12

Engineered correctly, the result is a
very flexible coating that possesses an active chemistry for the control of corrosion, especially crevice corrosion, where differential oxygen concentration cells exist. Importantly, the HRCSA coatings exert minimal shrinkage stress, a beneficial attribute because cold weather can impart substantial hygrothermal stresses to overcoat systems, and, in turn, the deleterious stresses can then be imparted to underlying coatings.

The lower tensile strength of HRCSA coatings is highly advantageous. For instance, even at −10 °C (+14 °F), the HRCSA used in this work has an adhesion value of 100–300 psi and does not disbond in overcoat scenarios, whereas high-build epoxies with tensile strengths close to 1,000 psi might disbond under similar conditions. Similar to certain high-quality penetrating sealer epoxies used for overcoating purposes, HRCSA coatings have the added ability to displace moisture.

The environmental and cost advantages associated with HRCSA coatings make them rather attractive. For example, from a toxicity standpoint, the higher the LC50-96h of a coating (i.e., the lethal concentration to kill 50% fish in a 96 hour duration), the less toxic is the coating. While many zinc coatings have an LC50-96h of approximately 10 ppm, and many epoxies have values of about 300–600 ppm, the HRCSA used in the project described below had an LC50-96h of approximately 42,000 ppm.

As useful as HRCSA technology is, the disadvantages of all coating types must be taken into account when selecting a coating for a given project. The most obvious disadvantage that may be important is the initially soft nature of the coating film and its early susceptibility to high dirt retention during the early stages of cure (during the first few days after application). The fact that the coating is softer than two-part polyurethane and epoxy overcoat systems also means that it is more prone to mechanical damage. Furthermore, while HRCSA coatings can be produced in any color, like epoxies, they do not possess high gloss. Unlike epoxies, but similar to urethanes, however, HRCSAs do not chalk or fade and provide good color stability.

**Bridge River Penstock Project**

The application of the HRCSA coating system was carried out between the months of June and early October 2008 while the temperature range and humid-
ity varied considerably. Each “can” of the penstock was prepared with low-pressure water cleaning at 3,500 to 5,000 psi (24 to 34 MPa). Figure 1 on p. 18 shows the penstock on the concrete saddles and Fig. 3 on p. 20 shows typical areas where considerable coating degradation was found. Each can of the penstock sat on saddles, and the crevice corroded joints and connections were cleaned at around 5,000 psi using a zero-degree rotating tip (turbo nozzle) at a maximum of a four-inch standoff distance (Figs. 4 and 5, pp. 20 and 22).

The joints between gaps and between the metal and concrete at the saddles were carefully cleaned to ensure total removal of contaminants such as moss, loose paint, loose rust, and soluble salts. In this way, an SSPC-SP 12 WJ4 standard was achieved, and moss, loose paint, and loose rust were removed. Areas of accessible corrosion were power tool cleaned to bare metal (SSPC-SP 11), and in those areas, edges of intact paint were feathered back to provide smooth transitions. Edges of intact paint also were feathered where the existing coating had been challenged by the 5,000 psi water washing process used to remove areas of poorly adhered original finish from the underlying lead-based primer.

A geotextile was used throughout the surface preparation, and the lead-contaminated water and removed coatings were collected and disposed of. The water from the pressure washing operation first went into large settling containers (around 500 U.S. gallons) in which the particulates settled out and were subsequently disposed of (Fig. 6, p. 22). The supernate (i.e., the clean liquid on top of the settled particulates) was
pumped out and passed through an activated carbon filtration unit; the clean water was then released back into the environment (Fig. 7, p. 23). According to the U.S. Environmental Protection Agency's (EPA) Toxicity Characteristic Leaching Procedure, if >5 ppm leachable lead is found in the waste material tested, then the latter must be treated and disposed of in accordance with EPA requirements under U.S. Code of Federal Regulations (CFR) Title 40, Parts 261, 262 and 263. This was carried out in this project.

Only the lower portions of the penstock displayed poor bonding between the pre-existing finish and primer, whereas the upper portions exhibited a tightly adhered original finish, one that could not be removed with a dull putty knife. The marked contrast between coating adhesion in the upper and lower penstock was thought to be caused by the moisture that formed on the lower portions and remained there throughout the year. The bare areas were then primed with the HRCSA self-priming finish.

Interestingly, the greatest degradation of the old coating system was not on the exposed side—the side most subjected to sunlight and possible photodegradation—but on the side subject to lower light intensity, where the aged coating system experienced the longest "wet time." In fact, the coating degradation was evidenced mainly around the spring line (mid point)—areas of high algae growth, wind flow, and dirt accumulation. Figure 9 on p. 25 shows the greater level of exposed lead-based alkyd paint in this region after the pressure washing was complete.

Prepared surfaces were then tested for soluble salts; the upper limit for chlorides had been set at 10 µg/cm². Surfaces were not coated with the HRCSA coating system until they had chloride levels below 10 µg/cm².

The HRCSA coating was considered to be a "one-coat" system—but with multiple steps and two materials: the HRCSA penetrant sealer and the HRCSA self-priming finish coat. At the ends of the penstock cans, where they exited the concrete housing, each painting step was completed one after the other, wet on wet, with no waiting time.
between application of the materials. The first step was to spot prime with the self-priming finish any bare, rusted, and residual lead-based paint (Fig. 10, p. 25). The second step was the immediate application of the self-priming finish coat as shown adjacent to a Dresser coupling in Fig. 11 on p. 26.

In the early phase of the work, the HRCSA penetrant was applied liberally to all joints and connections, including the areas around bolts, nuts, and rivets where gaps existed. In the case of the saddles, copious amounts of penetrant sealer were sprayed into the inaccessible areas to displace any trapped water not purged by the compressed air and to consolidate any rust residues. Excess penetrant was then brushed out. In later work, a flexible polysulfide caulk was selected for these areas.

Although the joints and connections appeared dry at the concrete saddles, they were blown dry with clean, dry, oil-free, high-pressure (100 psi) compressed air. In this overcoat project, as with any other, it was crucial that the coating film thicknesses were within the ranges specified (in this instance, one coat at approximately 7 mils dft). Intercoat contamination was not allowed to occur, and recoat intervals were within the HRCSA manufacturers’ acceptable limit. As soon as the HRCSA penetrant had been used for crevices, stripe “caulk coats” of the self-priming HRCSA finish coat were applied at a minimum wet film thickness of 14–18 mils to the same crevices. Then an overall prime coat was applied to all prepared areas where the steel was bare or where residual lead-based paint was visible. The aim was to increase the minimum dft to 10 mils.

Finally, a full coat of the HRCSA self-priming finish was applied to all surfaces to give a dft of 7–8 mils. This was effectively completed in one constant application, wet on wet. All that was required of the spray equipment operator was to apply the self-priming finish in stages, i.e., to apply a stripe/caulk coat, the prime coat, and then the final finish (Fig. 12, p. 27).

Thus, although it may seem that an HRCSA system stretches the meaning of the term “one-coat system,” it is actually a three-step, wet-on-wet, single-coat process: the first step is to penetrate the connections, the second step is to caulk the joint and spot prime the bare metal, and the third step is all wet-on-wet to overcoat everything. There is no need to come back later after a drying period for second and third coats.

Areas where the existing finish remained were overcoated with one coat of the HRCSA finish as shown in Fig. 13 on p. 27. The spray application of the green colored, single-component HRCSA
finish proceeded well, except for one period of time when the ambient temperature was in the 90–100 F range and the HRCSA finish temporarily exhibited poor flow-out (i.e., uneven sheen). A combination of high coatings temperature, high ambient temperature, and high substrate temperature meant that the solvent required for even wetting was flashing before it had reached the substrate. As expected, the simple remedial action was to cool the drums of HRCSA finish before spray application (Figs. 14 and 15). The paint crew effectively created an air conditioned enclosure on the back of the truck used that day or the airless pump and drums used that day.

Conclusions
The primary determinant of success in most overcoating applications is associ-
ated with the judicious selection of the coating for structure critical connections. HRCSA coatings possess the best attributes for successful overcoating projects.

For cost, safety, and environmental reasons, HRCSA coatings are routinely used for overcoating lead-based paint on bridges. This article illustrates their usefulness when applied to hydroelectric facilities such as penstocks, dam gates, gate housings, miscellaneous dam structures, and substations.

HRCSA penetrant sealers and HRCSA finishes were applied as a wet-on-wet, one-coat, multi-step system to a hydroelectric penstock previously coated with lead-based paint.

The life expectancy for the HRCSA overcoating system is approximately 25 years when the surface preparation is an SSPC-SP 12 WJ4 carried out with third-party independent inspection.

The References section includes:

8. W. Sennick, Termarust Technologies, correspondence to authors, June 2007.
10. www.sctsaci.co/products.html

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